Umwelt Bundes Amt
Für Mensch und Umwelt

Integrierte Vermeidung und Verminderung der Umweltverschmutzung (IVU)

„Merkblatt über die besten verfügbaren Techniken für Abfallbehandlungsanlagen“

mit ausgewählten Kapiteln in deutscher Übersetzung

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Umweltbundesamt
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Das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und die 16 Bundesländer haben eine Verwaltungsvereinbarung geschlossen, um gemeinsam eine auszugsweise Übersetzung der BVT-Merkblätter ins Deutsche zu organisieren und zu finanzieren, die im Rahmen des Informationsaustausches nach Artikel 16 Absatz 2 der Richtlinie 96/61/EG über die integrierte Vermeidung und Verminderung der Umweltverschmutzung (IVU-Richtlinie) (Sevilla-Prozess) erarbeitet werden. Die Vereinbarung ist am 10.1.2003 in Kraft getreten. Von den BVT-Merkblättern sollen die für die Genehmigungsbehörden wesentlichen Kapitel übersetzt werden. Auch Österreich unterstützt dieses Übersetzungsprojekt durch finanzielle Beiträge.

Als Nationale Koordinierungsstelle für die BVT-Arbeiten wurde das Umweltbundesamt (UBA) mit der Organisation und fachlichen Begleitung dieser Übersetzungsarbeiten beauftragt.

Die Kapitel des von der Europäischen Kommission veröffentlichten BVT-Merkblattes „Referenzdokument über die besten verfügbaren Techniken für Abfallbehandlungsanlagen“, in denen die Besten Verfügbaren Techniken beschrieben sind Kapitel 4 und 5, sind im Rahmen dieser Verwaltungsvereinbarung in Auftrag des Umweltbundesamtes übersetzt worden.

Die nicht übersetzen Kapitel liegen in diesem Dokument in der englischsprachigen Originalfassung vor. Diese englischsprachigen Teile des Dokumentes enthalten weitere Informationen (u.a. Emissionssituation der Branche, Technikbeschreibungen etc.), die nicht übersetzt worden sind. In Ausnahmefällen gibt es in der deutschen Übersetzung Verweise auf nicht übersetzten Textpassagen. Die deutsche Übersetzung sollte daher immer in Verbindung mit dem englischen Text verwendet werden.

Das Kapitel „Zusammenfassung“ basiert auf der offiziellen Übersetzung der Europäischen Kommission in einer zwischen Deutschland, Luxemburg und Österreich abgestimmten korrigierten Fassung.

Die Übersetzungen der weiteren Kapitel sind ebenfalls sorgfältig erstellt und fachlich durch das Umweltbundesamt und Fachleute der Bundesländer geprüft worden. Diese deutschen Übersetzungen stellen keine rechtsverbindliche Übersetzung des englischen Originaltextes dar. Bei Zweifelsfragen muss deshalb immer auf die von der Kommission veröffentlichte englischsprachige Version zurückgegriffen werden.

Dieses Dokument ist auf der Homepage des Umweltbundesamtes abrufbar:
(http://www.bvt.umweltbundesamt.de/kurzue.htm)

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This document is one of a series of foreseen document as below (at the time of writing, not all documents have been drafted):

Full title	**BREF code**
Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs	ILF
Reference Document on the General Principles of Monitoring	MON
Reference Document on Best Available Techniques for the Tanning of Hides and Skins	TAN
Reference Document on Best Available Techniques in the Glass Manufacturing Industry	GLS
Reference Document on Best Available Techniques in the Pulp and Paper Industry	PP
Reference Document on Best Available Techniques on the Production of Iron and Steel	I&S
Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries	CL
Reference Document on the Application of Best Available Techniques to Industrial Cooling Systems	CV
Reference Document on Best Available Techniques in the Chlor – Alkali Manufacturing Industry	CAK
Reference Document on Best Available Techniques in the Ferrous Metals Processing Industry	FMP
Reference Document on Best Available Techniques in the Non Ferrous Metals Industries	NFM
Reference Document on Best Available Techniques for the Textiles Industry	TXT
Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries	REF
Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry	LVOC
Reference Document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Reference Document on Best Available Techniques in the Food, Drink and Milk Industry	FM
Reference Document on Best Available Techniques in the Smitheries and Foundries Industry	SF
Reference Document on Best Available Techniques on Emissions from Storage	ESB
Reference Document on Economics and Cross-Media Effects	ECM
Reference Document on Best Available Techniques for Large Combustion Plants	LCP
Reference Document on Best Available Techniques in the Slaughterhouses and Animals By-products Industries	SA
Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities	MTWR
Reference Document on Best Available Techniques for the Surface Treatment of Metals	STM
Reference Document on Best Available Techniques for the Waste Treatments Industries	WT
Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals (Ammonia, Acids and Fertilisers)	LVIC-AAF
Reference Document on Best Available Techniques for Waste Incineration	WI
Reference Document on Best Available Techniques for Manufacture of Polymers	POL
Reference Document on Energy Efficiency Techniques	ENE
Reference Document on Best Available Techniques for the Manufacture of Organic Fine Chemicals	OFC
Reference Document on Best Available Techniques for the Manufacture of Specialty Inorganic Chemicals	SIC
Reference Document on Best Available Techniques for Surface Treatment Using Solvents	STS
Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals (Solids and Others)	LVIC-S
Reference Document on Best Available Techniques in Ceramic Manufacturing Industry	CER

ZUSAMMENFASSUNG

Das Merkblatt zu den besten verfügbaren Techniken (BVT-Merkblatt) mit dem Titel „Abfallbehandlungsanlagen“ beruht auf einem Informationsaustausch nach Artikel 16 Absatz 2 der Richtlinie 96/61/EG des Rates (IVU-Richtlinie bzw. in Österreich die IPPC-Richtlinie). In der vorliegenden Zusammenfassung werden die wichtigsten Ergebnisse, die wesentlichen Schlussfolgerungen zu den BVT und die damit verbundenen Emissions- und Verbrauchswerte beschrieben. Sie ist im Zusammenhang mit dem Vorwort zu sehen, in dem die Zielsetzungen dieses Dokuments, seine Verwendung und seine Rechtsgrundlage erläutert werden.

Diese Zusammenfassung kann als eigenständiges Dokument gelesen und verstanden werden. Dem Charakter einer Zusammenfassung entsprechend sind jedoch nicht alle Aspekte des gesamten Merkblattes enthalten. Im Prozess der BVT-Entscheidungsfindung ist diese Zusammenfassung daher nicht als Ersatz für den vollen Wortlaut anzusehen.

Anwendungsbereich des Dokuments
Das vorliegende Dokument soll zusammen mit weiteren BVT-Merkblätter der Reihe, die in Anhang I Nummer 5 der IVU-Richtlinie aufgeführten industriellen Tätigkeiten der „Abfallbehandlung“ umfassen. Gegenstand eines anderen Merkblattes ist die Abfallverbrennung wie auch andere Verfahren der thermischen Abfallbehandlung wie zum Beispiel die Pyrolyse und Vergasung (Anhang I Nummer 5.2 der Richtlinie). Obwohl in Anhang I Nummer 5.4 Deponien genannt werden, beinhaltet das vorliegende Dokument keine BVT für Deponien.

Die Codes für Verwertungs- (R-Codes) und Beseitigungsverfahren (D-Codes) der Anhänge II A und II B der Richtlinie 75/442/EG, welche die IVU-Richtlinie betreffen, wurden gemäß der Entscheidung 96/350/EG der Kommission geändert. Da diese letzte Anpassung den neuesten Codes für Verwertungs- und Beseitigungsverfahren (R- und D-Codes) entspricht, spiegelt die nachstehende Tabelle in Übereinstimmung mit der Sichtweise des Informationsaustauschforums (IEF) und der Technischen Arbeitsgruppe (TWG) und unter Berücksichtigung der Zielsetzung der IVU-Richtlinie die Codes für die Art von Abfallbehandlungsverfahren wider, um die es im vorliegenden Dokument geht.

Abfallbehandlungsverfahren	**R- bzw. D-Code 96/350/EG**
Hauptverwendung als Brennstoff oder andere Mittel der Energieerzeugung	R 1
Rückgewinnung/Regenerierung von Lösemitteln	R 2
Verwertung/Rückgewinnung von anderen anorganischen Stoffen (d. h. anderen als den unter R 4 aufgeführten Metallen und Metallverbindungen)	R 5
Regenerierung von Säuren oder Basen	R 6
Wiedergewinnung von Bestandteilen, die der Bekämpfung der Verunreinigungen dienen	R 7
Wiedergewinnung von Katalysatorenbestandteilen	R 8
Ölraffination oder andere Wiederverwendungsmöglichkeiten von Öl	R 9
Austausch von Abfällen, um sie einem der unter R 1 bis R 11 aufgeführten Verfahren zu unterziehen	R 12
Ansammlung von Abfällen, um sie einem der unter R 1 bis R 12 aufgeführten Verfahren zu unterziehen (ausgenommen zeitweilige Lagerung - bis zum Einsammeln - auf dem Gelände der Entstehung der Abfälle)	R 13
Biologische Behandlung, die nicht an anderer Stelle in Anhang II der Entscheidung 96/350/EG beschrieben ist und durch die Endverbindungen oder Gemische entstehen, die mit einem der in D 1 bis D 12 aufgeführten Verfahren entsorgt werden	D 8
Chemisch/physikalische Behandlung, die nicht an anderer Stelle in Anhang II der Entscheidung 96/350/EG beschrieben ist und durch die Endverbindungen oder Gemische entstehen, die mit einem der in D 1 bis D 12 aufgeführten Verfahren entsorgt werden (z. B. Verdampfen, Trocknen, Kalzinieren usw.)	D 9
Vermengung oder Vermischung vor Anwendung eines der in D 1 bis D 12 aufgeführten Verfahren	D 13
Rekonditionierung vor Anwendung eines der in D 1 bis D 13 aufgeführten Verfahren	D 14
Lagerung bis zur Anwendung eines der in D 1 bis D 14 aufgeführten Verfahren (ausgenommen zeitweilige Lagerung - bis zum Einsammeln - auf dem Gelände der Entstehung der Abfälle)	D 15

Im vorliegenden Dokument behandelte Abfallbehandlungsverfahren

Eine vollständige „Lebenszyklusanalyse“ für einen bestimmten Abfall, betrachtet neben sämtlichen Gliedern der Abfallkette auch die Auswirkungen des Endprodukts/Abfalls auf die Umwelt. Die IVU zielt nicht auf diese Analysen ab, sondern stellt die Anlagen in den Mittelpunkt. So ist beispielsweise die Minimierung des Aufkommens und/oder Toxizität des an der Quelle in industriellen Anlagen erzeugten Abfalls ein wesentlicher Bestandteil der IVU und zugleich auch Gegenstand aller BVT-Merkblätter der einzelnen industriellen Sektoren (siehe dazu das Verzeichnis auf der Rückseite des Titelblatts dieses Dokuments). Ein weiteres Beispiel zeigt, dass sich die Abfallbehandlung auch auf strategische Entscheidungen darüber erstreckt, welche Art von Abfall in den verfügbaren Abfallbehandlungen/Verfahren/Varianten behandelt bzw. welcher Behandlung eine Abfallart unterzogen wird. Diese Entscheidung hängt davon ab, welche Abfallbehandlungsmöglichkeiten auf lokaler, regionaler, nationaler oder internationaler Ebene zur Verfügung stehen, wobei auch die Frage eine Rolle spielt, wo der Abfall erzeugt wird.

Einige vertreten die Auffassung, dass sich der Geltungsbereich des Dokuments auf sämtliche derzeit im Abfallsektor verfügbaren Abfallbehandlungstätigkeiten erstrecken sollte. Hierfür wurden drei Gründe genannt. Erstens seien die technischen Merkmale solcher zusätzlichen Behandlungen sehr ähnlich, wenn nicht gar identisch mit denen der im vorliegenden Dokument aufgeführten Behandlungsverfahren. Zweitens wurde befürchtet, dass sich die Wettbewerbsfähigkeit einiger nicht in der IVU-Richtlinie aufgeführter Abfallbehandlungsanlagen erhöhen könnte, denn für ihren Betrieb würden möglicherweise weniger strenge Umweltnormen gelten, als die BVT fordern. Drittens könnte interpretiert werden, dass zu Anlagen, die nicht berücksichtigt werden, auch keine BVT festgelegt werden kann und sie somit keinen BVT-Anforderungen unterliegen können.

Der Geltungsbereich des Dokuments sollte nicht als Versuch gewertet werden, die IVU-Richtlinie oder andere abfallrelevanten Rechtsvorschriften auszulegen.

Allgemeine Informationen zum Abfallbehandlungssektor

Der Abfallsektor ist in der EU sehr stark reguliert. Daher stehen in diesem Sektor eine Vielzahl rechtlicher Definitionen gemeinhin verwendeter Begriffe zur Verfügung. In Abfallbehandlungsanlagen werden Verwertungs- und Beseitigungsprozesse durchgeführt. Es wird für Abfallbehandlungsanlagen im Gegensatz zu anderen industriellen Sektoren nicht als typisch angesehen, ein Produkt herzustellen. Sie sollen hingegen nach allgemeinem Verständnis Dienstleistungen für die Gesellschaft in Form der Behandlung von Abfällen erbringen. Dennoch ist bekannt, dass aus einigen Abfallbehandlungen Produkte resultieren. Wie aus nachstehender Tabelle ersichtlich ist, existieren in der EU mehr als 14 000 Abfallbehandlungsanlagen. Aus ihr geht auch hervor, dass es sich hierbei mehrheitlich um chemisch/physikalischen Behandlungsanlagen handelt.

Abfallbehandlung	**Anzahl der bekannten Anlagen**
Chemisch/physikalische Behandlung	9907
Umladestation	2905
Biologische Behandlung	615
Aufbereitung von Altöl und Nutzung als Brennstoff	274
Herstellung von Brennstoffen aus Abfällen	266
Behandlung anorganischer Abfälle (ohne Metalle)	126
Behandlung von Lösemittelabfällen	106
Altölraffination	35
Aktivkohlebehandlung	20
Verwertung von Rückständen aus der Abgas- und Abwasserreinigung	20
Behandlung von Altkatalysatoren	20
Behandlung von Abfallsäuren/-basen	13
GESAMT	**14307**
Anmerkung: Die Angaben in der Tabelle können von den tatsächlichen Zahlen abweichen. Dafür gibt es im Wesentlichen zwei Gründe: Einerseits sind die Schätzzahlen für Europa zu niedrig angesetzt, weil aus einigen EU-Ländern keine Zahlen zu ihren Anlagen gemeldet wurden. Andererseits fließen in diese Angaben in der Regel sämtliche Kapazitäten ein, was bedeutet, dass die Zahl der den Bestimmungen der IVU-Richtlinie unterliegenden Anlagen niedriger sein könnte.	

Gemeldete Abfallbehandlungsanlagen in der EU

Angewandte Techniken, Emissions- und Verbrauchswerte im Abfallbehandlungssektor
Dieses Dokument bietet ein aktuelles Bild der derzeitigen technischen und umweltrelevanten Gegebenheiten des Abfallbehandlungssektors. Es umfasst eine kurze technische Beschreibung der branchentypischen Tätigkeiten und Prozesse und wird ergänzt durch ermittelte tatsächliche Emissions- und Verbrauchswerte der Anlagen. Insbesondere enthält das Dokument Ausführungen zu folgenden Punkten:

- häufig angewandte Techniken, z.B. allgemeines Anlagenmanagement, Aufnahme, Annahme, Rückverfolgbarkeit, Qualitätssicherung, Lagerung und Handhabung, Energiesysteme
- biologische Behandlungsverfahren, z.B. anaerober und aerober Abbau und biologische „off-site“ Behandlung von Boden
- chemisch/physikalische Behandlung von Abwässern, festen Abfällen und Schlämmen
- Wiedergewinnung von Stoffen und Substanzen aus Abfall, z. B. Regenerierung von Säuren und Basen, Katalysatoren, Aktivkohle, Lösemitteln und Harzen sowie Altölraffination
- Herstellung fester/flüssiger Brennstoffe aus nicht gefährlichem und gefährlichem Abfall
- Behandlungstechniken zur Minimierung von Emissionen in Abluft, Abwasser und Rückstände aus der Abfallbehandlung.

Des Weiteren werden in diesem Dokument relevante Umweltfragen des Abfallbehandlungssektors beschrieben. Diese betreffen Emissionen in die Luft und in das Wasser, Abfall- und Bodenkontamination. Aufgrund der großen Bandbreite von Abfallbehandlungsverfahren und Abfallarten sind nicht alle Arten von Emissionen für alle Verfahren von Belang. So betreffen bei der chemisch-physikalischen Behandlung von Abwasser auftretende Emissionen hauptsächlich das Abwasser, während die Regenerierung von Aktivkohle in erster Linie mit Emissionen in die Luft zusammenhängt. Diese Besonderheiten werden im vorliegenden Dokument beschrieben und ermöglichen es dem Leser, die bei den einzelnen Anlagenarten auftretenden wichtigsten Umweltfragen zu erkennen.

Bei der Festlegung der BVT zu berücksichtigende Techniken
Bei der Festlegung der BVT werden derzeit 940 Techniken berücksichtigt. Einige andere Techniken sind möglicherweise nicht einbezogen worden, weil keine Informationen zur Verfügung gestellt wurden. Die berücksichtigten Techniken sind jeweils anhand desselben Konzepts analysiert worden. Die Ausführungen zu den Ergebnissen der Analyse umfassen eine kurze Beschreibung, den erzielten Nutzen für die Umwelt, medienübergreifende Effekte, Betriebsdaten, Anwendbarkeit und Wirtschaftlichkeit. In einigen Fällen wurden die treibenden Kräfte für die Einführung, und Beispiele für Abfallbehandlungsanlagen, die diese Techniken nutzen, beschrieben. Die Analyse der Techniken wird mit Angabe der Literatur, welche als Daten in Kapitel 4 genutzt wurde, abgeschlossen. Die Techniken wurden in acht Abschnitte untergliedert. Gegenstand des ersten Abschnitts sind allgemeine Techniken, die drei letzten Abschnitte betreffen in der Branche genutzte End-of-Pipe- Techniken. In den vier mittleren Abschnitten werden verschiedene spezifische Abfallbehandlungsverfahren behandelt.

Aufgrund der hohen Zahl und der großen Bandbreite von Techniken, die bei der Festlegung der BVT berücksichtigt wurden, ist eine kurze Zusammenfassung eine Herausforderung. Die nachstehende Tabelle ist als Kurzübersicht über die in diesem Dokument bei der Festlegung der BVT berücksichtigten Techniken gedacht. In der Tabelle wird für jede der in diesem Dokument aufgeführten Abfallbehandlungstypen die Zahl der unterschiedlichen Typen von Techniken genannt. Es wurden vier verschiedene Kategorien festgelegt. Die erste Kategorie betrifft Techniken zur Verbesserung der Umweltleistung der eigentlichen Abfallbehandlung oder zur Vermeidung von Kontamination oder zur Bewirtschaftung der Abfallbehandlungsanlage. Die drei anderen Kategorien decken folgende Aspekte ab: a) Techniken zur Minderung von Luftemissionen, b) Techniken zur Minderung von Wasseremissionen und c) Behandlung von festen Rückständen die während der Abfallbehandlung entstehen, sowie Techniken zur Verminderung und Vermeidung von Bodenkontamination. In vielen Fällen erweist sich die Zuordnung einiger Techniken zu einer bestimmten Kategorie als schwierig. Die Anzahl der in der nächsten Tabelle aufgeführten Techniken entspricht nicht der Anzahl der Teilabschnitte in einem Abschnitt. In vielen Fällen wird mehr als eine Technik in einem Abschnitt dieses Dokuments zugeordnet.

Art der Abfallbehandlung	Anzahl der angewandten Techniken betreffend				GESAMT
	Abfallbehandlung, Vermeidung und Management	Luft-emissionen	Abwasser	Feste Rückstände	
Allgemeine Techniken	296	26	16	31	**369**
Biologische Behandlung	41	58	3	4	**106**
Chemisch/physikalische Behandlung	133	17	4	6	**160**
Rückgewinnung von Stoffen	44	44	19	7	**114**
Herstellung von Brennstoffen aus Abfall	39	16	0	0	**55**
Abgasreinigung		57			**57**
Abwasserbehandlung			52		**52**
Behandlung von Rückständen				27	**27**
GESAMT	**553**	**218**	**94**	**75**	**940**

Bei der Festlegung der BVT zu berücksichtigende Techniken

Anhand der Angaben in der vorstehenden Tabelle kann mühelos berechnet werden, dass mehr als die Hälfte der Techniken eine Verbesserung der Umweltleistung von Abfallbehandlungs- Vermeidungs- oder Managementverfahren betreffen. Von den übrigen Techniken entfallen etwa 25 Prozent auf die Abluftreinigung, der Rest ist mehr oder minder gleichmäßig auf die Abwasserbehandlung und die Behandlung von festen Rückständen verteilt. Unter einem anderen Blickwinkel kann berechnet werden, dass mehr als ein Drittel der Techniken als allgemeine Techniken eingestuft wurden. Hinsichtlich der vier verschiedenen Typen von speziellen Behandlungsverfahren ist die chemisch-physikalische Behandlung der Abschnitt mit den meisten Techniken.

Beste verfügbare Techniken für den Abfallbehandlungssektor

Das vorliegende Dokument beinhaltet identifizierte beste verfügbaren Techniken (BVT) für den Abfallbehandlungssektor. Diese beziehen sich auf die wichtigsten Umweltfragen und betreffen in der Regel bei normalem Anlagenbetrieb auftretende Emissionen. In einigen Fällen werden auch BVT-Schlüsse benannt, die sich auf Emissionen beziehen, die durch Zwischenfälle und (schwere) Unfälle (Störfälle) verursacht wurden.

Die identifizierten BVT werden in nachstehender Tabelle zusammengefasst. Aus der Tabelle können allerdings nur dann Schlüsse für Entscheidungshilfen herangezogen werden, wenn sie in Zusammenhang mit dem vollständigen Abschnitt über BVT gelesen wird. Das ist hauptsächlich darauf zurückzuführen, dass jede BVT-Schlussfolgerung zahlreiche Details beinhaltet, die sich darauf beziehen, wann die BVT-Schlussfolgerung anwendbar ist. Einige Fakten können dem BVT-Kapitel auszugsweise entnommen werden.

- BVT-Schlussfolgerungen für den Abfallbehandlungssektor werden auf zwei Ebenen dargelegt. Eine Ebene befasst sich mit allgemeinen BVT-Schlussfolgerungen, d.h. sie sind auf den gesamten Sektor anwendbar. Die andere Ebene betrifft spezifische BVT-Schlussfolgerungen, z.B. für verschiedene Typen von spezifischen Prozessen und Tätigkeiten, die in den Anwendungsbereich fallen. Damit stellen die BVT für einen spezifischen Typ von Abfallbehandlungsanlage eine Kombination aus „allgemeinen“, im gesamten Sektor anzuwendenen Elementen und „tätigkeitsspezifischen“, im Einzelfall anzuwendenden Elementen dar. In einigen Fällen können auch andere BVT-Merkblätter als Leitfaden dienen, die bei der Analyse einer spezifischen Anlage zu berücksichtigen sind. Beispielsweise umfassen die BVT für die Altölraffination die mit 1 bis 64 sowie 95 bis 104 nummerierten BVT-Elemente. Überdies kann in Betracht gezogen werden, dass andere mit dem Thema in Verbindung stehende BVT-Merkblätter zusätzliche Hinweise enthalten. Zur weiteren Veranschaulichung kann angeführt werden, dass die BVT für flüssige Brennstoffe aus gefährlichem Abfall die BVT-Elemente 1 bis 64, 117 bis 121 sowie 129 und 130 umfassen.
- Einige BVT beruhen auf konkreten Techniken und Technologien.
- Einige identifizierte BVT beziehen sich auf gefährliche Abfälle. Solche Techniken wurden mithilfe derselben Strategie identifiziert, wie sie im Europäischen Abfallverzeichnis in der Abfallrahmenrichtlinie genutzt wurde.
- Bei der Festlegung von BVT für diesen Sektor wurden einige mit deren Anwendung zusammenhängende Emissionswerte ermittelt. Dabei handelt es sich um Emissionen von flüchtigen organischen Verbindungen und Partikeln in die Luft und Wasserparameter wie chemischer und biologischer Sauerstoffbedarf sowie Schwermetalle. Außerdem wurden bei mechanisch-biologischer Behandlung auftretende Geruchs- und Ammoniakemissionen und bei der Altölbehandlung Kohlenwasserstoff- und Phenolemissionen in das Wasser ermittelt.

Kategorie	Festgelegte BVT-Elemente betreffend
Allgemeine BVT	
Umweltmanagement	1. Umweltmanagementsysteme 2. Bereitstellung vollständiger Angaben zu den Tätigkeiten am Anlagenstandort 3. Vorhandensein eines Verfahrens für die Betriebsführung 4. Bestehen enger Beziehungen zum Abfallerzeuger/Kunden 5. Verfügbarkeit von qualifiziertem Personal
Verbesserung des Kenntnisstands über den Abfallinput	6. Vorhandensein konkreter Kenntnisse über den Abfallinput 7. Einführung eines Verfahrens für die Schritte vor der Annahme 8. Einführung eines Annahmeverfahrens 9. Einführung verschiedener Probenahmeverfahren 10. Vorhandensein einer Aufnahmeeinrichtung
Abfalloutput	11. Analyse des Abfalloutputs
Managementsysteme	12. Rückverfolgbarkeit in der Abfallbehandlung 13. Vorschriften für das Vermengen/Vermischen 14. Verfahren für die Trennung/Verträglichkeitsverfahren 15. Effizienz der Abfallbehandlung 16. Plan für das Verhalten nach Unfällen 17. Dokumentation von Störfällen 18. Pläne zur Bekämpfung von Lärm und Schwingungen 19. Stilllegung von Anlagen
Energie-, Wasser- und Rohstoff-management	20. Energieverbrauch und -erzeugung 21. Energieeffizienz 22. Interne Leistungsvergleiche 23. Einsatz von Abfall als Rohstoff
Lagerung und Hand-habung	24. Allgemeine Lagertechniken 25. Bündelung 26. Kennzeichnung von Rohrleitungen 27. Abfalllagerung/-sammlung 28. Allgemeine Handhabungstechniken 29. Techniken für das Verdichten/Vermischen von verpacktem Abfall 30. Leitfaden zum Sortieren vor der Lagerung 31. Verfahren zur Handhabung von Abfall in Containern
Sonstige nicht an anderer Stelle ge-nannte, häufig ange-wandte Techniken	32. Einsatz von Absauglüftern beim Zerkleinern, Häckseln und Sieben 33. Zerkleinern und Häckseln von Sonderabfall in geschlossenen Anlagen 34. Waschverfahren
Behandlung zur Minderung von Luft-emissionen	35. Verwendung von abdeckbaren Tanks, Gefäßen und Gruben 36. Geschlossene Systeme mit Vorrichtung zur Ableitung in geeignete Abgasreinigungsanlagen 37. Geeignete Extraktionssysteme für einige Lagerungs- und Behandlungstätigkeiten 38. Betrieb und Wartung von Vorrichtungen zur Emissionsminderung 39. Wäscher zur Entfernung wichtiger anorganischer Gase 40. Verfahren zur Feststellung und Behebung von Leckagen 41. Verringerung der Emissionen von flüchtigen organischen Verbindungen und Partikeln in die Luft

Kategorie	Festgelegte BVT-Elemente betreffend
Abwassermanagment	42. Wasserverwendung und Kontamination von Wasser 43. Geeignete Abwasserspezifikation für die am Anlagenstandort betriebene Abwasserbehandlungsanlage bzw. geeignete Einleitungskriterien 44. Vorkehrungen, um zu verhindern, dass Abwasser an den Behandlungsanlagensystemen vorbei geleitet wird 45. Sammeln von Abwässern 46. Getrennthaltung von Abwässern 47. Vorhandensein eines geschlossenen Betonbodens in allen Behandlungsbereichen 48. Sammeln von Regenwasser 49. Wiederverwendung von behandelten Abwässern und Regenwasser 50. Tägliche Überprüfung der Abwasserbehandlungssysteme und Führung eines Tagebuchs 51. Ermittlung der wichtigsten gefährlichen Bestandteile des behandelten Abwassers 52. Für die jeweilige Abwasserart geeignete Behandlungsverfahren 53. Verbesserung der Zuverlässigkeit der Kontroll- und Verminderungsleistung für Abwässer 54. die wichtigsten Bestandteile von behandeltem Abwasser 55. Abwassereinleitung 56. Emissionswerte für den chemischen und biologischen Sauerstoffbedarf und für Schwermetalle im Zusammenhang mit dem Einsatz von BVT
Management von Rückständen, die während des Prozesses entstehen	57. Plan zur Behandlung von Rückständen 58. Verwendung wiederverwendbarer Verpackungen 59. Wiederverwendung von Fässern 60. Erfassung des Abfallbestands am Standort 61. Wiederverwendung von Abfall
Bodenkontamination	62. Herstellung und Instandhaltung der Oberfläche in Betriebsbereichen 63. Undurchlässiger Boden und Drainage 64. Minimierung der am Standort vorhandenen oberirdischen und unterirdischen Ausrüstungen
BVT für spezifische Arten der Abfallbehandlung	
Biologische Behandlung	65. Lagerung und Handhabung in biologischen Systemen 66. Abfallarten und Sortierverfahren 67. Verfahren der anaeroben Faulung 68. Senkung der Emissionen von Staub, Stickstoffoxiden, Schwefeloxiden, Kohlenmonoxid, Schwefelwasserstoff und flüchtigen organischen Verbindungen in die Luft beim Einsatz von Biogas als Brennstoff 69. Techniken zur mechanisch-biologischen Behandlung 70. Verringerung der bei der mechanisch-biologischen Behandlung auftretenden Emissionen von Gerüchen, Ammoniak, Stickstoffmonoxid (Lachgas) und Quecksilber 71. Minderung der Emissionen von Gesamtstickstoff, Ammoniak, Nitrat und Nitrit in das Wasser
Chemisch-physikalische Behandlung von Abwässern	72. Techniken mit chemisch/physikalischen Verfahren arbeitenden Reaktoren 73. Notwendigkeit der Festlegung zusätzlicher Abwasserparameter 74. Neutralisationsprozess 75. Ausfällung von Metallen 76. Trennung von Emulsionen 77. Oxidation/Reduktion 78. Zyanidhaltige Abwässer 79. Abwässer, die Chrom-VI -Verbindungen enthalten 80. Nitrithaltige Abwässer 81. Ammoniakhaltige Abwässer 82. Minderung der Luftemissionen während der Filtration und Entwässerung 83. Flockung und Verdampfung 84. Reinigung während des Siebens
Chemisch-physikalische Behandlungen von festen Abfällen	85. Erreichen der Unlöslichkeit amphoterer Metalle 86. Auslaugbarkeit anorganischer Verbindungen 87. Beschränkung der Annahme von Abfällen, die mittels Verfestigung/Immobilisierung zu behandeln sind 88. Geschlossene Systeme 89. Systeme zur Minderung der Emissionen beim Be- und Entladen 90. Auf Deponien zu verbringende feste Abfälle

Chemisch-physikalische Behandlung von kontaminiertem Boden	91. Überwachung der Aushubarbeiten 92. Ermittlung der Eignung des anzuwendenden Verfahrens 93. Sammel- und Überwachungsausrüstung 94. Prozesseffizienz
Altölraffination	95. Überwachung des Materialeingangs 96. Überprüfung auf chlorierte Lösemittel und polychlorierte Biphenyle 97. Kondensation der Gasphase in Anlagen zur kontinuierlichen Entspannungsdestillation 98. Emissionsminderung beim Be- und Entladen von Fahrzeugen 99. Verschiedene Maßnahmen zur Emissionsminderung beim Vorhandensein chlorierter Arten 100. Thermische Oxidation 101. Vakuumsysteme 102. Nutzung der bei der Vakuumdestillation oder beim Einsatz von Dünnschichtverdampfern anfallenden Rückstände 103. Hochleistungsfähige Verfahren der Altölraffination 104. Emissionswerte für Kohlenwasserstoff und Phenole im Abwasser
Regenerierung von Lösemittelabfall	105. Überwachung des Materialeingangs 106. Eindampfen des Rückstands
Regenerierung von Altkatalysatoren	107. Verwendung von Beutelfiltern 108. Einsatz von Systemen zur Minderung der Schwefeloxidemission
Regenerierung von Aktivkohleabfällen	109. Qualitätskontrollverfahren 110. Herkunft der Aktivkohleabfälle 111. Einsatz eines Regenerators zur Behandlung technischer Kohlenstoffe 112. Einsatz eines Nachbrenners zur Regenerierung technischer Kohlenstoffe 113. Einsatz eines Nachbrenners zur Regenerierung von lebensmittel- und trinkwassertauglichen Aktivkohlen 114. Einsatz einer Abgasbehandlungsanlage 115. Wäschersysteme 116. Abwasserbehandlungsanlagen
Aufbereitung von Abfall zur Nutzung als Brennstoff	117. Vermittlung der vorhandenen Kenntnisse über die Zusammensetzung des aus Abfall hergestellten Brennstoffs 118. Qualitätssicherungssysteme 119. Herstellung verschiedener Arten von Brennstoffen aus Abfall 120. Abwasserbehandlung 121. Sicherheitsaspekte
Herstellung fester Brennstoffe aus nicht gefährlichem Abfall	122. Visuelle Prüfung der eingehenden Abfälle 123. Einsatz von Magnetscheidern für Eisenmetalle und Abscheidern für Nichteisenmetalle 124. Nutzung von Nahinfrarotverfahren 125. Herstellung des Brennstoffs in der richtigen Größe
Herstellung fester Brennstoffe aus gefährlichem Abfall	126. Trocknung und Erhitzung 127. Vermengung und Vermischung 128. Verhinderung der Emission von Partikeln
Herstellung flüssiger Brennstoffe aus gefährlichem Abfall	129. Einsatz von nicht in den Behälter eingebauten Wärmeaustauschern 130. Homogenität des flüssigen Brennstoffs

BVT für den Abfallbehandlungssektor

In Entwicklung befindliche Techniken

Im vorliegenden Dokument werden auch die von der TWG identifizierten Techniken aufgeführt, die bisher nicht kommerziell genutzt werden und sich derzeit in der Forschungs- oder Entwicklungsphase befinden. Angesichts der möglichen Auswirkungen dieser Verfahren innerhalb des Abfallbehandlungssektors wurden sie aufgenommen, um bei einer zukünftigen Revision des Dokuments Berücksichtigung zu finden.

Abschließende Bemerkungen

Schon zu Beginn des Informationsaustauschs zeichnete sich ab, dass es unterschiedliche Auffassungen darüber gibt, welche Abfallbehandlungsanlagen in das Dokument Eingang finden sollen und welche nicht. Ferner wurde festgestellt, dass einige Anlagen nur teilweise den Bestimmungen der IVU-Richtlinie unterliegen. Vor allem deswegen verwendeten die Experten viel Zeit auf die Klärung und das Verständnis dieser Fragen, so dass für die Festlegung der sektorspezifischen BVT nur in begrenztem Maße Zeit zur Verfügung stand. Dies dürfte der Grund sein, warum im Rahmen des Informationsaustauschs nur eine beschränkte Anzahl an BVT-Schlussfolgerungen ermittelt werden konnte. Hinzu kommt, dass während der beiden Plenarsitzungen (Auftakt- und Abschlusssitzung) unterschiedliche Ansichten über die Struktur des Dokuments erörtert wurden.

Ein hohes Maß an Konsens bestand im Hinblick auf das BVT-Kapitel. Es wird aber auch die Meinung vertreten, dass der Geltungsbereich des Dokuments weiter gefasst werden sollte und dass im Dokument in seiner jetzigen Fassung nicht berücksichtigte Abfallbehandlungsanlagen einbezogen werden sollten.

In Vorbereitung zukünftiger Revisionen des Dokuments sollten alle Mitglieder der TWG und alle Interessierten weiterhin Daten über die derzeitigen Verbrauchs- und Emissionswerte und die Leistungsfähigkeit der bei der Festlegung der BVT zu berücksichtigenden Techniken sammeln.

Die Europäische Kommission initiiert und fördert im Rahmen ihrer FuE-Programme zahlreiche Projekte betreffend saubere Technologien, neue Abwasserbehandlungs- und Recyclingverfahren sowie Managementstrategien. Diese Projekte können möglicherweise einen nützlichen Beitrag zu künftigen Überarbeitungen dieses Dokuments leisten. Die Leser werden daher gebeten, das Europäische Büro für die integrierte Vermeidung und Verminderung der Umweltverschmutzung (EIPPCB) über etwaige Forschungsergebnisse zu unterrichten, die für den Umfang dieses Merkblattes von Bedeutung sind (siehe auch Vorwort).

VORWORT

1. Status dieses Dokuments

Sofern nicht anders angegeben, beziehen sich alle Hinweise auf „die Richtlinie“ im vorliegenden Dokument auf die Richtlinie 96/61/EG des Rates über die integrierte Vermeidung und Verminderung der Umweltverschmutzung. Wie die Richtlinie berührt auch dieses Dokument nicht die Vorschriften der Gemeinschaft über die Gesundheit und Sicherheit am Arbeitsplatz.

Dieses Dokument ist Teil einer Reihe, in der die Ergebnisse eines Informationsaustauschs zwischen den EU-Mitgliedstaaten und der betroffenen Industrie über beste verfügbare Techniken (BVT), die damit verbundenen Überwachungsmaßnahmen und die Entwicklungen auf diesem Gebiet vorgestellt werden. Es wird von der Europäischen Kommission gemäß Artikel 16 Absatz 2 der Richtlinie veröffentlicht und muss daher gemäß Anhang IV der Richtlinie bei der Festlegung der „besten verfügbaren Techniken” berücksichtigt werden.

2. Rechtliche Pflichten und Definition der BVT gemäß der Richtlinie über die integrierte Vermeidung und Verminderung der Umweltverschmutzung

Um dem Leser das Verständnis des rechtlichen Rahmens zu erleichtern, in dem das vorliegende Dokument ausgearbeitet wurde, werden im Vorwort die wichtigsten Bestimmungen der Richtlinie über die integrierte Vermeidung und Verminderung der Umweltverschmutzung beschrieben und eine Definition des Begriffs „beste verfügbare Techniken” gegeben. Diese Beschreibung muss zwangsläufig unvollständig sein und dient ausschließlich der Information. Sie hat keine rechtlichen Konsequenzen und ändert oder berührt in keiner Weise die Bestimmungen der Richtlinie.

Die Richtlinie dient der integrierten Vermeidung und Verminderung der Umweltverschmutzung, die durch die im Anhang I aufgeführten Tätigkeiten verursacht wird, damit insgesamt ein hoher Umweltschutz erreicht wird. Die Rechtsgrundlage der Richtlinie bezieht sich auf den Umweltschutz. Bei ihrer Anwendung sollten auch die anderen Ziele der Gemeinschaft, wie die Wettbewerbsfähigkeit der europäischen Industrie, berücksichtigt werden, so dass sie zu einer nachhaltigen Entwicklung beiträgt.

Im Einzelnen sieht sie ein Genehmigungsverfahren für bestimmte Kategorien industrieller Anlagen vor und verlangt sowohl von den Betreibern als auch von den Durchführungsbehörden und sonstigen Einrichtungen eine integrierte, ganzheitliche Betrachtung des Umweltverschmutzungs- und Verbrauchspotenzials der Anlage. Das Gesamtziel dieses integrierten Konzepts muss darin bestehen, das Management und die Kontrolle der industriellen Prozesse so zu verbessern, dass ein hoher Schutz der gesamten Umwelt gewährleistet ist. Von zentraler Bedeutung für dieses Konzept ist das in Artikel 3 verankerte allgemeine Prinzip, nach dem die Betreiber alle geeigneten Vorsorgemaßnahmen gegen Umweltverschmutzungen zu treffen haben, insbesondere durch den Einsatz der besten verfügbaren Techniken, mit deren Hilfe sie ihre Umweltschutzleistungen verbessern können.

Der Begriff „beste verfügbare Techniken“ ist in Artikel 2 Absatz 11 der Richtlinie definiert als „der effizienteste und fortschrittlichste Entwicklungsstand der Tätigkeiten und entsprechenden Betriebsmethoden, der spezielle Techniken als praktisch geeignet erscheinen lässt, grundsätzlich als Grundlage für die Emissionsgrenzwerte zu dienen, um Emissionen in und Auswirkungen auf die gesamte Umwelt allgemein zu vermeiden oder, wenn dies nicht möglich ist, zu vermindern.“ Weiter heißt es in der Begriffsbestimmung in Artikel 2 Absatz 11:

„Techniken“ beinhalten sowohl die angewandte Technologie als auch die Art und Weise, wie die Anlage geplant, gebaut, gewartet, betrieben und stillgelegt wird.

Als „verfügbar“ werden jene Techniken bezeichnet, die in einem Maßstab entwickelt sind, der unter Berücksichtigung des Kosten/Nutzen-Verhältnisses die Anwendung unter in dem betreffenden industriellen Sektor wirtschaftlich und technisch vertretbaren Verhältnissen ermöglicht, gleich, ob diese Techniken innerhalb des betreffenden Mitgliedstaats verwendet oder hergestellt werden, sofern sie zu vertretbaren Bedingungen für den Betreiber zugänglich sind.

Als „beste“ gelten jene Techniken, die am wirksamsten zur Erreichung eines allgemein hohen Schutzes für die Umwelt als Ganzes sind.

Anhang IV der Richtlinie enthält eine Liste von „Punkten, die bei Festlegung der besten verfügbaren Techniken im Allgemeinen wie auch im Einzelfall zu berücksichtigen sind unter Berücksichtigung der sich aus einer Maßnahme ergebenden Kosten und ihres Nutzens sowie des Grundsatzes der Vorsorge und Vermeidung“. Diese Punkte schließen jene Informationen ein, die von der Kommission gemäß Artikel 16 Absatz 2 veröffentlicht werden.

Die für die Erteilung von Genehmigungen zuständigen Behörden haben bei der Festlegung der Genehmigungsauflagen die in Artikel 3 verankerten allgemeinen Prinzipien zu berücksichtigen. Diese Genehmigungsauflagen müssen Emissionsgrenzwerte enthalten, die gegebenenfalls durch äquivalente Parameter oder technische Maßnahmen erweitert oder ersetzt werden. Entsprechend Artikel 9 Absatz 4 der Richtlinie müssen sich diese Emissionsgrenzwerte, äquivalenten Parameter und technischen Maßnahmen unbeschadet der Einhaltung der Umweltqualitätsnormen auf die besten verfügbaren Techniken stützen, ohne dass die Anwendung einer bestimmten Technik oder Technologie vorgeschrieben wird. Hierbei sind die technische Beschaffenheit der betreffenden Anlage, ihr Standort und die jeweiligen örtlichen Umweltbedingungen zu berücksichtigen. In jedem Fall haben die Genehmigungsauflagen Vorkehrungen zur weitestgehenden Verminderung weiträumiger oder grenzüberschreitender Umweltverschmutzungen vorzusehen und einen hohen Schutz für die Umwelt als Ganzes sicherzustellen.

Gemäß Artikel 11 der Richtlinie haben die Mitgliedstaaten dafür zu sorgen, dass die zuständigen Behörden die Entwicklungen bei den besten verfügbaren Techniken verfolgen oder darüber informiert sind.

3. Ziel des Dokuments

Entsprechend Artikel 16 Absatz 2 der Richtlinie hat die Kommission „einen Informationsaustausch zwischen den Mitgliedstaaten und der betroffenen Industrie über die besten verfügbaren Techniken, die damit verbundenen Überwachungsmaßnahmen und die Entwicklungen auf diesem Gebiet“ durchzuführen und die Ergebnisse des Informationsaustausches zu veröffentlichen.

Der Zweck des Informationsaustausches ist unter der Erwägung 25 der Richtlinie erläutert, in der es heißt: „Die Entwicklung und der Austausch von Informationen auf Gemeinschaftsebene über die besten verfügbaren Techniken werden dazu beitragen, das Ungleichgewicht auf technologischer Ebene in der Gemeinschaft auszugleichen, die weltweite Verbreitung der in der Gemeinschaft festgesetzten Grenzwerte und der angewandten Techniken zu fördern und die Mitgliedstaaten bei der wirksamen Durchführung dieser Richtlinien zu unterstützen.“

Zur Unterstützung der unter Artikel 16 Absatz 2 vorgesehenen Maßnahmen hat die Kommission (GD Umwelt) ein Informationsaustauschforum (IEF) geschaffen, unter dessen Schirmherrschaft mehrere technische Arbeitsgruppen eingesetzt wurden. Bei diesem Forum und in den technischen Arbeitsgruppen sind, wie in Artikel 16 Absatz 2 verlangt, sowohl die Mitgliedstaaten als auch die Industrie vertreten.

In dieser Dokumentenreihe werden der Informationsaustausch, wie er gemäß Artikel 16 Absatz 2 stattgefunden hat, genau wiedergegeben und der Genehmigungsbehörde Referenzinformationen für die Genehmigungsauflagen zur Verfügung gestellt. Mit ihren Informationen über die besten verfügbaren Techniken sollen diese Dokumente als ein wertvolles Mittel zur Verbesserung der Umweltschutzleistung dienen.

4. Informationsquellen

Dieses Dokument enthält eine Zusammenfassung von Informationen, die aus verschiedenen Quellen, einschließlich sachkundiger Angaben der zur Unterstützung der Kommission geschaffenen Arbeitsgruppen, stammen und von den Dienststellen der Kommission geprüft wurden. Alle Beiträge werden dankbar anerkannt.

5. Anleitung zum Verständnis und zur Benutzung des Dokuments

Die im vorliegenden Dokument enthaltenen Informationen sind als Unterstützung bei der Bestimmung der BVT in speziellen Fällen gedacht. Bei der Bestimmung der BVT und bei den auf BVT basierenden Genehmigungsauflagen ist stets vom Gesamtziel, d. h. einem hohen Schutz für die Umwelt als Ganzes, auszugehen.

Der verbleibende Teil dieses Abschnitts beschreibt, welche Art von Informationen die einzelnen Kapitel des Dokuments enthalten.

Kapitel 1 und 2 geben allgemeine Informationen über die Branche und über die in der Branche angewandten industriellen Verfahren. Kapitel 3 enthält Daten und Angaben über die Emissions- und Verbrauchswerte bestehender Anlagen. Sie zeigen den Stand zum Zeitpunkt der Erarbeitung des Dokuments.

In Kapitel 4 werden eingehender die Verfahren zur Emissionsverminderung und andere Methoden beschrieben, die als die wichtigsten für die Bestimmung der BVT wie auch für die auf BVT basierenden Genehmigungsauflagen betrachtet werden. Diese Informationen schließen die Verbrauchs- und Emissionswerte ein, die sich mit dem jeweiligen Verfahren erreichen lassen, einige Vorstellungen über die mit der jeweiligen Technik verbundenen Kosten und die medienübergreifenden Aspekte sowie Angaben über die Anwendbarkeit der Technik in Anlagen, die der IVU-Genehmigung unterliegen, z. B. neue, bestehende, große oder kleine Anlagen. Verfahren, die allgemein als veraltet gelten, wurden nicht berücksichtigt.

In Kapitel 5 werden die Verfahren und die Emissions- und Verbrauchswerte aufgeführt, die allgemein den Anforderungen an die besten verfügbaren Techniken entsprechen. Dabei geht es darum, allgemeine Angaben über die Emissions- und Verbrauchswerte bereitzustellen, die für die auf BVT basierenden Genehmigungsauflagen oder für allgemein verbindliche Vorschriften gemäß Artikel 9 Absatz 8 als Bezug gelten können. Jedoch muss darauf hingewiesen werden, dass es sich in diesem Dokument nicht um Vorschläge für Emissionsgrenzwerte handelt. Bei den Genehmigungsauflagen sind lokale, standortspezifische Faktoren wie die technische Beschaffenheit der betreffenden Anlage, ihr Standort und die örtlichen Umweltbedingungen zu berücksichtigen. Ferner ist bei bestehenden Anlagen die wirtschaftliche und technische Vertretbarkeit einer Modernisierung zu beachten. Allein die angestrebte Sicherung eines hohen Schutzes für die Umwelt als Ganzes erfordert nicht selten ein Abwägen der einzelnen Umweltauswirkungen, das wiederum oft von lokalen Erwägungen beeinflusst wird.

Obgleich im vorliegenden Dokument der Versuch unternommen wird, einige dieser Aspekte aufzugreifen, ist eine umfassende Behandlung in diesem Rahmen nicht möglich. Somit sind die in Kapitel 5 aufgeführten Verfahren und Zahlenwerte nicht notwendigerweise auf alle Anlagen anwendbar. Andererseits verlangt die Pflicht zur Sicherung eines hohen Umweltschutzes einschließlich einer weitestgehenden Verminderung der weiträumigen oder grenzüberschreitenden Umweltverschmutzung, dass Genehmigungsauflagen nicht aus rein lokalen Erwägungen festgesetzt werden. Daher ist die vollständige Berücksichtigung der im vorliegenden Dokument enthaltenen Informationen durch die Genehmigungsbehörden von größter Bedeutung.

Da sich die besten verfügbaren Techniken mit der Zeit ändern, wird dieses Dokument bei Bedarf überprüft und aktualisiert. Stellungnahmen und Vorschläge sind an das Europäische IPPC-Büro beim Institut für technologische Zukunftsforschung zu senden:

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Merkblatt über die besten verfügbaren Techniken für Abfallbehandlungsanlagen

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UMFANG

Das vorliegende Dokument, soll zusammen mit weiteren BVT-Merkblätter der Reihe, die in Anhang I Nummer 5 der IVU-Richtlinie aufgeführten industriellen Tätigkeiten der „Abfallbehandlung“ umfassen. Gegenstand eines anderen Merkblattes ist die Abfallverbrennung wie auch andere Verfahren der thermischen Abfallbehandlung wie zum Beispiel die Pyrolyse und Vergasung (Anhang I Nummer 5.2 der Richtlinie). Obwohl in Anhang I Nummer 5.4 Deponien genannt werden, beinhaltet das vorliegende Dokument keine BVT für Deponien. Folglich konzentriert sich der Umfang dieses Dokument auf die folgenden Punkte des Anhangs I der Richtlinie:

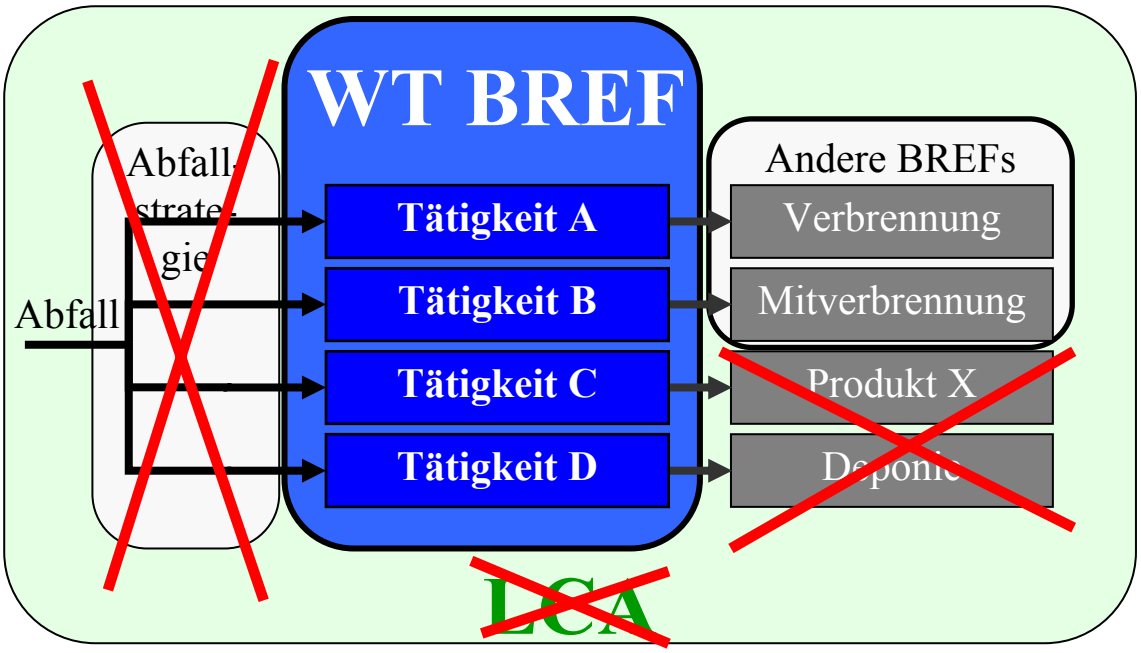
- *Anlagen zur Beseitigung oder Verwertung von gefährlichen Abfällen im Sinne des in Artikel 1 Absatz 4 der Richtlinie 91/689/EWG vorgesehenen Verzeichnisses gefährlicher Abfälle (diese Anlagen sind in den Anhängen II A und II B – Verwertungsverfahren R1, R5, R6, R8 und R 9) der Richtlinie 75/442/EWG definiert) mit einer Kapazität von über 10 t pro Tag*
- *Anlagen zur Altölbeseitigung im Sinne der Richtlinie 75/439/EWG des Rates vom 16. Juni 1975 mit einer Kapazität von über 10 t pro Tag*
- *Anlagen zur Beseitigung nicht gefährlicher Abfälle im Sinne des Anhangs II A der Richtlinie 75/442/EWG (Rubriken D8, D9) mit einer Kapazität von über 50 t pro Tag.*

Die Codes für Verwertungs- (R-Codes) und Beseitigungsverfahren (D-Codes) der Anhänge II A und II B der Richtlinie 75/442/EG, welche die IVU-Richtlinie betreffen, wurden gemäß der Entscheidung 96/350/EG der Kommission geändert. Da diese letzte Anpassung den neuesten Codes für Verwertungs- und Beseitigungsverfahren (R- und D-Codes) entspricht, spiegelt die nachstehende Tabelle in Übereinstimmung mit der Sichtweise des Informationsaustauschforums (IEF) und der Technischen Arbeitsgruppe (TWG) und unter Berücksichtigung der Zielsetzung der IVU-Richtlinie die Codes für die Art von Abfallbehandlungsverfahren wider, um die es im vorliegenden Dokument geht.

Abfallbehandlungsverfahren	**R- bzw. D-Code 96/350/EG**
Hauptverwendung als Brennstoff oder andere Mittel der Energieerzeugung	R 1
Rückgewinnung/Regenerierung von Lösemitteln	R 2
Verwertung/Rückgewinnung von anderen anorganischen Stoffen (d.h. anderen als den unter R 4 aufgeführten Metallen und Metallverbindungen)	R 5
Regenerierung von Säuren oder Basen	R 6
Wiedergewinnung von Bestandteilen, die der Bekämpfung der Verunreinigungen dienen	R 7
Wiedergewinnung von Katalysatorenbestandteilen	R 8
Ölraffination oder andere Wiederverwendungsmöglichkeiten von Öl	R 9
Austausch von Abfällen, um sie einem der unter R 1 bis R 11 aufgeführten Verfahren zu unterziehen	R 12
Ansammlung von Abfällen, um sie einem der unter R 1 bis R 12 aufgeführten Verfahren zu unterziehen (ausgenommen zeitweilige Lagerung - bis zum Einsammeln - auf dem Gelände der Entstehung der Abfälle)	R 13
Biologische Behandlung, die nicht an anderer Stelle in Anhang II der Entscheidung 96/350/EG beschrieben ist und durch die Endverbindungen oder Gemische entstehen, die mit einem der in D 1 bis D 12 aufgeführten Verfahren entsorgt werden	D 8
Chemisch/physikalische Behandlung, die nicht an anderer Stelle in Anhang II der Entscheidung 96/350/EG beschrieben ist und durch die Endverbindungen oder Gemische entstehen, die mit einem der in D 1 bis D 12 aufgeführten Verfahren entsorgt werden (z. B. Verdampfen, Trocknen, Kalzinieren usw.)	D 9
Vermengung oder Vermischung vor Anwendung eines der in D 1 bis D 12 aufgeführten Verfahren	D 13
Rekonditionierung vor Anwendung eines der in D 1 bis D 13 aufgeführten Verfahren	D 14
Lagerung bis zur Anwendung eines der in D 1 bis D 14 aufgeführten Verfahren (ausgenommen zeitweilige Lagerung - bis zum Einsammeln - auf dem Gelände der Entstehung der Abfälle)	D 15

Das restliche Kapitel versucht zu klären, welche Tätigkeiten der gesamten Abfallwirtschaftskette in diesem Dokument enthalten sind.

Der Abfallbehandlungssektor und das Abfallbehandlungsdokument (WT)
Die Kette der Tätigkeiten, die die Abfallwirtschaft betreffen ist lang und liegt zum Teil außerhalb des Anwendungsbereichs der IVU-Richtlinie. Die folgende Abbildung versucht zusammenzufassen, welche Tätigkeiten aus dem Abfallbehandlungssektor in der Serie der BVT-Merkblätter abgedeckt werden.



Abfallwirtschaft und BVT-Merkblatt Abfallbehandlung
Anmerkung: Durchgestrichene Bereiche bedeuten, dass sie in diesem Dokument nicht enthalten sind

Eine vollständige „Lebenszyklusanalyse“ (LCA) für einen bestimmten Abfall, betrachtet neben sämtlichen Gliedern der Abfallkette auch die Auswirkungen des Endprodukts/Abfalls auf die Umwelt. Die IVU zielt nicht auf diese Analysen ab, sondern stellt die Anlagen in den Mittelpunkt. So ist beispielsweise die Minimierung des Aufkommens und/oder Toxizität des an der Quelle in industriellen Anlagen erzeugten Abfalls ein wesentlicher Bestandteil der IVU und zugleich auch Gegenstand aller BVT-Merkblätter der einzelnen industriellen Sektoren (siehe dazu das Verzeichnis auf der Rückseite des Titelblatts dieses Dokuments). Ein weiteres Beispiel zeigt, dass sich die Abfallbehandlung auch auf strategische Entscheidungen darüber erstreckt, welche Art von Abfall in den verfügbaren Abfallbehandlungen/Verfahren/Varianten behandelt bzw. welcher Behandlung eine Abfallart unterzogen wird. Diese Entscheidung hängt davon ab, welche Abfallbehandlungsmöglichkeiten auf lokaler, regionaler, nationaler oder internationaler Ebene zur Verfügung stehen, wobei auch die Frage eine Rolle spielt, wo der Abfall erzeugt wird.

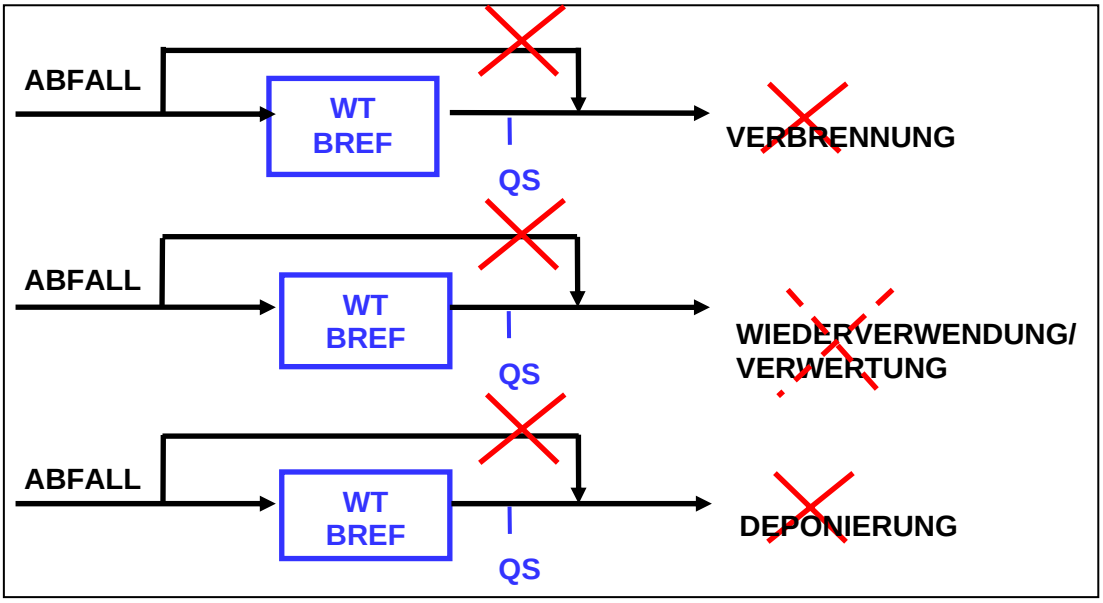
Wie in der vorhergehenden Abbildung gezeigt wurde, liegt die Abfallverbrennung derzeit nicht im Anwendungsbereich dieses Dokuments. Sie wird in jedem individuellen BVT-Merkblatt angesprochen, in denen die verschiedenen Verbrennungsverfahren abhängig vom industriellen Sektor in der er angewandt, analysiert wird (z.B. Abfallverbrennung, Großfeuerungsanlagen, Zementöfen). Indem die Aufbereitung von Abfall zur Nutzung als Brennstoff enthalten ist, deckt dieses Dokument die Behandlungsarten ab, die eingesetzt werden können, um verschiedene Abfallarten für die von verschiedenen Verbrennungsprozessen geforderte Brennstoffqualität geeignet zu machen.

Einige Materialien werden anhand von Legislativen kategorisiert zum Beispiel als Sekundärbrennstoffe (engl. REF), von Ersatzbrennstoffe (engl. RDF) oder feste Sekundärbrennstoffe (engl. SRF) eingestuft. Es besteht hier nicht die Absicht, in eine Diskussion über die Definition der einzelnen Abfallbegriffe einzusteigen. Zum letzteren Punkt können zum Beispiel Informationen in den Vorschlägen für CEN-Normen gefunden werden. Auch können einige dieser Materialien entsprechend der Legislative als gefährliche Abfälle klassifiziert werden.

Dieses Dokument enthält diejenigen Abfallbehandlungsarten, die einen Abfall wiederverwendbar oder wiederverwertbar machen können. Allerdings sind in diesem Dokument jedoch nicht solche Wiederverwendungs- oder Verwertungsmöglichkeiten enthalten, bei denen Abfälle ohne vorherige Behandlung direkt von einem Industriesektor in den anderen gehen (z. B. Wiederverwendung von Gießereisand oder einiger geeigneter Katalysatoren als Rohstoff in Zementöfen, Wiederverwendung von Altmetallen in der NE-Metallverarbeitung). Dieser Punkt wird in der folgenden Abbildung gezeigt.

Wie oben erwähnt, enthält dieses Dokument keine Techniken in Bezug auf Deponien. Die einzigen enthaltenen Themen stehen in Zusammenhang mit der Behandlung von Abfall um ihn für die Deponierung besser geeignet zu machen.

Die folgende Abbildung versucht, die in den obigen Absatz enthaltenen Punkte zu verdeutlichen und zusammenzufassen.



Beispiele für in diesem Dokument nicht enthaltenen Abfallbehandlungen
Bemerkung: QS: Qualitätssicherung

In diesem Dokument enthaltene abfallbezogene Tätigkeiten

Unter Berücksichtigung aller oben aufgeführten Punkte/Argumente, des Anhangs I der IVU-Richtlinie, der anderen bereits erschienenen oder noch in Bearbeitung befindlichen BVT-Merkblätter und der gesetzlichen Anforderungen der Europäischen Kommission listet die folgende Tabelle die in diesem Dokument enthaltenen Abfallbehandlungsverfahren auf:

Behandlung	Abfallart oder Beispiele von Abfallarten	Zusätzliche Informationen
Anlagen, die hauptsächlich Behandlungen ausführen, deren Outputs deponiert werden		Die TWG hat anerkannt, dass es in vielen Fällen Anlagen gibt, wo es sehr schwierig zu differenzieren ist, ob es sich bei ihrem Output um Stoffe für eine weitere Verwendung oder um zu entsorgende Materialien handelt, z. B. bei Schwankungen, die abhängig von Marktbedingungen, der Verfügbarkeit oder der Zusammensetzung des Abfalls sind, was bedeuten kann, dass abhängig vom Zeitpunkt seiner Erzeugung der Output recycelt, entsorgt oder unter manchen ökonomischen Bedingungen sogar als Produkt/Rohmaterial für andere Verfahren verkauft werden kann.
Alle Arten	Ausgehobener Boden	
Alle Arten	FCKW-haltige Materialien	Einige Verbrennungsanlagen für teilhalogenierte FCKW
Alle Arten	Mit POPs (z. B. mit PCBs und Dioxinen) verunreinigte Materialien	Kommunikation der Kommission an den Rat, das Europäische Parlament und den Wirtschafts- und Sozialausschuss (COM(2001) 593). Die Kommunikation bezieht sich auf IVU und BVT (pp. 7,15,17), aber insbesondere auf das BVT-Merkblatt Abfallbehandlungsanlagen (so genannte R&D Abfall). In ihr steht: "Im Zusammenhang mit dem BVT-Merkblatt zu R&D Tätigkeiten, zu erarbeiten in den Jahren 2002 bis 2004, wird besondere Aufmerksamkeit darauf gelegt werden, BVT für die Behandlung von mit PCBs und Dioxinen verunreinigten Abfallstoffen festzulegen." Dieses Dokument enthält nicht die Verbrennung solcher Materialien.

Behandlung	Abfallart oder Beispiele von Abfallarten	Zusätzliche Informationen
Alle Arten	Öl-/Wasserschlamm	
Alle Arten	Schadstoffhaltige Kunststoffe	
Alle Arten	Schlamm aus Abwasserbehandlungs-anlagen	
Alle Arten	Verbrauchte Katalysatoren	Der Katalysatorbehandlungssektor enthält diejenigen Behandlungen, die einen verbrauchten Katalysator wiederverwendbar oder regenerierbar machen. Dieses Dokument kann jedoch nicht die Verwendungsmöglichkeiten abdecken, bei denen Abfälle direkt ohne die Notwendigkeit einer Behandlung von einem industriellen Sektor in einen anderen gehen (z. B. Wiederverwendung von Katalysatoren als Rohmaterial in Zementöfen, Wiederverwendung von Altmetallen in der NE-Metallverarbeitung). Diese Themen sind in den BVT-Merkblättern für die einzelnen industriellen Sektoren enthalten. Dieses Dokument berücksichtigt und untersucht die Auswirkungen der verschiedenen zu behandelnden und umzuwandelnden Abfallarten, so dass der Abfall in eine zur Nutzung in bestimmten Verfahren geeignete Form gebracht wird. Die Regenerierung von Katalysatoren kann betriebsintern oder betriebsextern durchgeführt werden. Dieses Dokument behandelt betriebsexterne Anlagen. Verbrauchte Katalysatoren können manchmal in der Industrie in prozessintegrierten Anlagen regeneriert werden. Die Regenerierung von Katalysatoren in integrierten Anlagen der Industrie ist nicht in diesem Dokument enthalten. Deshalb konzentriert sich dieses Dokument auf allein stehende Regenerierungsanlagen
Alle Arten	Mit Quecksilber verunreinigter Abfall	
Übliche Behandlungsarten		
Vermengung und Vermischung		
Rekonditionierung		
Lagerung von Abfall und Rohmaterialien		BVT-Merkblatt Lagerung Zeitweilige Abfalllagerung
Abfallannahme, -beprobung, -beurteilung und –analytik		Mit Abfallbehandlungsanlagen verbundene Tätigkeiten
Abfallumlade- und Abfallumschlagstationen		
Abfallumschlagstationen (für gefährliche oder nicht gefährliche Abfälle)		
Biologische Behandlungsverfahren		
Aerobe/anaerobe Behandlungsverfahren	Ausgehobener kontaminierter Boden	Ex-Situ-Sanierung
Aerobe/anaerobe Behandlungsverfahren	Nicht an der Quelle getrennter Abfall (z.B. gemischter Siedlungsabfall)	Vorbehandlung vor der Beseitigung, dabei wird ein Produkt erzeugt ,das sich nicht zur Kompostierung eignet
Biologische Behandlung	Biologisch abbaubare wässrige Flüssigkeiten, z. B. Lebensmittelabfälle, Methanol und andere wassermischbare Lösemittel	Flüssige Abfälle in großen Mengen, die mit Tankfahrzeugen zu Abwasserbehandlungsanlagen gefahren werden Aerobe und/oder anaerobe Behandlung abhängig von der Gestaltung der Abwasserbehandlungsanlage
Mechanisch-biologische Behandlungsverfahren		Vorbehandlung vor der Beseitigung

Behandlung	Abfallart oder Beispiele von Abfallarten	Zusätzliche Informationen
Chemisch-physikalische Behandlungsverfahren		
Neutralisation von Säuren	Salz-, Schwefel-, Salpeter-, Fluss-, Phosphorsäure und saure Salze, wie z. B. Aluminiumchlorid usw.	Mischung der Säuren entweder mit Abfalllaugen oder mit Rohmaterialien wie Kalk. Salpeter- und Flusssäuren werden normalerweise getrennt behandelt.
Neutralisation/Behandlung von Alkalien	Natrium- und Kaliumhydroxid, Kalk, Ammoniaklösung , Ammoniumsalze und Amine	Alkalien und Kalk werden mit Säuren neutralisiert. Wässrige Ammoniaklösungen können durch Strippen mit Luft behandelt werden. Ammoniumsalze und Amine sollten bei pH <9 aufbewahrt werden, um eine Freisetzung von Gasen zu vermeiden.
Behandlung von Chromsäure	Chromoxid (CrO_3) ist sauer, giftig, wasserlöslich und ein Oxidationsmittel	Umwandlung von Cr^{6+} zu ungefährlicherem Cr^{3+} durch Zugabe eines Reduktionsmittels wie Natriummetabisulfit und anschließende Fällung
Cyanidentgiftung	Cyanidsalze, z. B. Natriumcyanid aus der Oberflächenbehandlung von Metallen	Umwandlung von Cyanid zu ungefährlicherem Cyanat bei pH >10 unter Verwendung eines Oxidationsmittels
Entwässerung	Schlamm aus der Sedimentation	Herstellung eines festen Filterkuchens durch Filtration durch Gewebefiltertücher/Zentrifugen oder Filterpressen
Ex-situ-Behandlung	Ausgehobener kontaminierter Boden	
Filtration	Abwasser aus Entwässerung, auch eingesetzt für wässrige, ölverunreinigte Substanzen	Mikro- und Ultrafiltration zur Entfernung von Feststoffen. Nanofiltration und Umkehrosmose können zur Entfernung von gelösten Molekülen eingesetzt werden, werden aber zurzeit nicht zur chemisch-physikalischen Behandlung angewendet
Annahmeeinrichtungen in Häfen	Verunreinigtes Wasser	
Öl-Wasser-Trennung	Wässrige, mit Öl verunreinigte Materialien	Kippbleche oder Koagulationsabscheider, mit denen die Unterschiede im spezifischen Gewicht genutzt werden
Chemisch-physikalische Behandlung	Asbest	
Chemisch-physikalische Behandlung	Kontaminiertes Holz	
Chemisch-physikalische Behandlung	Verunreinigte Schamotte	
Chemisch-physikalische Behandlung	Flüssige, schlammförmige und feste Abfälle (z. B. Salze und Lösungen, die Cyanide, Pestizide, Biozide und kontaminierte Holzschutzmittel enthalten)	Chemisch-physikalische Behandlungsverfahren werden in der Praxis sehr breit angewendet, einschließlich aller Maßnahmen zur Behandlung flüssiger, schlammförmiger und fester Abfälle. Phasentrennung (Entfernung von Feststoffen, Emulsionstrennung , Trennung nicht mit einander löslicher Flüssigkeiten, Fällung, Sedimentation), mechanische Behandlungsverfahren, Eindampfung , Entwässerung , Trocknung , Stabilisierung und Verfestigung von Abfall, Neutralisation, Entgiftung , Kalzinierung, Vermengung, Vermischung
Fällung	Metalle, zum Beispiel Zn, Ni, Cr, Pb, Cu	Fällung unter Verwendung von Säuren und Alkalien zur Einstellung des pH auf minimale Löslichkeiten
Abtrennung von Quecksilber aus Abfall	Mit Quecksilber verunreinigter Abfall	
Trennung, chemisch-physikalische Behandlung	Öl-Wasser-Mischungen und Emulsionen	
Absetzung	Abwasser, das neutralisierte Säuren/Basen, ausgefällte Metalle und andere Feststoffe enthält	Die Feststoffe setzen sich aus dem Abwasser ab. Die Feststoffbildung und Effizienz des Absetzens können durch Zugabe eines Flockungsmittels unterstützt werden. In einigen Anlagen wird die Entspannungsflotation (engl. DAF) (hauptsächlich für organische Schlämme)angewendet, um einen schwebenden ausgeflockten Feststoff herzustellen

Behandlung	Abfallart oder Beispiele von Abfallarten	Zusätzliche Informationen
Verfestigung und Stabilisierung	Flugaschen und Verbrennungsschlacken vor der Deponierung. In manchen Fällen für flüssige und halbfeste Kohlenwasserstoffe. Mineralische industrielle feste Abfälle und Schlämme	Verbrennungsschlacken sind meistens in anderen BVT-Merkblättern als Bestandteile ihrer Entstehungsprozesse enthalten. Die Mischung von Abfällen mit Absorbentien oder Bindern, z. B. Bentonit, Asche, Ofenasche zur Verringerung der Umweltauswirkungen
UV- und Ozonbehandlung	Verunreinigtes Wasser	
Behandlungsverfahren zur hauptsächlichen stofflichen Verwertung		
Aufkonzentrierung	Säuren und Basen	Anlagen zur thermischen Regeneration von HCl und zur Aufkonzentrierung von verbrauchter H_2SO_4. Die restlichen Regenerationsverfahren für Schwefelsäure sind im BVT-Merkblatt „Anorganische Grundchemikalien“ enthalten
Verwertung von Materialien	Abfall aus umwelttechnischen Anlagen	
Verwertung von Metallen	Flüssige und feste fotografische Abfälle	
Regenerierung	Organische Lösemittel	
Regenerierung	Verbrauchte Ionenaustauscherharze	
Regenerierung und Behandlung	Verbrauchte Aktivkohle	Enthält die Regenerierung von Aktivkohle. Die Regenerierung von Aktivkohle bei der Chlor-Alkali-Elektrolyse nach dem Amalgamverfahren behandelt das BVT-Merkblatt „Chloralkaliindustrie“
Re-Raffination	Öle	
Behandlungsverfahren,die hauptsächlich zur Herstellung eines Brennstoffs dienen		
Aufbereitung von Abfall zur Nutzung als Brennstoff	Gefährliche und nicht gefährliche Materialien	Alle Arten von Behandlungen (z. B. Umgruppierung, Vermengung, Vermischung, Trennung) zur Aufbereitung von Abfall für die Nutzung in allen Arten von Verbrennungsprozessen (Verbrennung, Großfeuerungsanlagen, Zementöfen, Chemiewerke, Eisen und Stahl usw.)
Herstellung von festem Brennstoff aus Abfall	Nicht gefährlicher Abfall	z. B. aus Siedlungs- und Gewerbeabfall
Herstellung von flüssigem Brennstoff aus Abfall	Gefährlicher Abfall	
Herstellung von flüssigem Brennstoff aus flüssigem Abfall, z. B. Mischung oder Verarbeitung von Öl	Altöle Öle (einschließlich Pflanzenöle) Mit Wasser verunreinigtes Öl Organische Lösemittel	Alle für Altöle oder Lösemittelabfälle eingesetzten Behandlungsarten sind in diesem Dokument enthalten (z. B. Reinigung und weitere Aufbereitung von Altölen, Raffination). Grobe Filterung, Erwärmung und/oder Zentrifugieren und Mischen, um Verbrennungsmaterial zu erzeugen

In diesem Dokument enthaltene Abfälle und Abfallbehandlungsanlagen.

1 GENERAL INFORMATION

[5, Concawe, 1996], [7, Monier and Labouze, 2001], [13, Marshall, et al., 1999], [14, Ministry for the Environment, 2000], [36, Viscolube, 2002], [39, Militon, et al., 2000], [40, Militon and Becaud, 1998], [41, UK, 1991], [42, UK, 1995], [53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [124, Iswa, 2003], [125, Ruiz, 2002], [126, Pretz, et al., 2003], [128, Ribi, 2003], [150, TWG, 2004], [152, TWG, 2004]

1.1 The purpose of waste treatment

Secondary products are inherent to any industrial process and normally cannot be avoided. In addition, the use of products by society leads to residues. In many cases, these types of materials (both secondary products and residues) cannot be re-used by other means and may become not marketable. These materials are typically given to third parties for further treatment.

The reason for treating waste is not always the same and often depends on the type of waste and the nature of its subsequent fate. Some waste treatments and installations are multipurpose. In this document, the basic reasons for treating waste are:

- to reduce the hazardous nature of the waste
- to separate the waste into its individual components, some or all of which can then be put to further use/treatment
- to reduce the amount of waste which has to be finally sent for disposal
- to transform the waste into a useful material.

The waste treatment processes may involve the displacement and transfer of substances between media. For example, some treatment processes results in a liquid effluent sent to sewer and a solid waste sent to landfill, and others result in emissions to air mainly due to incineration. Alternatively, the waste may be rendered suitable for another treatment route, such as in the combustion of recovered fuel oil. There are also a number of important ancillary activities associated with treatment, such as waste acceptance and storage, either pending treatment on site or removal off site.

1.2 Installations for the treatment of waste

This section summaries the waste treatment sector in the EU. A short explanation of the treatments performed is included here.

The waste sector is highly regulated in the EU. For this reason many legal definitions of common terms used in this sector are available (e.g. waste, hazardous waste). Some definitions are available in the European Waste Framework Directive and amendments to it.

Ultimately, waste is either recovered or disposed of. Waste treatment installations therefore carry out operations for the recovery or disposal of waste. Waste treatment installations are not typically considered to produce a product like other industrial sectors. Instead, it is considered that they provide services to society to handle their waste materials. A waste treatment facility typically covers the contiguous land, structures, and other areas used for storing, recovering, recycling, treating, or disposing of waste.

As in the case with the classification of waste types, waste treatment (WT) activities are legally classified by Annex II of the Waste Framework Directive. A copy of this classification is provided in Section 8.1.1 of the Annex of this document, together with examples of their application.

The concept of a facility dedicated to the management of waste is not new. Long before the enactment of waste legislation (hazardous or non-hazardous), companies which produced waste already recognised the need for the specialised treatment and disposal of their wastes. Many waste producers constructed and operated their own dedicated facilities, typically on-site facilities.

Other companies that generated waste, and do not have have suitable site or do not generate a sufficiently large volume of waste to justify the investment in an on-site facility, transported their waste off site to specialised facilities for treatment and disposal. Such facilities are typically referred to as commercial, off-site facilities. The commercial waste management industry thus began the development of these off-site facilities in the late 1960s. His role was to collect and transport waste to specialised off-site facilities where they carried out the treatment and disposal of that waste.

Just as there are many types of waste, there are many ways in which wastes can be managed. For example, there are at least 50 commercially applied technologies for the treatment of hazardous waste. A waste facility may function with just one technology, or it may combine multiple technologies, particularly if it is a commercial facility serving a number of waste producers.

There are some differences between a typical commercial off-site facility and an on-site facility typically specializing in the treatment of a particular type of waste. This derives in part from the fact that an off-site facility accepts waste from outside the local community, while an on-site facility handles only that waste generated by what could be a long-standing and important economic activity in the community. From a technical perspective, the off-site facility generally handles a wider range of waste types and is typically larger and more complex.

For example, off-site waste facilities may be categorised as follows:

- installations focused mainly on recovering material as a saleable product (typically solvents, oils, acids, or metals). Some use the energy value in the waste
- installations focused on changing the physical or chemical characteristics of a waste, or degrade or destroy the waste constituents, using any of a wide variety of physical, chemical, thermal, or biological methods
- installations focused on permanent emplacement of waste on or below the surface of the land. Such installations are not covered in this document.

The following sections within this section cover more specific information gathered, on the types of waste installations, classified by the main type of waste treatment carried out. Not all types of waste treatments covered in this document are covered in this section, possibly because such a treatment may be considered quite minor.

1.2.1 Waste transfer installations

Operations carried out in these installations include: reception, bulking, sorting, transferring pending, prior to submission to a disposal/recovery operation. In some cases, blending and mixing may also be carried out in these installations. Waste transfer stations may involve individual operations or may be an integrated part of a treatment process. All sites typically undertake some kind of bulking operation to agglomerate the solids, where liquids are decanted from one container to another. The liquid transfer can be from a tanker to a holding tank, or from fractions of litre up to a more than 200 litre drum. Operations typically carried out are inspection, sampling, physical sorting and packaging, decanting, blending, drum emptying, storage, drum/IBC reclamation and in some cases disposal of wiping cloths, solidification and the crushing of oil filters. Waste transfer stations tend to fall into two categories according to the objective of the installation:

- **focus on the output stream.** This corresponds to sites that act as a feeder for other processes: e.g. solvent regeneration, incineration, chemical treatment. These sites target specific waste streams that can be checked, analysed and bulked up to provide a steady feedstock for an associated process. They may also take in and process a variety of other materials in order to provide a full service to their clients. These sites tend to handle a much higher proportion of certain waste streams and acceptance, storage and control systems are therefore designed for these wastes
- **focus on the input waste.** These sites are independent transfer stations and generally accept a full range of materials from the neighbouring area. Typically they also bulk and blend materials to produce a range of waste streams suitable for disposal through different treatment, recovery and disposal processes, but they do not usually target any specific waste group. There may be a bias towards particular waste streams, but this will likely be due to local patterns of waste arisings and commercial opportunities, rather than the need to provide a feedstock for a particular downstream process.

The majority of operations linked to waste preparation may be distinguished under two groups:

- **regrouping/reconditioning.** Here the aim is to group together wastes in small or medium quantities, when they have the same nature and when they are compatible. The resulting waste though still has to be treated. The purpose of regrouping is to obtain larger and more homogeneous volumes for waste treatment, to improve safety (e.g. facilitation of handling) and to rationalise the logistics cost. The combination of processes used in waste preparation and in pretreatment operations depends on the specifications of final treatment
- **pretreatment.** Here the aim is to adapt the waste to the type of recovery and/or disposal of the final treatment available. Pretreatment covers several aspects. It can be defined as those operations that lead to homogenisation of the chemical composition and/or physical characteristics of the wastes. Pretreatment produces a waste, which may be very different from the initial waste, although not from a regulatory point of view. This pretreated waste still has to be treated in a recovery and/or disposal plant. At the end of the pretreatment process, the pretreated waste should comply with chemical and physical specifications that are fixed by the end users.

Grouping and pretreatment activities may be located at the same site as the final treatment, on the waste production site or on a particular dedicated site. Nevertheless, regardless of the location, the operating processes are the same.

Table 1.1 below shows the number of waste transfer installations and capacity in different European countries.

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	10			
Denmark	0		0	
Germany	125			
Greece	6			
Spain	68			
France			3000	
Ireland	12			
Italy	0		0	
Luxembourg	1			
Netherlands	2			
Austria	16			
Portugal	5	143	3975 m^3	Y
Finland	5	0[1]	58	0
United Kingdom	439	2073		
Iceland	0		0	
Norway	0		0	
TOTAL	**689**	**2216**		

[1] No non-hazardous installations, other than facilities where waste is unloaded in order to permit its preparation for futher treatment.
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.1: Waste transfer installations
[39, Militon, et al., 2000], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, TWG, 2004]

1.2.2 Installations containing a biological treatment of waste

Refer to the Scope chapter of this document to see which biological treatments of waste are covered. However, note that the data contained in Table 1.2 refer to all biological treatments, including those not covered in the Scope. The reason for this is that available statistics typically refer to national data and it is difficult to separate information of only those installations covered in the Scope of this document.

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	5	Y		
Denmark	1	0		0
Germany	57	200		
Greece	0	Y	0	
Spain	3	Y	140	
France	0	Y	0	
Ireland	1	Y		
Italy	74	3		180
Luxembourg	0	Y	0	
Netherlands	7	Y		
Austria	8	16 [1]	103	706 [1]
Portugal	1	9	88	514
Finland	20	41	98	305
Sweden		Y		
United Kingdom	0	173		
Iceland	0	0	0	0
Norway	0	Y	0	
TOTAL	**177**	**442**	**429**	**1705**

Y: exists but no data are available
[1] Data corresponds to MBT only
Data in this table correspond to all types of biological treatments and not only to those related with the ones inside the scope of this document. Therefore, the number of installations covered by this document will be less than the figures appearing in this table
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.2: Installations for the biological treatment of waste
[39, Militon, et al., 2000], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, TWG, 2004]

In Finland there are 561 waste water treatment installations in which the septic tank sludges are also treated. There are 41 installations (aerobic 27 and anaerobic 14) for treating non-hazardous wastes. Besides the non-hazardous waste installations mentioned in Table 1.2, there are also 129 composting facilities, with a total capacity of 542 kt/yr.

In some countries (e.g. UK and Italy), biological treatment is mainly carried out by water companies, utilising existing capacity on waste water treatment works. It is estimated that there are potentially around 30 possible installations. The volumes of waste treated are small, typically less than 1 % of the input of the waste water treatment works, but in some cases this represents a significant COD load (in one case, 50 % of total COD input to the waste water treatment works). However, this type of treatment poses questions because there is a possibility of diluting contaminants as well as contaminating the sewage sludges coming from this kind of treatment.

1.2.3 Installations for the physico-chemical treatment of waste waters

This sector is represented by a large range of processes which are classed as 'chemical treatments'. These range from blending systems with no actual chemical interactions to complex plants with a range of treatment options, some custom designed for specific waste streams.

The process is designed to treat waste waters (contaminated with, e.g acid/alkalis, metals, salts, sludges), but usually accepts a range of organic materials as well, e.g. process plant washings and rinsings, residues from the oil/water separation, cleaning wastes, interceptor wastes, etc. These could contain almost any industrial material. It is likely that the treatment process will have some effect on the organic materials, for example due to some chemical oxidation of COD, some organics could be adsorbed or entrained in the sludge or, in emulsion treatment, part of the organic content could become separated from the aqueous phase.

These treatment systems remove and/or detoxify hazardous constituents dissolved or suspended in water. The selection and sequence of unit processes will be determined by the characteristics of the incoming wastes and the required effluent quality. An example of a physico-chemical treatment facility of waste waters typically contains the following unit processes: cyanide destruction, chromium reduction, two-stage metal precipitation, pH adjustment (e.g. neutralisation), solid filtration, biological treatment, carbon adsorption, sludge dewatering, coagulation/flocculation and some others.

Country	**Number of known installations**		**Known capacity (kt/yr)**	
	Hazardous	**Non-hazardous**	**Hazardous**	**Non-hazardous**
Belgium	8	Y		
Denmark	4	Y		
Germany	249	9000		
Greece	0	0	0	0
Spain	49		901	
France	19	Y	301	
Ireland	4	Y		
Italy	147	Y		
Luxembourg	1	0		0
Netherlands	30	0		0
Austria	33	Y	515	
Portugal	2	Y	22000 m^3	
Finland	36	0 [1]	144	0
United Kingdom	32	289		
Iceland	0	0	0	0
Norway	4	Y		
TOTAL	**618**	**9289**	**1883**	

Y: exists but no data are available
[1] No non-hazardous installations with this operation only
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.3: Installations for the physico-chemical treatment of waste
[60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, TWG, 2004]

The physico-chemical (Ph-c) treatment of waste water typically divides the waste into another type of waste (typically solid) and an aqueous effluent which is not usually considered waste as it is part of another legislation.

Ph-c plants are essential to medium and small companies including commercial enterprises. Waste which must be treated by Ph-c plants will, in future, continue to be produced (in the course of production); obligatory acceptance of waste by generally accessible Ph-c plants is an advantage for trade and industry, facilitating correct disposal of waste and easing the economic burden for industry and trade.

The following principal configurations can be identified:

- company in-house Ph-c plants. These are specialised for the treatment of the waste produced by a company
- generally accessible Ph-c plants (service plants). These are suitable for the treatment of waste produced in certain regions.

1.2.4 Installations for the treatment of combustion ashes and flue-gas cleaning residues

During combustion processes, solid waste may be generated. Such solid waste is typically called ‘ashes’. Two types are usually present; one called ‘bottom ash’, typically recovered at the bottom of the combustion chamber and another called ‘fly ash’ that is smaller and flows with the combustion fumes. This latter one is usually recovered with flue-gas cleaning equipment. Such flue-gas cleaning equipment is not only applicable to fly ash but also to extract from the other pollutants flue-gases. In doing so, different types of waste can be generated. This section contains those installations that treat such a variety of waste generated during combustion processes as well as other flue-gas cleaning processes.

Combustion ashes and flue-gas cleaning residues are one of the main waste stream treated by stabilisation and solidification processes, either in the combustion plant (e.g. in some incinerators), or on waste treatment facilities. Other methods are vitrification, purification and recycling of some components (e.g. salts). Another method of treating combustion ashes involves the fusion of ash by plasma at very high temperatures in order to vitrify the structure. One installation exists in France with a total treatment capacity of 3.5 kt per year.

1.2.5 Installations for the treatment of waste contaminated with PCBs

Incineration, when available, is the most widely available and used technology for PCB destruction. The complete destruction of PCB by incineration only takes place under well defined conditions (e.g. high temperature and a higher residence time). Because of the cost of incineration, however, and its non-availability in many countries, alternative technologies are sometimes used.

1.2.6 Installations for treatment of waste oil

Used lubricating oils can be recovered to a quality essentially equal to some groups of base oils used to produce lubricating oils (some base oil groups III and IV rarely, if ever, contain re-refined oils). This process is typically referred to as 'oil re-refining'.

The recovery of oil from waste is typically a part of the waste industry. There are licensed sites that specialise in the recovery of oil from different waste streams. In addition, a number of chemical treatment plants and transfer stations have oil separation units that undertake a first separation of oil from water before sending the oil layer through to a specialist plant for further processing. Some factors that define this sector are:

- companies that serve particular industrial sectors tend to offer a general waste service to that sector, and this may include waste oils
- companies that collect used lubricating oils from garages are also likely to collect oil filters, steering, brake and transmission oils, antifreeze and batteries
- companies handling transformer oils are likely to collect oils with some small amounts of PCBs
- some chemical and biological treatment plants undertake small scale oil recovery operations as part of their pretreatment processes. These are generally simple gravity separation systems.

There are large numbers of dedicated oil treatment and processing plants in the EU. Some companies carry out simple purification, removing the sediment and water from waste oil. Two type of treatments are applied to waste oils. One refers to its use as fuel and the other one corresponds to the re-refining of it so that part of it (typically 50 – 60 %) can be re-used as a base oil for lubricants. Oil processors show a wide range of intrinsic knowledge about their operations.

There are a wide variety of processes and licensors currently offering ways to deal with waste oils. There are four main processes used for the treatment of waste oils: blending, separation-chemical treatment, distillation and cracking.

In all waste oil treatment processes, the economic and calorific values of the waste oils are recovered to varying degrees. The two main techniques used are re-refining and direct burning (mainly in cement factories), each accounting for about 30 % of the total quantity recovered. The two other methods which, together, account for the remaining third are reprocessing and reclaiming, the latter principally being used for hydraulic oils.

The level of knowledge about oils is markedly different between sites. Partly due to the fact that waste oil is an extremely complex and changing material with a huge potential range of individual components that are not all categorised at present.

Data currently available regarding waste oil (WO) management in Europe are of very poor quality, particularly concerning regeneration. Figure 1.1 shows a summary of the percentages of the types of treatments used for the WO in each EU country. According to data from the sector in 1993, the used oils collected where disposed of by direct burning (32 %), by re-refining to base oils (32 %), by reprocessing to industrial fuel (25 %) and by reclaiming specific industrial oils 11 %. These percentages however have since changed considerably, as shown in the following figure.

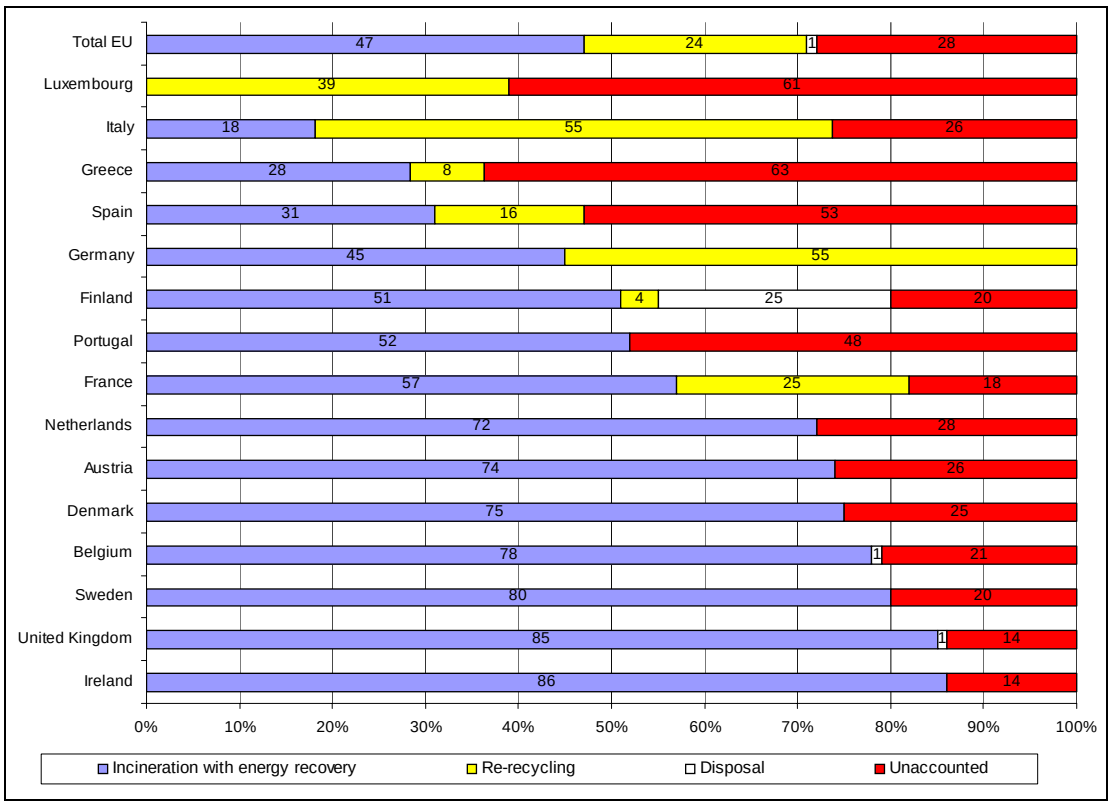


Figure 1.1: Management of waste oils in the EU in 1999
[7, Monier and Labouze, 2001], [86, TWG, 2003], [150, TWG, 2004]

Re-refining

About 220 kt of re-refined base oil was produced in 2000 according to [7, Monier and Labouze, 2001], which accounts for less than 5 % of the overall base oil demand in Europe.

In recent years, the level of regeneration carried out has noticeable decreased in some EU countries which were pioneers in its use such as France, Germany, Italy and others such as the UK. This is tempered by the fact that there are some new projects emerging in several countries: France, Germany, Italy, Spain.
The known installed feed capacity for re-refining base oil throughout Europe is just over 500 kt/yr, with installation capacities ranging from 35 to 160 kt/yr. Currently, there are around 400 re-refining facilities worldwide, with an overall capacity of 1800 kt/yr. Although most of these plants are located in East Asia (India, China and Pakistan), their individual capacity is mainly low, c.a. 2 kt/yr each, on average. Most of these plants use acid/clay and there are few which produce good quality re-refined base oils or which take into account environmental issues.

Country	Number of known installations	Known capacity (kt/yr)
Belgium	2	45
Denmark	1	40
Germany	8	770
Greece	1	40
Spain	2	69
France	2	200
Ireland	0	0
Italy	7[1]	273[1]
Luxembourg	0	0
Malta	2	2.4
Netherlands	0	0
Austria	0	0
Poland	1	80
Portugal	0	0
Finland	5	88
Sweden	0	0
United Kingdom	3 [2]	5 [2]
Yugoslavia	1	
TOTAL	**35**	**1612.4**

1 Two installations are currently not working. Capacity of the two installations not working is 25 kt/yr.
2 A TWG member questionned such figures to not be correct
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.4: Installations for re-refining waste oil in European countries
[5, Concawe, 1996], [7, Monier and Labouze, 2001], [13, Marshall, et al., 1999], [36, Viscolube, 2002], [86, TWG, 2003], [128, Ribi, 2003], [150, TWG, 2004]

Re-refining plants can adjust the quantity of re-refined base oil and fuels produced according to the international and local situation (crude oil prices, market demand, subsidies, etc.).

Preparation of waste oil to be used mainly as fuel
About 50 % of WOs (i.e. waste oil from ship and tank cleaning, waste oil from oil/water separator, waste oil from emulsions, etc.) is not waste lubricant oil or cannot be regenerated into base oil. These WOs can be converted into other oil products (e.g. fuel).

About 50 % of WOs were used as fuel in the EU in 1999. About 400 kt of WO are burned in cement kilns at the European level, which represents about 17 % of the total WO and 35 % of the WO burned, with the rate varying greatly between different countries. It represents the major exploitation route in France, Greece and Sweden, but only one of several alternative routes in Austria, Belgium, Italy and the United Kingdom. Some other sectors in the EU using WO as fuel are:

- blast furnaces, as a substitute for coke (e.g. Belgium)
- brick kilns (e.g. Spain)
- ceramic kilns (e.g. Spain)
- large combustion plants (e.g. Spain)
- lime kilns (e.g. Spain, Belgium)
- cracking plants, to produce new fuels (e.g. in Belgium in accordance with legal standards)
- port receiving facilities which convert waste oil into ship's fuel (e.g. Malta)
- waste incinerators (e.g. 2 kt in 2002 in hazardous waste incinerators in Belgium)
- space heaters (e.g. service stations, greenhouses, etc.)
- asphalt plants.

The two latter applications are no longer used in Flanders (Belgium) because of more stringent environmental regulations brought into force in January 1999. Table 1.5 indicates the amount of used oil burned in some EU countries

Burning options	Amount of waste oil (kt)	%
Cement kilns	307	42
Mixed with fuel oil	213	29
Other	120	16
Waste incinerators	52	7
Garage heaters	40	6
Total burned	**732**	**100**
Data only correspond to Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Spain and the United Kingdom. Note: Obtaining a complete set of data on volumes of used oil burned in all EU countries in this study is difficult as details of the burning options are not consistently recorded.		

Table 1.5: Volumes of used oil burned in EU per year
[5, Concawe, 1996]

There is also a significant volume of oil contaminated waters collected for recovery. These wastes have a net negative value but are processed so as to maximise the recovery of the hydrocarbon for use as a fuel. Table 1.6 shows some installations carrying out this activity.

Country	Number of known installations			Known capacity (kt/yr)		
	Using waste oil in direct burning	Using reprocessed waste oil as fuel	Non- hazardous oil	Using waste oil in direct burning	Using reprocessed waste oil as fuel	Non- hazardous oil
Belgium	1	10				
Denmark	4	Y				
Germany	12	1		310	100	
Greece	0					
Spain	4	Y	1			
France	60			725		
Ireland		Y				
Italy	2					
Luxembourg	0	0		0	0	
Malta	0	1		0	4.7	
Netherlands		Y				
Austria	4	0	0		0	0
Portugal	Y	Y	1			
Finland	3	4	1	155	54.5	0.2
Sweden	2	3				
United Kingdom	160	Y				
TOTAL	**252**	**19**	**3**	**1190**	**159.2**	**0.2**
Y: exists but no data is available Note: Columns related to non-hazardous oil correspond to the production of biodiesel from used vegetable oil. Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.						

Table 1.6: Installations where waste oils are used as fuel or where waste oil is reprocessed to produce a fuel
[7, Monier and Labouze, 2001], [13, Marshall, et al., 1999], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [128, Ribi, 2003], [150, TWG, 2004]

Under EU legislation, it is illegal to dispose of WO in landfills, storm-water or waste water drains. In some cases, used oil is applied to unsealed roads as a dust suppressant in some rural areas. About 25 % of the WO in the EU was unaccounted eliminated for in 1999.

1.2.7 Installations for treatment of waste solvent

Solvents are extensively used in chemical and biological processes. During these processes, waste solvent is produced and it is recycled in-house. These treatments are an integral part of the chemical/biological processes and they are covered in the different BREF documents. However for economic or technical reasons, sometimes the waste solvents are delivered to a third party (e.g. waste manager) for treatment. In some cases, the product of the treatment is returned to the waste producer and in other cases this does not happen.

Waste solvents are also produced in the area of solvent-based surface treatment (such as cleaning or degreasing in many different industrial sectors and in dry cleaning installations). In most cases, the contaminated solvents or the bottoms of the distillation columns (solvent content 1 – 10 % in the case of closed cleaning installations/devices with internal distillation devices) are delivered to solvent distillation installations and regenerated. The quality of the distillation products is as good as that of new solvents.

In accordance with the Waste Framework Directive, the first option for waste solvents, as well as for the rest of waste, is that it should be recycled. This has helped to generate an active solvent recycling market. Similarly to waste oils, waste solvents which are not suitable for regeneration because of certain compositions or because of very low purity can also be recovered as a secondary liquid fuel (SLF), for example, in the cement industry and hazardous waste incinerators. A fundamental difference with waste oils is that waste solvent qualities fluctuate much more than the quality of waste oil.

Solvent regeneration facilities separate contaminants from waste solvents and thus restore the solvent to its original quality or may be to a lower grade product (e.g. in the case of lacquer thinner). Distillation (batch, continuous, or steam) is used by most commercial solvent processors, and typically recovers about 75 % of the waste solvent. The residue, known as 'distillation bottoms', can be a liquid or a sludge, depending upon a number of conditions, and typically requires management as a hazardous waste. Other separation technologies used by solvent processors include: filtration, simple evaporation, centrifugation, and stripping.

Country	Number of known installations	Known capacity (kt/yr)
Belgium	5	>8
Denmark	0	
Germany	21	
Greece	3	
Spain	14	64
France	27	90.7
Ireland	2	
Italy	2	
Luxembourg	0	
Netherlands	8	
Austria	2	
Portugal	1	10000 m^3
Finland	4	11
United Kingdom	8	>12
Iceland	0	
Norway	11	
TOTAL	**108**	**185.7**
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.		

Table 1.7: Waste solvent installations in European countries
[40, Militon and Becaud, 1998], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [129, Cruz-Gomez, 2002]

1.2.8 Installations for the treatment of waste catalysts, waste from pollution abatement and other inorganic waste

The treatment of waste catalysts depends on the type of catalyst (catalytic active substance and supporting structure or carrier) as well as the included by-products from the catalytic process. These treatments include: regeneration of catalysts to be re-used as catalysts again, recycling of components from catalysts and disposal in landfills. An example installation is an Austrian facility for the recovery of Ni from food industry catalysts (Fe/Ni alloy).

Hydrometallurgical technology can be used to extract and concentrate metals from liquid waste. Non-liquid wastes first require dissolution.

In Malta, there are two underground asbestos storage sites and one overground pending treatment. The asbestos originated from ships being repaired in dock yards and from unused asbestos pipes.

	Treatment of waste catalysts		**Treatment of other inorganic waste (excluding metals and metal compounds)**		**Recovery of waste from pollution abatement**	
Country	**Number of known installations**	**Known capacity (kt/yr)**	**Number of known installations**	**Known capacity (kt/yr)**	**Number of known installations**	**Known capacity (kt/yr)**
Belgium	0	0	13		1	
Denmark	0	0	3		1	
Germany	1		63		2	
Greece	5		0	0	0	0
Spain	0	0	6	195	15	3
France	3	4.9	0	0	0	0
Ireland	4		0	0	0	0
Luxembourg	0	0	0	0	0	0
Malta			3			
Netherlands	2		17		1	
Austria	3		14		0	0
Portugal	0	0	0	0	0	0
Finland [1]	0	0	9	3	0	0
Iceland	0	0	0	0	0	0
Norway	2		1		0	0
TOTAL	**20**	**4.9**	**129**	**198**	**20**	**3**

[1] The treatment of 1 million lamps containing mercury is not included.
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.8: Installations for the treatment of waste catalysts, waste from pollution abatement and other inorganic waste in European countries
[40, Militon and Becaud, 1998], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [150, TWG, 2004]

1.2.9 Installations for treatment of activated carbon and resins

Most waste activated carbon and resin is a result of water purification processes. It is very difficult to estimate the regeneration throughput in Europe, mostly due to the fact that many operators regenerate their adsorbent on site (often sporadically) rather than sending it to large centralised reactivation plants.

Activated carbon is used in three principal applications: the treatment of drinking water; in the food and drink industry, for example for removing colour in the refining of sugar; and in general industrial applications, e.g. removal of VOCs from process vent streams. These applications affect the type of contamination on the carbon and the regeneration process that is then required.

For example, carbon which has been used in industrial applications ('industrial carbons'), such as in effluent treatment, requires a more stringent pollution abatement system than that used for the treatment of potable water or for that from the food industry.

At some point in the lifetime of the process, the carbon will become exhausted with the material that it is adsorbing. The carbon should then be regenerated or, if this is not possible, disposed of. The choice of route is naturally determined by economics and scale. In the treatment of potable water, the carbon is used in large quantities and is contained in large open topped concrete-lined carbon beds. These have a life expectancy before exhaustion of a few years. When they are re-generated, they result in large quantities to be treated. It is this application that represents the most common in the UK in terms of volume and it is regenerated either on site by a purpose built plant or transported off site for regeneration by a merchant operator. Because of the nature of the market there is a tendency that more regeneration facilities, once designed purely for 'in-house' materials, now offer a merchant regeneration service.

There are at least 19 sites in Europe regenerating activated carbons from off site. The estimated numbers are mentioned in the next Table 1.7.

Country	Number of known installations	Known capacity (kt/yr)
Belgium	2	
Germany	3	
France	1	
Italy	5	
Netherlands	1	
Austria	1	
Finland	1	
Sweden	1	
United Kingdom	4	
TOTAL	**19**	**>50**
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.		

Table 1.9: Activated carbon installations in European countries [150, TWG, 2004]

The most common reactivation furnaces are direct fired rotary kilns and multiple hearth furnaces. Indirect fired rotary kilns, fluidised bed, vertical tube type and infrared are sometimes used. The type of granular activated carbon (GAC) reactivation furnaces in use worldwide in early 1990 are shown in Table 1.10.

Type of GAC reactivation furnace	Number of units
Multiple hearth	>100
Fluidised bed	<20
Indirect fired rotary kiln	>50
Direct fired rotary kiln	<30
Vertical tube-type	<30
Infrared furnaces (horizontal and vertical)	<9

Table 1.10: Type of GAC reactivation furnaces in use worldwide [42, UK, 1995]

Quantitative figures for ion exchange resin regeneration facilities are not available.

1.2.10 Installations for the treatment of waste acids and bases

There are several installations in the EU which regenerate HCl. No installations have been identified to recover HBr. Waste sulphuric acid can be regenerated in the following ways:

- thermal decomposition of waste/spent/recovered sulphuric acid, the result then being used as a primary or supplementary source of SO_2 feed to a sulphuric acid contact process. This is covered in the LVIC(AAF) BREF [62, EIPPCB, 2003], as is any process that produces SO_2 as a feedstock by decomposition/calcinations
- a process based on the reconcentration of weak/spent/waste sulphuric acid, with or without separation of potential impurities (e.g. salts). This will be included in this document
- industrial processes that use sulphuric acid and include a recycling of the spent sulphuric acid as an integral part of the process. This will be covered in the BREF where the industrial process is covered (e.g. BREF LVIC-solids and others for titanium dioxide production).

Country	Number of known installations	Known capacity (kt/yr)
Belgium	1	
Denmark	1	
Germany	2	
Greece	0	
Spain	1	42
France	3	2
Ireland	1	
Luxembourg	0	
Netherlands	0	
Austria	4	
Portugal	0	
Finland	0	
Iceland	0	
Norway	0	
TOTAL	**13**	**44**
Values correspond to regeneration installations covered by this document and the LVIC-AAF BREF Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.		

Table 1.11: Installations for the regeneration of waste acids or bases
[40, Militon and Becaud, 1998], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003]

Acid recovery usually involves the separation of unreacted acid from an acid waste such as spent pickle liquor generated by the steel industry. One method used in the steel industry, involves cooling the sulphuric acid to precipitate ferrous compounds. In another method, acid can be regenerated by injecting it into a spray roaster.

1.2.11 Installations for the treatment of contaminated wood

In some cases, contaminated wood is directly incinerated. In other cases, contaminated wood is thermally treated by carbonisation/pyrolysis. All these treatments are covered by the WI BREF. However, in some cases treatments are used focused on the extraction of heavy metals from the solid residue generated by carbonisation of contaminated wood – these processes are covered in this document. One installation is in operation in France.

1.2.12 Installations for the treatment of contaminated refractory ceramics

Two installations are in operation in France with a total treatment capacity of 50 kt per year.

1.2.13 Installations for the preparation of waste to be used as fuel

Currently, there are several factors driving the concept of using waste as a fuel in combustion processes:

- Waste Framework Directive and its amendments sets a waste management hierarchy. This gives a preference to recycling and recovery (including the use of waste as a source of energy)
- waste sector regulations, such as the 'packaging waste' Directive, 'end-of-life vehicles' Directive, 'waste from electrical and electronics', 'waste incineration' Directive, 'waste catalogue', 'dangerous substances' Directive and 'dangerous preparation' Directive may also influence the option
- the Landfill Directive prohibits the landfilling of waste with a high content of biodegradable materials. Therefore, there is a need to establish alternative ways for treating the respective waste fractions. Co-incineration is one option among others (e.g. incineration, mechanical-biological treatment)
- under the requirement of the Kyoto protocol, greenhouse gas emissions have to be reduced worldwide. Co-incineration of waste fractions as a replacement for conventional fuels may be one option to reduce greenhouse gas emissions
- as liberalisation of the energy market intensifies economic pressure on the energy producers/consumers. The co-combustion of waste opens a new scope of business for them, which makes operation of combustion plants more attractive economically
- to reduce the cost of fuel used in the combustion processes.

The term 'waste fuel' is used in this document for all types of waste materials that are prepared to be used as fuel in any combustion process. Waste fuels can be gaseous, liquid or solids. For instance, liquid waste fuels can be prepared from waste oils, solvents, and distillation bottoms. The way the liquid waste fuel is going to be used in the combustion process influences the way the waste fuel is prepared. For example, some liquid waste fuels can be prepared by blending different wastes that have high calorific values and feed them independently into the combustion chamber or they can be mixed/blended with conventional fuels (e.g. waste oil and fuel oils). Some liquid wastes, for instance oils, normally need pretreatment to remove bottoms, sediments, and water. This may be achieved through separation and dehydration.

Some combustion processes that may use waste as (part) fuel are the combustion plants for the production of heat and/or power, marine engines, cement kilns, blast furnaces in iron and steel production, brick kilns in the production of ceramics, lime kilns and asphalt production. The type of furnace or boiler used, the combustion conditions (e.g. temperature) that the process should operate, the impact on the emissions or products and the type of fuel already in use has a strong influence in which the type of waste(s) may be acceptable and how the waste fuel is prepared.

The purpose of those installations is to guarantee the following aspects:

- optimise the valorisation of certain waste avoiding its landfilling
- the quality of thermal destruction
- provide the required physico-chemical properties of the waste fuel to end user.

The basic principles of waste fuel production are the following:

- the chemical and physical quality of the fuel shall meet any specifications or standards ensuring environmental protection, protection of the kiln/furnace process, and quality of the material produced, where the combustion process where the waste fuel is used produces a product (e.g. cement)
- energy and mineral contents must remain stable to allow optimal feed in the kiln/furnace
- the physical form must allow safe and proper handling, storage and feeding.

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	12	Y		
Denmark	4	13		
Germany	16	34		
Greece	0	0		
Spain	33	5	204	
France	54	Y	542	1400
Ireland	2	Y		
Italy		27		2080
Luxembourg	0	Y		
Netherlands	1	Y		
Austria	8	10		
Portugal	0	Y		165
Finland	7	37	106	800
Sweden	Y	Y		
United Kingdom	Y	Y		
Iceland	1	Y		
Norway	2	Y		
TOTAL	**140**	**126**	**852**	**4445**

Y: exists but no data are available
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.12: Installations for the preparation of waste to be used as fuel
[39, Militon, et al., 2000], [40, Militon and Becaud, 1998], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, TWG, 2004]

Preparation of municipal solid waste to be used as fuel

The current best estimate of the quantity of solid recovered fuels produced and consumed in Europe is about 1.4 Mt/yr, as set out below.

Country	Producers	Production		Consumption		- Export/Import +		CK
		kt/yr	toe/yr	kt/yr	kt/yr	toe/yr	kt/yr	%
Belgium	7	<100	<50000	<100	<50000	n.a.	n.a.	(100)
Denmark	1	0	0	0	0			
Germany	19	500 (650)	250000 (325000)	500 (650)	250000 (325000)	n.a.	n.a.	85
Greece		0	0	0	0			
Spain		n.a.	n.a.	n.a.	n.a.			
France	3	0	0	0	0			
Ireland		<200 (250)	<100000 (125000)	<200 (250)	<100000 (125000)	n.a.	n.a.	
Italy	25	0	0	0	0			
Luxembourg	23	0	0	0	0			
Netherlands		250 (350)	100000	15	6000	-145	60000	20
Austria	26 [3]	160	50000	100	50000			7
Portugal	8	0	0	0	0			
Finland	10	170	58000	170	58000	n.a.	n.a.	0
Sweden	4	[1]		[1]		+500 [2]		
United Kingdom		60 (100)	30000 (50000)	60 (100)	30000 (50000)	n.a.	n.a.	
Iceland		0	0	0	0			
Norway	29	[1]		[1]				
TOTAL	**155**	**1380**						

toe/yr = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)
CK = % of consumption that occurs in cement kilns
The figures in this table are only indicative as they do not correspond to the same harmonised definition used throughout the European Union
[1] There is no overall statistic for Sweden or Norway because this fuel is used in ordinary heat/power plants and in waste incinerators without a demand for detailed specifications. Data for Sweden (2001) are: waste incineration plants for district heating 856000 t/yr and power plants for district heating 455000 t/yr.
[2] No exact figures exist, but approximate figures give 500 kt of waste imported in 1999. 90 % consisted of wood, paper, plastic and rubber.
[3] A TWG member thinks that this value is too high but has not provided any alternative value.

Table 1.13: Summary of European solid recovered fuels market in 2000 in Europe [21, Langenkamp and Nieman, 2001], [126, Pretz, et al., 2003], [150, TWG, 2004]

Industry's best estimate of solid recovered fuel production in 2005 is about 11 Mt/yr. (Table 1.14)

Country	Production		Consumption		- Export/Import +		Δ 2000
	kt/yr	toe/yr	kt/yr	toe/yr	kt/yr	toe/yr	%
Belgium	100	50000	100	50000	n.a.	n.a.	0
Denmark	0		0				
Germany	3000	1500000	4000	2000000	+1000	+500000	
Greece	500	250000	500	250000	n.a.	n.a.	
Spain	1000	500000	1000	500000	n.a.	n.a.	
France	1000	500000	0	0	-1000	-500000	
Ireland	500	250000	500	250000	n.a.	n.a.	
Italy	1000	500000	1000	500000	n.a.	n.a.	
Luxembourg	50	25000	50	25000	n.a.	n.a.	
Netherlands	1000	400000	600	240000	-400	-160000	
Austria	500	250000	500	250000	n.a.	n.a.	400
Portugal	500	250000	500	250000	n.a.	n.a.	
Finland	350	120000	350	120000	n.a.	n.a.	100
Sweden	500	250000	1000	4500000	+500	+200000	
United King-dom	600	300000	600	300000	n.a.	n.a.	
Switzerland	0	0	0	0			
Iceland	0		0				
Norway	150	75000	150	75000	n.a.	n.a.	
Total	**10750**	**5220000**					

Notes: toe/yr = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)
Δ 2000 = Difference from year 2000
It is assumed that no solid recovered fuel (SRF) is exported outside the European Union.
The figures in this table are only indicative as they do not correspond to the same harmonised definition used t by the European Commission.
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Table 1.14: Forecast/potential for the European solid recovered fuels market in 2005 [126, Pretz, et al., 2003]

The consumption of hard coal and lignite for power production in the EU was 145 Mtoe/yr in 1999 (European Commission 1999 Annual Energy Review). Using this figure, it can be calculated that the total production of solid recovered fuel as forecast in Table 1.14 for 2005 (i.e. more than 5 Mtoe/yr) represents a substitution rate of 3.5 %.

Preparation of waste fuel from hazardous waste

The use of hazardous waste as fuel started in the mid seventies when the petroleum crisis drastically increased the cost of the fuel oil and also when, in different countries, new regulations were issued concerning waste disposal. As a large amount of energy rich waste (mainly solvents) was available, the co-processing of waste in cement kilns was an obvious answer to the situation on both environmental and economical terms. Later, in order to increase the energy saving, more and more sophisticated pretreatment processes have been developed, first to produce liquid waste fuel and more recently, i.e. in the nineties to produce solid waste fuel.

Estimated data were provided by some EU companies and are shown below in Table 1.15. These data are based on the market situation in EU-15.

	Number of installations	2001 Production (kt/yr)
Liquid waste fuel from organic liquid	107	650
Liquid waste fuel from fluidification	7	108
Liquid waste fuel from emulsions	3	48
Liquid waste fuel	117	806
Solid waste fuel	26	465
Total	**143**	**1271**

Note: The data correspond to estimations established in December 2002
Liquid waste fuel (excluding oils). Data have been established for regrouping and pretreatment plants from France, Belgium, the Netherlands, Germany, Italy, Switzerland, Spain, Portugal, Ireland, United Kingdom, Sweden, Norway, Czech Republic and Slovakia. The size and capacity of a liquid waste fuel pretreatment plant varies widely, from 5000 to 100000 tonnes/year. For regrouping facilities, the typical size of a plant ranges from 1000 to 20000 tonnes/year.
Solid waste fuel. Data have been established for pretreatment plant production in 2001 from France, Belgium, the Netherlands, Germany, Italy, Switzerland, Spain, Portugal, Poland, Norway and Slovakia. The average size capacity of a solid waste fuel pretreatment plant is 18000 tonnes/year, with capacities ranging from 2000 to 70000 tonnes/year.

Table 1.15: Production and site numbers of preparation of waste fuel mainly from hazardous waste in EU-15
[122, Eucopro, 2003], [150, TWG, 2004]

1.3 Economic and institutional aspects of the waste treatment sector

Waste treatment is typically a high volume low return process. A fixed or lowered base price, either for the incoming waste or for the recycled product, has placed the commercial emphasis on maximising throughput and reducing cost overheads.

Cost and price of waste treatment is typically established on the basis of investments and running costs. However, in some cases, prices may be determined by operators at the 'low' end of the market. In some other cases, the prices are fixed by agreement between the waste producer and the waste manager, where these may be different for a particular waste depending on who has produced it. Although there are exceptions, and also particularly for older plants, investment levels have been low, due to the low returns and competition with the low prices of landfills. It is expected that high levels of investment will be required to meet the standards set by the actual regulatory regime.

The industry has generally maximised the constructive use of some waste types to treat other wastes, this is expected to continue, particularly using waste as a raw material.

Competition exists between regional, national and international companies. One example is in the collection of waste oil, where national collectors work on large volumes as an economy of scale while local/regional operators, compete with the advantage of having lower overhead costs.

Hazardous waste management facilities typically, under the duty to tender delivery, accept all types of hazardous waste for correct disposal without regard to competition. However, some dedicated facilities which may be in competition for certain types of waste, would only need to bid for any hazardous waste that they can handle. In this respect, different configurations have been developed for the designated hazardous waste management facilities and competing facilities.

Some WT plants, due to their regionalisation and/or the need for proximity, contribute to a substantial decrease in waste transportation. However, other WT plants are working on a supraregional, national or even international basis mainly depending on the specialisation of certain treatment operations.

Impact of new waste legislation on the waste treatment sector

Waste production is avoided in accordance with Council Directive 75/442/EEC of 15 July 1975 on waste; where waste is produced, it is recovered or, where it is technically and economically impossible, it is disposed of while avoiding or reducing any impact on the environment. It is worth mentioning that the IPPC Directive would have a direct impact on the waste treatment industry as well as on producers of waste.

Regulatory conditions are being put in place, some of them at EU level (e.g. incineration, landfilling, electrical and electronic waste, end-of-life vehicles), to break the cycle of high volume, low return and low investment. This is expected to lead to greater investment in the sector and a move towards developing techniques to treat those wastes which were previously directly landfilled, or to improving processes which before were not treating the wastes effectively. This will require the development of dedicated plants and, probably, equipment for the treatment of specific wastes.

Whilst restrictions on landfilling, which will be introduced by the Landfill Directive, will require more treatment of waste either prior to or instead of landfill, this may lead to the continuing development of sites utilising stabilisation and fixation techniques. However, these techniques are still quite basic and subject to a number of serious problems.

Waste oil treatment is also likely to increase and change, especially as the implementation of the Landfill Directive bans the landfilling of oil/water streams from 2002 to 2007.

Regulatory compliance could be thought of as a separate function reacting to external forces, yet in reality this is essentially the driving force for the entire facility. The market for waste facilities is heavily influenced by dynamic regulatory programmes that continue to undergo significant change. The operation of a facility is thus geared around managing waste in a manner that meets, if not exceeds, environmental regulations. This is no easy matter due to the large amount of regulation the industry is subject to.

Waste oils
Environmental consciousness in the 1980s has had a number of consequences on the waste oils treatment sector, in particular:

- the shutting down of many acid/clay re-refining plants, mainly in the US, for both economic and environmental reasons
- the use of improved equipment and devices to reduce the potential pollution from burning used oil
- the development of improved re-refining technologies for both environmental and product quality reasons.

Physico-chemical (Ph-c) treatment plants
There are continuous changes in the production process modifying the type of waste as well as the auxiliary substances used. In this respect, even the Ph-c plants are subject to constant adaptation processes, both in terms of the procedures used and the controls. Furthermore, changes in the regulatory frameworks also lead to plant reconfigurations; in general, these changed regulations aim at a significant reduction in Ph-c plant emissions. The reconfiguration can affect all the functional areas of a Ph-c plant, including plant technology, process materials, laboratory equipment, and even the general and specialist knowledge of the staff.

Preparation of municipal solid waste (MSW) to be used as fuel
The history of use MSW as fuel goes back to the oil crisis of 30 years ago. Then RDF (refuse derived fuel) was promoted as a substitute low cost fuel, although the fuel was never fully accepted by the market. However, in the past 10 years there has been a growing interest within the cement, lime, steel and energy industries in fuels derived from waste, mainly due to economic reasons. Existing European energy policy targets and waste management policy give an impetus to the usage of waste derived fuels based on non-hazardous wastes. These fuels, with an average content of 50 - 60 % on biogenics, may contribute considerably to the reduction of CO_2 emissions and the doubling of the share of renewable energy. Moreover, due to market liberalisation and the need for cost reductions, industry is increasingly becoming more interested in less expensive homogenous substitute fuels of a specified quality. At present the main end-users are the cement and lime industries. However, the market potential for the future is the power generating sector.

Waste management policy aiming at a reduction in landfill disposal of biodegradable waste directly influenced the development of facilities for the production of waste fuels. Also the (high) tax system applied to landfilling is a major driving force in some Member States. Contrary to enforced changes 30 years ago due to the oil crisis, the producers of the waste fuels took the initiative for a quality system that should guarantee the properties of the solid waste fuel produced out of MSW and therefore make it a more reliable product. Quality systems exist in several Member States now. CEN was given a mandate by the Commission to develop standards for so-called ‘solid recoverd fuel’ (SRF) based on non hazardous wastes these are currently underway.

The main outlets of SRF are currently in the cement and lime industries. The use in coal fired power stations is an emerging sector. Steel mills use SRF as a carbon substitute. In Nordic countries, SRF is mainly used for the production of heat in industries and district heating.

The breakdown of the fuel consumption used to produce cement is given in Table 1.16.

Fuel	%
Petroleum coke	39
Hard coal	36
Fuel oil	7
Lignite	6
Gas	2
Waste	10

Table 1.16: Fuel consumption by the European cement industry [126, Pretz, et al., 2003]

The specific energy consumption for cement is 3 – 4 MJ/kg clinker. Assuming 0.75 kg clinker/kg cement, a substitution rate of fuel of 30 – 50 % and a LHV of SRF of 19 MJ/kg, this means there is a potential use of 6 – 11 Mt SRF/yr. Assuming an energy consumption of 4 MJ/kg lime, at the same substitution rate as for cement kilns, this means a potential of 1 – 2 Mt SRF/yr could be used for an annual production of 20 Mt of lime.

The estimated use of SRF in hard coal and lignite for power production in the EU is 14 – 29 Mt SRF/yr (supposing a substitutation rate at a minimum of 5 – 10 % on heat bases). The total potential market for SRF may be 21 – 42 Mt/yr, which is a substantial amount of the SRF that could be produced from MSW and other combustible wastes. There are large differences between countries. Germany still has a lot of lignite and coal fired power plants. France, has a policy geared towards using nuclear power plants, and therefore only has few coal fired power plants. In the 'CEN report on Solid Recovered Fuels' [21, Langenkamp and Nieman, 2001] a potential of SRF use is indicated as between 33 and 50 Mt/yr. The conclusion is that the SRF production is increasing and can become an essential link in the waste management system.

1.4 General environmental issues related to installations that treat waste

Waste composition is very variable and the potential range of components that might be present is enormous. Due to such variance in components and composition, there are very few common emissions from waste management operations since each site has a slightly different combination of unit operations, and accepts a different range of wastes based on local circumstances.

The intention of this section is to give a short overview of the main environmental issues in the sector. A more precise picture of the environmental issues of the sector is developed in Chapter 3.

Air emissions

Most waste installations have emissions to air of carbon dioxide, ammonia and particulate matter. Certain organic substances can be commonly identified at almost every site and it is worth noting that most sites create some kind of particulate emission simply through handling products. Issues such as odour and volatile organic compounds are also relevant. Other contaminants that might be found at some sites are hydrogen chloride, ammonia, amines, hydrogen sulphide. Other components that may occur are PAHs and dioxins mainly because they are imported with the waste to be treated. These are a problem from both a health and an environmental point of view. They are formed during the incomplete combustion of organic matter (e.g. incineration, co-incineration, combustion of some fuels) and via reformatting during cooling down of the off-gas. PAHs are relatively difficult to break down. Table 1.17 shows the main air emissions from waste treatment operations.

Main air emissions	Waste treatment operation
Acids (HCl)	Incineration Physico-chemical treatments
Ammonia	Biological treatments Physico-chemical treatments
Carbon oxides	Energy systems Thermal treatments Biological treatments
Microbiological pollution	Biological treatments Biofilters
Nitrogen oxides (N_2O, NO, NO_2)	Energy systems Thermal treatments Biological treatments
Sulphur oxides	Energy systems Thermal treatments
Particulates (including metals)	Energy systems Storage and handling of solids Thermal treatments
Volatile organic compounds (VOC)	Biological treatments Waste oil treatments Waste solvent treatments Hydrocarbons/water separation systems Storage and handling of organic substances
Note: Refer to Chapter 3 for specific emissions to different waste treatment operations.	

Table 1.17: Main air pollutants emitted by waste treatments and their main sources

Water emissions

Most waste installations declare an emission of total nitrogen, total organic carbon, total phosphorus and chloride to water. Table 1.18 gives a summary of the main water emissions from waste treatment operations.

Main water emissions	Waste treatment operations
Chlorinated compounds (e.g. AOX)	Waste solvents treatments
Metals (e.g. As, Cd, Cu, Hg, Ni, Sn, Zn)	Biological treatments Common storage and handling of waste Physico-chemical treatments of metal extraction, finishing waste, fine chemicals and organic manufacture. Waste oil treatments
Organic chemicals (e.g. BOD, COD, TOC, hydrocarbons, phenols, BTEX)	Waste oil treatments Waste solvent treatments Energy systems
Total nitrogen	Physico-chemical treatments Biological treatments
Total phosphorus	Physico-chemical treatments Biological treatments
Note: Refer to Chapter 3 for specific emissions to different waste treatment operations.	

Table 1.18: Main water pollutants (parameters) emitted by waste treatments and their main sources

Waste outputs

Generally, the output from WT installations is a treated waste. However, those outputs can be differentiated in two types. One type refers to the treated waste (typically representing the main part of the output) that in some cases can be re-used elsewhere. The other type is represented by the waste generated by the treatment process itself. The appearance of the latter one does not only just depend on the type of waste treated, but also on the type of treatment given to the waste. Indeed, this second type of waste is more dependent on the treatment than on the actual type of waste treated.

Soil and groundwater contamination

In the past, unprecautionary handling of wastes has been at the origin of land contamination, as has been the case in almost all industrial sectors. As is the case in many other industries, the waste treatment industry is not currently an activity which leads to land contamination. According to the process and the type of wastes used, prevention actions have been developed such as retention, impermeabilisation, and undergroundwater monitoring, in order to prevent and control soil and groundwater contamination.

2 APPLIED PROCESSES AND TECHNIQUES

This section describes those treatments and processes within the waste treatments sector which are included within the Scope of this document. This chapter is for those interested in gaining a general understanding of the processes and activities found in the industrial sector, and for those interested in the interrelationships between the industrial processes and the topics described in later chapters of this document, i.e. consumptions, emissions and best available techniques.

Therefore, the aim of this chapter is not to replicate published engineering information already available in general literature. This means that some techniques widely used in the WT sector will not be described in this chapter because they are simple unit operations widely explained elsewhere. For those techniques, summary tables will be presented which will highlight as far as possible the purpose, the principle and the users.

Structure of this chapter
The processes and activities found in the WT sector are divided into six sections in this document. Such structure/classification should not be interpreted as any attempt to interpret IPPC Directive or any EC waste legislation. These are:

- common techniques. This covers those stages found in the waste sector that are generally applied and that are not specific to any individual type of waste treatment (e.g. reception, blending, sorting, storage, energy system, management). The unit operations associated with these treatments are also covered. Figure 2.2 shows a flow diagram for a typical waste treatment installation. The brown boxes correspond to the parts that will be covered in this first section
- biological treatments and some mechanical-biological treatments (e.g. aerobic/anaerobic digestions). The unit operations associated to these treatments are also covered
- physico-chemical treatments. This covers treatments such as precipitation, decanting and centrifuging, solvent recovery and any thermal treatments not included in the WI BREF. The unit operations associated to these treatments are also covered
- treatments applied to waste in order to enable the recycling/regeneration of materials (e.g. catalysts, solvents, waste oils, etc.). The unit operations associated to those treatments are also covered
- treatments applied to turn a waste into a material that can be used as a fuel in different industrial sectors. The unit operations associated to these treatments are also covered
- end-of-pipe techniques used in waste treatment installations for the abatement of emissions.

Figure 2.1 and Figure 2.2 illustrate the classification mentioned above. This classification is also repeated in each of the following chapters to maintain coherence and to make it easier for the reader to cross-reference information.

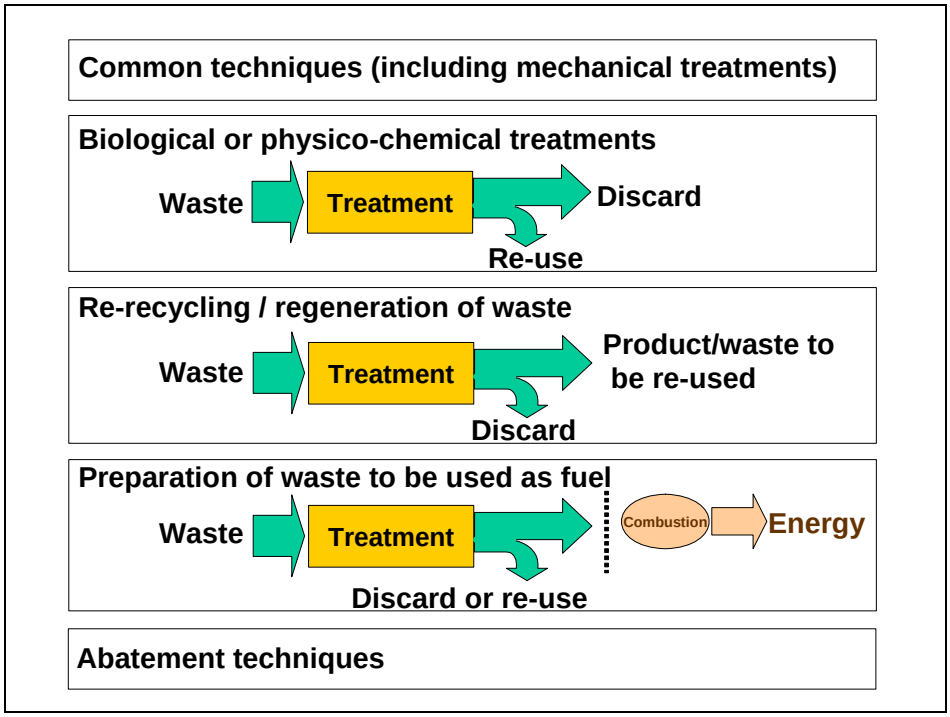


Figure 2.1: Structure of the chapters
Note: This figure only tries to give a snapshot of how information is structured in this document. Exceptions to any of these categories might be present and sometimes it is difficult to classify a treatment under certain block.
Within the block 'preparation of waste to be used as fuel', the combustion process is not included under the scope of this document. For further information, please refer to Scope section.
Such structure should not be interpreted as any attempt to give guidance if a waste treatment is Recovery or Disposal under the EC waste legislation.
[150, TWG, 2004]

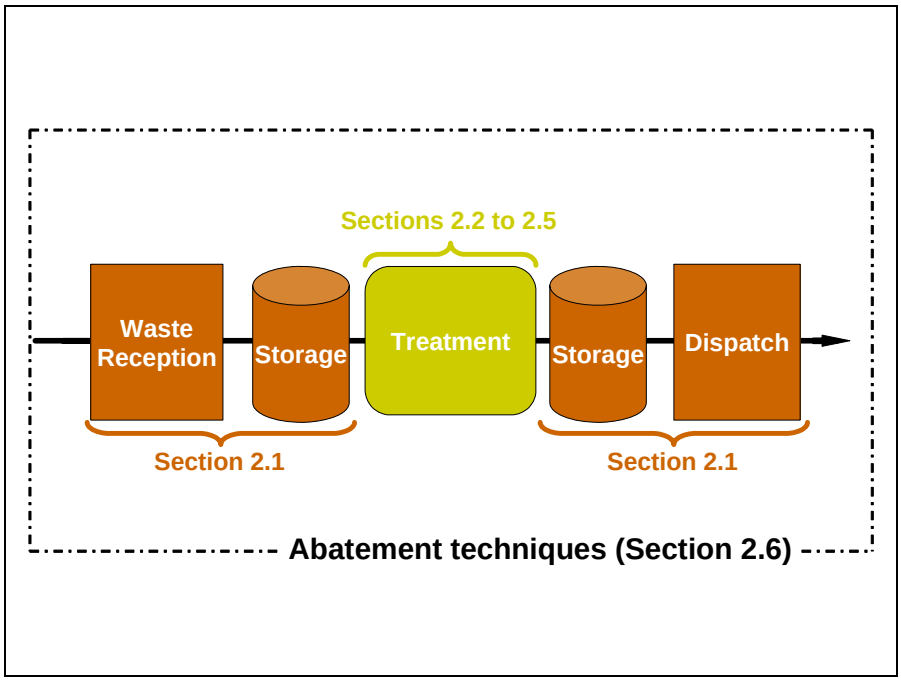


Figure 2.2: Typical operations in waste treatments and how these have been distributed in this and subsequent chapters

Many techniques listed in this chapter are briefly described, with information provided in the structure shown in Table 2.1. This same structure is used for each technique, to help the reader to easily assess the information within this document.

Name of the type of information	Type of information included
Purpose	A brief explanation of what this type of WT is used for
Principle of operation	The type of process carried out and a brief explanation of it
Feed and output streams	The type of waste that can be treated by the treatment, as well as details of any products of the operation
Process description	A brief description of the process. Where appropriate, figures and diagrams will be used
Users	Reference to the number of plants using the technique in Europe and worldwide. Also, details of which WT sector uses this type of technique

Table 2.1: Information contained in the description of each technique included in Chapter 2 [150, TWG, 2004]

Waste treatment installations

While the waste is in storage, a treatment schedule is developed that identifies the waste to be treated, its storage location, any necessary preparations, the treatment method, and the rate at which the waste is to be fed. At the start of the waste treatment, the waste is typically fed by bulk materials handling systems, such as pipelines or conveyors, to the equipment used to perform the prescribed treatment steps. Treatment operations may be carried out on a batch or continuous basis.

Different types of approaches are common for waste treatment installations. They can broadly be classified into three groups:

- waste installations included in the same place where the waste is produced. These typically serve a rather small number of wastes types and can provide only a restricted number of treatments
- specific dedicated waste installations, which may provide one or several operations but which typically treat only a small number of waste types or which produce a relatively small amount of output
- integrated waste treatment installations. Some waste treatment installations are not stand-alone installations only containing a single type of treatment. Some of them are designed to provide a wide variety of services, and they are designed to treat a great variety of waste types. As mentioned in Section 1.1, waste treatment installations are designed to produce required waste treatment services. For example, sometimes they are designed to provide a certain type of treatment to deal with a large amount and variety of different waste types (e.g. aqueous wastes, municipal solid wastes). Figure 2.3 is one example of such a complex installation.

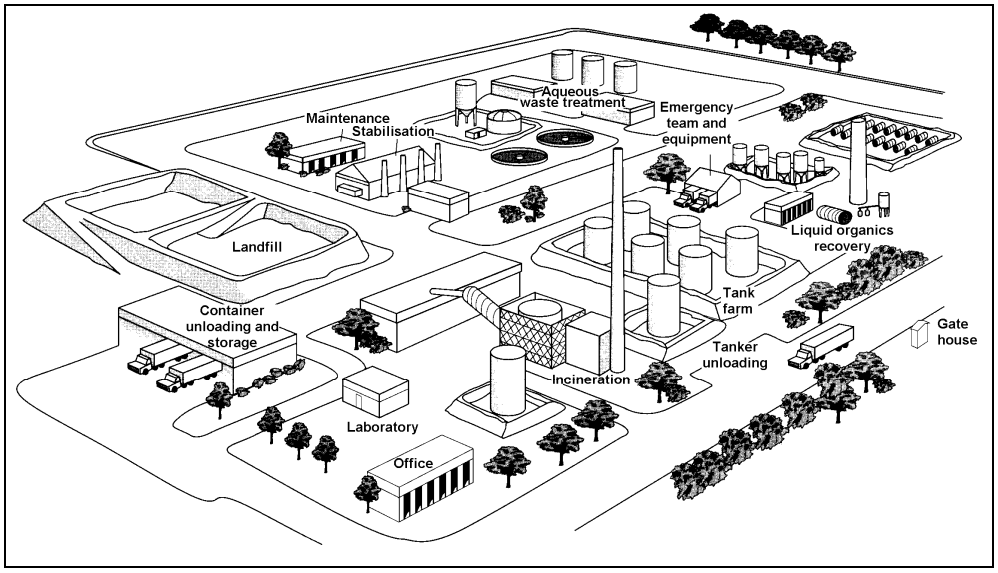


Figure 2.3: Example of an integrated waste treatment installation
[53, LaGrega, et al., 1994]

Table 2.2 matches the operations carried out at WT installations with the components of the fully integrated facility. It is important to note that all components operate under an umbrella of a number of special measures. These special precautionary measures include security, inspections, maintenance, training, incident prevention, emergency planning, safety, monitoring, and auditing.

	Operations subsystems				
Facility components	**Pre-shipment waste analysis**	**Waste receiving**	**Waste storage and preparation**	**Waste treatment**	**Solid outputs management**
Analytical laboratory	**X**	**X**			
Truck waiting area		**X**			
Gatehouse		**X**			
Weighbridge		**X**			
Drum unloading and storage		**X**	**X**		
Tank farm		**X**	**X**		
Bulk waste and waste preparation		**X**	**X**		
Biological treatment				**X**	**X**
Physico/chemical treatment				**X**	**X**
Stabilisation plant				**X**	**X**
Regeneration				**X**	
Preparation of waste to be used as fuel				**X**	**X**
Incinerator*				**X**	**X**
Landfill cells*					**X**
* Not covered in this document					

Table 2.2: Examples of operations subsystems and their components
[53, LaGrega, et al., 1994], [150, TWG, 2004], [152, TWG, 2004]

What processes are applied to each type of waste?
In order to select which type of treatment may be given to a certain waste, decision trees have been developed.

2.1 Common techniques applied in the sector

[40, Militon and Becaud, 1998], [50, Scori, 2002], [51, Inertec, et al., 2002], [53, LaGrega, et al., 1994], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [116, Irish EPA, 2003], [119, Watco, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [156, VROM, 2004] [157, UBA, 2004].

This section discusses the pretreatments/activities or post-treatments/activities (see the introduction to Chapter 2 and Figure 2.2) commonly used in the WT sector and included under the scope of this document. It also includes some treatment activities that are commonly used in the whole sector. For example, it includes techniques used for repackaging, crushing, sieving, drying, blending, sorting, homogenisation, scrapping, fluidification, washing, baling, regrouping and storage, transportation, reception and traceability control, as well as management techniques used in waste treatment installations. Only those techniques important from an environmental point of view are described in detail. Other techniques considered to be generic techniques or very specialised techniques have not been described but have been listed in the two last sections of this Section 2.1. Those techniques applied for the abatement of emissions (e.g. air filters, biofilters, waste water treatments) are briefly mentioned in Section 2.6 and are widely analysed in the last three sections of Chapter 4.

2.1.1 Reception, acceptance, traceability and quality assurance

For most WT plants, the following order is relevant: a) acceptance b) storage c) treatment d) storage of residues and emissions. Each of the previous steps requires knowledge and control of the waste as well as specific acceptance and processing management. Knowledge of wastes, before they are accepted and treated, is a key factor for the management of a WT plant. The aim of this section is to present the different types of controls and analyses which can be carried out during the waste treatment process, from the pre-acceptance and arrival of the waste at the site, to the final dispatch of the waste.

Pre-acceptance and acceptance procedures

Many WT sites (e.g. hazardous waste treatment facilities) require information and/or samples to be provided prior to the transport of waste to the site, to enable them to ensure that the waste is within the requirements of the site licence and will not adversely affect their treatment process. Pre-acceptance includes taking a sample, filling out an identification form, carrying out the analysis and then assessing whether the waste can be accepted into the installation. If it can be pre-accepted, the waste is transported into the installation, where a second analysis is carried out to once again help make the decision of whether to accept or reject the waste. Then the acceptance procedure contains two stages: First, the pre-acceptance phase; and second the acceptance phase.

Pre-acceptance
Pre-acceptance procedures of wastes follow three main steps:

a. information is provided from the waste producer. For example, a specific formula about the waste identification (main characteristics, health and safety considerations, how they are produced, etc.)
b. preliminary and complete analyses are carried out in order to characterise the waste
c. on the basis of all the information, the operator makes the final decision on whether to accept the wastes into the installation or not (bearing in mind the specifications included in its permit and other process requirements). There are always rules to accept wastes as complying with the description. Some of these rules are developed at national level and others are developed at installation level. For example, this can be certain percentages of differentiation or parameters restricted by the permit. In certain cases, a risk assessment may be carried out. The waste processor can evaluate the risk of contravention of certain rules in this way (e.g. national rules). An example of classification of the risk in the pre-acceptance phase may be:
    - waste is classified as 'high' risk if the waste or the client are new
    - waste is classified as 'low' risk if:
        - it is a known waste from a known client and
        - the waste is predictable in properties and composition and
        - there are low risks of contamination or dilution of the waste with other wastes or material.

In certain cases, part of this procedure (e.g the analysis) may have to be adapted, e.g if dangerous conditions for sampling occur at the time or when there is a very small quantity of waste.

The purpose of the full characterisation before shipment is to satisfy the following requirements, to:

- determine if the waste is acceptable for receipt at the facility in terms of:
    - the facility's permit
    - the capability of the facility to treat or dispose of the waste
- identify the inherent hazards of the waste so that appropriate precautions can be taken during its handling and storage at the facility to prevent incidents
- determine the physical characteristics and chemical constituents of the waste to allow selection of effective waste processing and disposal methods
- select the verification parameters to be tested upon arrival at the facility. These parameters can ensure that each shipment of waste is the same type as the fully characterised waste
- select any treatability parameters to be tested that could vary, so as to influence how waste processing would be programmed
- develop an estimate of the cost of treatment or disposal of the waste.

Acceptance
Upon receipt, a unique code is assigned to the waste containers, or batch, to ensure that the waste is traceable at all times. Individual containers or specific storage locations are marked accordingly. Some waste oil recovery companies tend to check the incoming feedstock by interviewing the truck driver and subjecting top and bottom samples from the truck to visual and olfactory inspection. A classification of the risk in the acceptance phase may be:

- wastes with high risk classification are typically always analysed at delivery
- wastes with a low risk classification are occasionally tested on conformity with the data from the pre-acceptance phase. The process of acceptance is typically guided by receivers with a role independent from process operators or waste acquirers. The whole procedure classifying the risks of non conformity with data from the pre-acceptance phase and the description of roles and responsibilities of the various persons involved in waste acceptance is typically part of the waste analysis plan.

Upon accepting the waste, the facility signs a declaration and sends a copy to the waste producer (originator). At that point, the facility may share liability, in some cases, with the producer and the transporter. In other cases, the waste producer maintains the responsibility of the waste treatment until the last treatment is performed. Thus, it is critical that the pre-shipment waste analysis has already been completed and the shipment scheduled. Without prior scheduling of the incoming shipment or if the shipment is improperly documented, the gatehouse will refuse entry to the truck.

Sampling and analysis
A proportion of the waste is screened at the site. The level of screening is a function of the amount of processing to be carried out, and the size of the container. For example, materials to be treated in an adjacent plant will be tested to check compatibility, as will drums of material for bulking and onward transfer. Screening systems vary from site to site according to the type of waste and its subsequent treatment. For example, screening may involve an initial check of the pH level, odour and flashpoint as the materials are unloaded, followed by a more detailed screening against the stated contents on the packing lists for materials that will be decanted at the site.

The way sampling and any analysis is carried out may vary depending on the purpose of the checks, for example pre-acceptance, acceptance, reception, process analysis, traceability, dispatch analysis, reception at the final user site or external analysis. CEN TC 292 work provides information on sampling and sample preparation. Some more information is also available in Section 3.7.

Laboratory
Upon collection of the sample, the laboratory typically analyses a portion for the verification parameters and retain the remainder for subsequent testing of treatability parameters. Upon verification of the waste shipment, the truck is directed to an unloading area where it is emptied and then reweighed before it leaves the facility. The essential tasks of the laboratory are:

- acceptance and identification
- establishing the treatment programme
- process control
- final inspection.

A waste analysis plan is a critical part of a facility. The plan specifies the parameters for which each waste will be analysed, the sampling and analytical methods to be used, and the frequency of analysis. Before a facility treats, stores, or disposes of a waste, it must profile the waste, including a detailed chemical and physical analysis of a representative sample of the waste. Commercial facilities require this full characterisation prior to shipment by the waste producer. Representative sampling of a waste shipment is conducted upon arrival at the facility to verify that the composition of the shipped waste matches the information given on the fully characterised waste sheets.

Plant laboratories assume central importance, for example in physico-chemical treatments of waste waters. Both process simulations to establish treatment programmes and analytical work is undertaken to determine the sequence of processes in the sense of process controls as well as emissions (waste water, exhaust air); the treatment programme contains exact instructions regarding how the waste is to be treated, which chemicals are to be used – according to type and quantity/dosage – and which controls and documents are drawn up. One example of these interrelationships is diagrammatically represented in Figure 2.4.

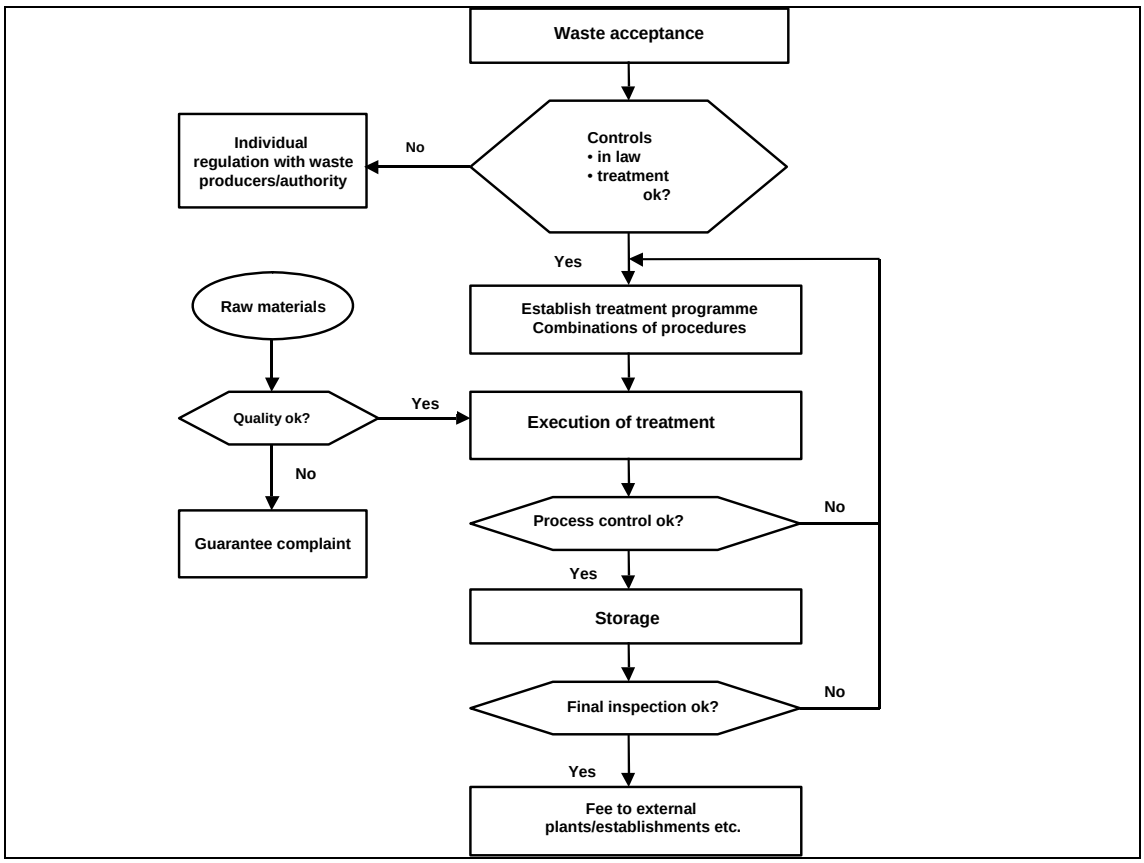


Figure 2.4: Simplified flow chart of an example of checking/inspection in a physico-chemical treatment plant of waste waters
[121, Schmidt and Institute for environmental and waste management, 2002]

Reception

Typically, wastes are physically inspected when they arrive at the site, to check the integrity of the containers and to visually verify the waste type. Most sites have a regular daily inspection of containers' integrity at the site.

Waste shipments typically arrive by truck at a facility's gatehouse. Scheduled and properly documented shipments are directed to the receiving station where any packaging is checked, the loaded truck is weighed, and representative samples are collected to test the verification parameters. The waste may arrive as bulk liquids in a tank truck, containerised liquids or sludges in drums, bulk shipments of contaminated soil in dump trucks, or by a number of other methods. Collecting a representative sample can pose a difficult task considering that a waste may be in multiple phases and states or have pockets of high contamination. The receiving station must use previously established procedures for each situation to ensure the collection of a representative sample.

The mere 'emptying' of a truck can pose a difficult challenge if the waste has stratified, a container has leaked, or if a solidification reaction has occurred. For such abnormal situations, facilities typically plan procedures and are prepared with special equipment to resolve such problems. Finally, the truck may need to be cleaned to remove any trace residues.

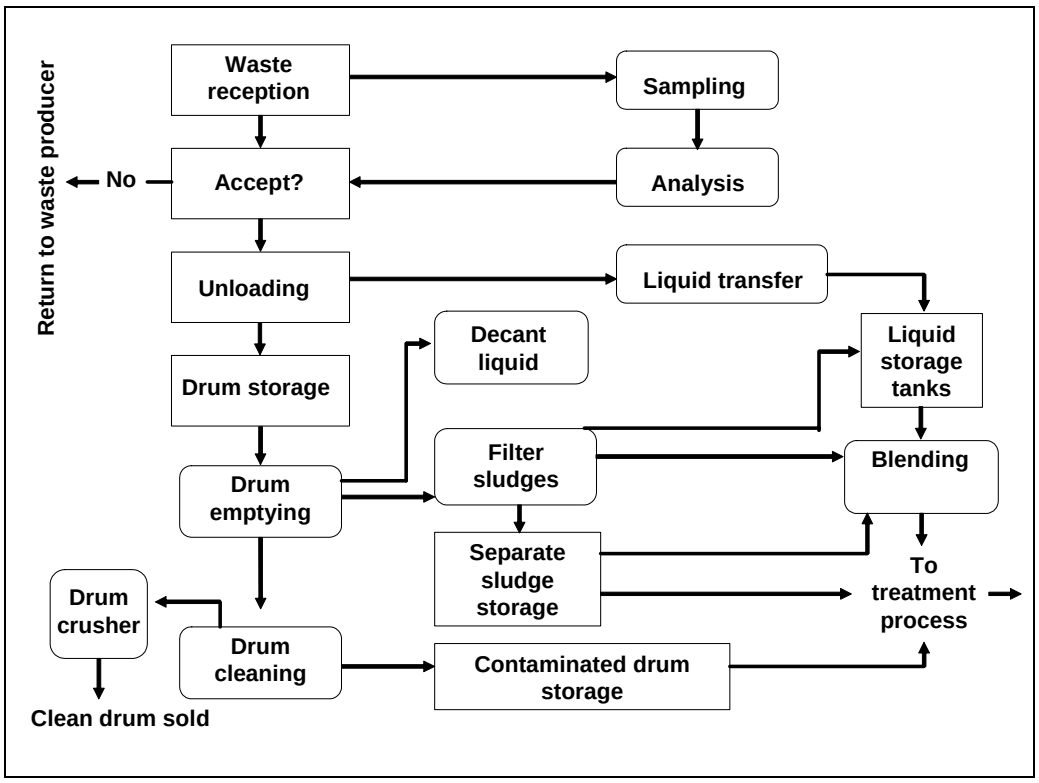


Figure 2.5: Example of waste reception and acceptance at a facility handling bulk liquids and drums
[80, Petts and Eduljee, 1994]

Quality assurance systems
One part of the waste management in the installation is the logistical organisation, for example, of solid waste fuel processing. By choosing and using specific waste materials, solid waste fuel producers set a kind of quality assurance themselves. Quality assurance systems already exist and further regulations are in the development phase.

In the past, solid waste fuel was mainly produced from process related wastes as mono-batches which were easier to handle because of their constant qualities. Nowadays, high calorific fractions of municipal solid wastes and of other mixed wastes are in the picture as a source for the production of solid waste fuel. The aim of a quality assurance system is to attain and ensure constant qualities to increase acceptance by end users and permitting authorities. The requirements mainly concern product quality.

2.1.2 Management techniques

This section covers operational management and emission management in the installation. Some special precautionary measures need to be applied regarding:

- security
- inspection and maintenance
- incident prevention
- emergency planning
- employee training
- safety
- monitoring
- audits.

Accidents
Accident risk is inherent when dealing with waste and in particular hazardous waste. Wastes are heterogeneous in nature and are often intrinsically aggressive to plant and equipment. Any failure in the management of the waste, from the process of characterisation and checking of wastes to the operational control reactions and the mixing of wastes, will significantly increase the risk from unwanted or runaway reactions.

2.1.3 Energy systems

Energy management issues are discussed in this section. Installations for the generation of steam and/or power are not covered here because they are covered by other BREF documents (e.g. large combustion plants, waste incineration).

Heat and power are needed to run an installation. Some common site equipment using fossil fuels include fork-lift trucks, small boilers, shredders and grinders. These take a mixture of standard vehicle diesel fuels, and a range of fuel oils. Some of this equipment can be electrically or even pneumatically powered. Some sites have on site boilers for steam production.

The main uses of energy on a waste treatment facility are:

- heating, lighting and power in facility buildings
- power for treatment processes and facility equipment, such as pumps, air compressors, centrifugues, etc.
- fuel to power vehicles.

Good design and management of energy systems are important aspects of minimising the environmental impact of a waste treatment facility.

2.1.4 Storage and handling

The objectives of storage are to:

- store the waste safely before its introduction as feed into the treatment
- provide adequate accumulation time. For example, during periods when treatment and disposal process systems are out of service, or when there is to be a time separation between treatment and dispatch of waste or for the purpose of controls and inspections or to accumulate enough waste to use the full capacity of the treatment, etc.
- uncouple the treatment and dispatch of waste
- allow effective use of classifying procedures to be made during storage/accumulation periods
- facilitate continuous treatment processes. Continuous treatment processes are not capable of reacting to sudden and significant changes in composition and reactions of waste while guaranteeing a specific treatment result. For this reason, homogenisation of the various properties and level of treatability of the waste must be achieved and ensured by intermediate storage/accumulation of the waste to be treated. Storage/reservoirs must therefore be set up before the actual treatment in Ph-c plants under continuous operation
- facilitate mixing, blending, and repackaging of the waste as deemed necessary
- allow the staged input of various wastes with reagents to the subsequent unit treatment processes
- collect a reasonable amount of waste prior to sending for certain treatments (e.g. transfer stations).

From small packages to large scale storage (regrouping)
Wastes can be sorted into different categories depending on the bulk shipment of compatible materials to specific disposal or treatment sites. For example, small containers may be packed into 205 litre drums with vermiculite as a packer filler for easier handling and transfer. Larger containers may simply be sorted into different waste categories and stored on pallets prior to onward shipment.

Certain wastes are decanted and bulked into larger containers, for example:

- laboratory containers or small commercial containers into 205 litre drums or IBCs
- drummed waste may be transferred into IBCs
- the liquid fraction of drummed waste is decanted into IBCs
- the aqueous fraction of two-phase wastes is decanted
- part of tanker loads can be stored to await further material to make up a full load.

Decanting the waste reduces the tonnage of packaging materials associated with the onward transfer; and produces a consistent set of larger units that can be stored more easily at the site and that are packaged and labelled ready for onward transit. This will be important for the onward receiving site, that may need a controlled and checked stream of material for their process.

One role of waste solvent facilities is to regroup and recondition of small volumes (drums, etc.) to prepare then as fuels or to regenerate a solvent that can be re-used. The goal of a solvent regroupment/liquid fuel preparation facility is to prepare a tailor-made, stable and homogeneous waste, which fits the requirements of its final uses (recycling, incineration or co-incineration).

Transfer of materials
The next stage destination for waste may be for reclamation, treatment or disposal, and may be processed at an adjacent site within the same complex, or it may need to be transferred to other vehicles for onward transfer.

The choice of transportation for the material depends on the physical form of the material to be transported. In other words, the transport of gases, liquids and solids all involve different techniques. Solids are transported by: conveyor belts, fork lift trucks, trucks, pneumatic conveyors, load shovels, cranes, walking floor, etc. Liquids and semi-liquids are transported by: pumps, pipes, conveyor belts, screws, elevators, etc., and gases by: compressors and pipes.

Due to consistent efforts to avoid waste arising and the separate collection of any waste arising, the handling of small quantities up to approx. 1 m^3, is particularly significant. Systems have been developed in some countries to separate the collection and transport of waste (e.g. the AS container system in Germany).

Package acceptance
Physico-chemical treatment plants accept waste, by tanker, truck, pipeline or ship, and generally store the waste prior to treatment, either in small containers or tanks.

Washing and cleaning of vehicles and receptacles/containers
After delivery and emptying, the vehicles/constructions and receptacles/containers could be cleaned on site (e.g. under agreement with the transport company) or off site except where the receptacles/containers are disposed of, the adherent residue is not harmful, or the constructions, receptacles or containers are used again to transport similar waste.

Because of the many different kinds of drums/containers/constructions, the cleaning – apart from the exceptions – is performed manually using spraying devices, high pressure rinsing devices, or brushing and brooming techniques. Cleaning can be performed inside or outside, in order to guarantee the re-use of the drums/containers/constructions. Cleaning inside is important to prevent substances being carried over. This may be crucial, for example, when the limit of chlorine-organic adsorbable materials in the waste water of a Ph-c plant (AOX value) is 1 mg/l, and this concentration can be affected by left over concentration in the refilling (e.g. by residues with corresponding AOX ingredients). Typically, a separate treatment of cleaning waters is carried out in order to assure that the sewer is not contaminated by such waters.

A facility for cleaning the containers can be an automatic installation which cleans their exterior and interior. The cleaning process is computer controlled by means of contact free sensors. The maximum capacity of the facility is 10 containers per hour. The working movements of the handling devices are carried out hydraulically. The cleaning devices are supplied with water by two high pressure pumps with a capacity of 132 kW each. The wash-water is run in a closed loop over the existing water treatment system.

Reclamation of containments
The majority of incoming containers (glass, metal or plastic) are shredded or crushed prior to recycling or disposal. Some drums and IBCs are sorted for re-use within the transfer operations and others are washed (or vented) prior to re-use or sale.

Drum emptying may be a simple bulking operation, and a sensible screening operation to check the contents of drums prior to landfill, as happens in some countries. The latter mentioned practice is actually forbidden by the Landfill Directive.

Ways of storage and facilities
Tank farms can be an integral part of a transfer and bulking operation, or can operate as stand alone activities. Bulk storage is likely to becoming more common as more wastes require treatment under the Landfill Directive. As this occurs there is likely to be difficulties in matching the wastes arising to the finite capacity of treatment plants, and consequently more interim storage units will be needed. Attention is drawn to the Storage BREF, the Seveso II Directive and to national regulations.

Liquids may be stored in tanks and/or containers (e.g. glass containers, drums, big containers), storage cells, storage buildings and outside storage (e.g. waste waters). Solids can be stored in heaps, sacks and bulk bags, silos and bunkers, and packed. Solid waste can be stored in closed areas, as for example closed building (e.g. with an appropriate filtering system and exhaust gas treatment to lower odour and air emissions) and handled with a crane, travelling crane or conveyor belt or silos (e.g. cylindrical or parallelepiped silos with a screw or a walking floor to extract the solid waste).

Upon unloading, the wastes are moved into storage, which may consist of tanks or impoundments for bulk liquids, hoppers for solids and sledges, or pads and warehouses for containers.

Some sites can store blended or raw waste material pending transfer for use in another process.

Storage areas are often the most visible aspects of the installation. The key issues for operators to address in relation to waste storage on the installation includes the following:

- location of storage areas
- storage area infrastructure
- condition of tanks, drums, vessels and other containers
- stock control
- segregated storage
- containment used to protect the environment and workers health.

Containers used to store shredded drums or intermediate bulk containers (IBC) are also covered in this document.

An important safety consideration in storage and handling is fire prevention and protection.

Laboratory smalls essentially consist of substances in containers of less than five litres capacity. They generally contain pure chemical elements and compounds from laboratories or arise when laboratory stores are cleared. The majority of operators offer a packing and collection service for laboratory smalls.

Laboratory smalls are usually sorted and bulked into drums (e.g. 205 litre or other sizes depending on the further treatment) in either designated enclosed buildings with positive ventilation and flameproof lighting, or within open-sided roofed areas.

Tanks are also used to store wastes. This may be part of a medium scale bulking operation to ensure that part tanker loads are bulked to give a full load for onward transfer to the next process; or a large scale tank farm operation. The former tends to have limited controls, similar to the storage of fuels on the site. Tanks are typically in the open, on hard-standing and bunded. The type of storage applied will depend on the need for homogenisation in the storage unit.

Often storage in containers also involves classification processes, the containers used also being fitted with skimming apparatus to remove floating material and suction apparatus to remove sediment. If classification procedures are disabled, the waste may instead undergo continuous agitation to maintain a state of homogeneity.

The storage, treatment and after-treatment functions are not separated but rather take place in the same container. A batch treatment process is used.

Storage capacity
Storage capacities need to be designed to typically ensure a continuous service. Other issues to be considered are the re-treatment of the output if its quality does not meet the required specifications and the dispatch frequency.

Emptying of containers
Fluid wastes are accepted and sedimentation is carried out. The fluid wastes are delivered either in containers, tank vehicles or suction pressure vehicles. When they are delivered in containers, they are picked up from the conveying band by a handling device, transported to the preselected receiving basin and there semi-automatically emptied. The contained coarse solids are removed and collected in containers. The fluid phase follows the downward slope and flows into the sedimentation basin. The sedimentation basins (8 in total) are selected by a control system.

When they are delivered in tank or suction pressure vehicles, they drive into the emptying area and their tanks are connected to the sieve filter via a tube. The fluid wastes flow from the tanks through the tube to the sieve filter, where coarse impurities (e.g. gloves and cloths) are removed. Metal elements are removed via a magnet separator. Afterwards, they are transferred via a pipe system into a basin pre-selected by a control system.

Computer-controlled high rack storage area for hazardous wastes
The high rack storage area serves as a secure storage and control area of wastes which have been delivered in closed containers. Non-packaged wastes cannot be put in storage. The storage area has 1680 storage positions in 2 store vessels and is geared to 250 to-bin and from-bin transfers. For these transfers the high rack area disposes of chain conveyors and bucket elevators. For fire prevention the reception area has fixed fire extinguishers that are coupled with acoustic alarm signal systems. Additionally, portable fire extinguishers are installed. From the high rack storage area, the wastes are transferred to the individual facilities where they are disposed of, recovered or pretreated for disposal or recovery.

Handling of materials from a Ph-c plant
The handling of material requires its correct packaging and load safety. Small quantities are packed in packaging units that are easy to handle, e.g. bottles or boxes. Large quantities in containers of, e.g. 100 to 12000 litres content volume. Prior to treatment, the units/containers have to be emptied. For this purpose appropriate devices are necessary, e.g.:

- tools for opening
- holding and clamping devices
- lifting and rotating devices.

In order to limit the variety of technical devices and, in order to ensure handling, the packaging units/containers are safe and efficient. The units/containers are combined with the systems. The emptying process requires:

- experienced staff
- knowledge about material/wastes
- safety equipment/devices
- measures/facilities for emission control
- suitable and easily manageable intercepting tanks
- regulation of the destination of the emptied units/containers.

Likewise, the upper bodies of the transport vehicles have to be emptied; this is usually done by means of pumps or in a free flow along a gradient. Experience shows that residues always remain inside the units/containers or in the upper bodies of the vehicles. Without regard to the kind of their subsequent utilisation these enclosures have to be completely emptied and cleaned. As experience shows, emptying is often hampered by sedimentation of solid, adhesive and hardening components in the waste. This may make it necessary, e.g. when emptying the upper bodies of the tank and suction vehicles, to remove the hardened components with tools or manually. It is advantageous for the process flow if the solid material can be transported in a lower container (folding plates, slides etc.).

After emptying, the units/containers/upper bodies have to be cleaned independent of their further utilisation. Exceptions to this rule can be made if:

- the units/containers are disposed of as waste and the adhesive residues of the transported waste do not make a difference
- if the subsequent utilisation is identical to the previous one.

The residues resulting from emptying, as well as the washing residues, are treated in the same way as the waste unless this is not possible due to its consistency. For example, sludge from the disposal of petrol or oil separators can be processed and recovered partly by simple washing procedures while the water phase has to be subjected to physico-chemical treatment. Washing is usually done with water. The effect can be enhanced by pressure (up to 100 bar), temperature (up to 80 ºC and vapour) and/or adding of solvents and/or tensides.

2.1.5 Blending and mixing

Wastes, once produced, should in principle be kept separate from other wastes. The reasons for this are that the re-use/recovery of homogenous streams are generally easier than that for composite streams. Under certain conditions, however, different waste streams can be processed just as well, or sometimes even better if they are composite. In this section, it is explored the different rules that may be applied on whether or not mixing/blending may be allowed and under what conditions this should be carried out.

Purpose
Due to the heterogeneous nature of waste, blending and mixing are required in most waste treatment operations in order to guarantee a homogeneous and stable feedstock of the wastes that will be finally processed. The term 'blending' is used more for mixing liquids than for solids, unless mixing a solid into a liquid. The term 'mixing' is used more for solids and semi solid materials (e.g. pasty material).

Certain types of wastes will require prior mixing or blending before treatment. For example, the concentration of waste constituents can vary considerably because of differences in incoming waste strengths. This is particularly true at most commercial treatment facilities. Mixing can control such variations to a range that will not upset the performance of the subsequent unit treatment processes. However, this issue should not be confused with dilution and this is the reason why these treatments are many times prohibited (e.g. hazardous waste and landfill Directives) over a wide range of concentrations. Blending and mixing are processes carried out because it is a technical requirement from the WT facility to guarantee a homogeneous and stable feedstock and not techniques to facilitate acceptance of waste.

As is prescribed in the Hazardous Waste Directive 91/689/EEC, mixing and blending operations are not permitted unless this is explicitly established in the licence of a collector or processor. An exemption from the permit requirement may be applied by the competent authority if establishments or undertakings carry out waste recovery and if competent authorities have established general rules for each type of mixing and blending laying down the types and quantities of waste and the conditions under which the mixing and blending may be applied and if Art 4 of the Waste Framework Directive is taken into account by establishing these general rules for the concerning establishments and undertakings. In this exemption case, registration of the establishments and undertakings is mandatory in order to ensure that the establishments and undertaking comply with the stated general rules. The following basic principles apply for granting such a licence:

- the mixing of wastes must be prevented from leading to a risk to human health and adverse effects on the environment
- mixing must be prevented from leading to any of the wastes to be mixed being treated or processed to a lower quality level than is desirable
- the mixing of wastes must be prevented from leading to environmental damage by the diffuse dispersal of environmentally hazardous substances.

The following elaboration of the basic principles for the mixing of waste applies to both hazardous and non-hazardous waste. Hazardous wastes must be kept separate from one another. Mixing can only be permitted if it will not result in risks to humans and the environment, and if there will be no problems with safety due to the mixing for all types of operations (for example safety risks for workers, neighbours of the plant etc.). Article 2, paragraph 3 of the Hazardous Waste Directive states that such an operation can only take place if a licence has been granted. Conditions may be attached to a licence, making it possible for the hazardous wastes referred to in the licence to be mixed with other (hazardous) wastes, preparations and other products referred to in the licence. Where the primary function of mixing wastes is to achieve dilution of a specific species in order to comply with less stringent regulations, this is prohibited. Within the boundaries of the licence for mixing and blending, the waste treatment manager is responsible for writing and applying operational guidelines on mixing and blending. Firstly, the basic principles for granting a licence are elaborated. Secondly, principles and considerations are given for writing operational guidelines for mixing and blending given these boundaries of a permit.

Principle of operation
Mix two or several wastes in order to typically generate a single output.

Feed and output streams
Applicable to solid and liquid waste. Outputs can also be in solid or liquid phase.

Process description

The basic principles referred to above in the purpose section (risk prevention, substandard processing and prevention of diffuse dispersal), have, as their main objective, protection of human health and of the environment against harmful influences and promotion of the recovery of wastes within these boundary conditions. For the sake of a high level of protection and effective supervision, these general basic principles need to be translated, in licensing procedures, into operational criteria on the basis of which it can be clearly determined if the mixing/blending of wastes can be allowed. The following elaboration of the basic principles is prescriptive:

- the mixing of substances that react strongly with each other (heat, fire, gas formation) or explosive substances (explosion) must be prevented. Mixing must be prevented from giving rise to risks to human health and the environment, both during the mixing operation itself, and during the subsequent treatment process. For licensing purposes, this means that the acceptance and processing policy of licence-holders is drawn up in such a way that, before wastes are combined, it is assessed whether this combination can take place safely. This can be achieved by carrying out compatibility tests before mixing/blending for any purpose for any type of waste
- the mixing of wastes must be prevented from leading to a lower level of processing waste than the best possible level of waste management or from leading to the application of non-environmentally sound waste management. This means, for example, that if a recovery operation is the minimum standard of processing a waste stream mixing of such wastes with other wastes in order to bring the mixture to any disposal route shall not be accepted. For instance, the mixing of liquid wastes or clinical wastes with other wastes for the purpose of landfilling is not permitted. Mixing of wastes with POP content above the low POP content (as defined under the Basel and Stockholm Treaties) with another material solely for the purpose of generating a mixture with POP content below the defined low POP content is not allowed because this is not environmentally sound
- the mixing of wastes must be prevented from leading to the undesired diffuse dispersal of environmentally hazardous substances. The effects of diffuse dispersal are determined by the type and concentrations of environmentally hazardous substances in combination with the processing route to be chosen, the emissions occurring and the quality and purpose of the residual substances released. In combination, it must be assessed what the negative consequences are of processing the environmentally hazardous substances concerned with regard to emissions into the soil, water, air or in residual substances and how these negative consequences compare with the environmental effects of another processing route. This assessment must also take into consideration the cyclical character of future re-use.

For solid wastes, the waste may be mixed with a crane, a closed mixer or a closed mixer with a turn-cup and an axis with knives. Blending operations generally involves large volumes, i.e. the discharge of tankers into tanks.

Users

Blending and mixing is typically applied only when quality and analytical values of the waste inputs are under or equal to the values of acceptance in the planned output treatment plant. These operations take place in all waste treatment activities (biological treatment, fuel preparation, contaminated soils, waste oils, etc.), and sometimes are quite specific to each WT activity. Some of these issues are also covered in the individual sections for each WT activity.

2.1.6 Decommissioning

Purpose
The purpose of decommissioning is to return the facility, on surrender of the waste licence, to a condition suitable for the selected afteuse. The importance of a proper closure is such that development of a closure plan is a necessity, since it will provide and document a plan for the final closure of a site prior to the startup of operation. This also fits in with a life cycle assessment of a planned site.

Principle of operation
For the decommissioning, the operator typically needs to demonstrate that, following decommissioning, the condition of the site will not cause, or be likely to cause, environmental pollution.

A closure plan needs to provide a clear and orderly set of actions and methods to be followed upon cessation of all operations at a facility. The steps need to be designed to ensure that the closed facility (a) poses a minimal risk to human health and the environment, and (b) requires minimal post-closure maintenance.

Feed and output streams
Not applicable.

Process description
The extent of the decommissioning/restoration will be dependent on the types of materials accepted, the design of the facility and the selected afteruse.

The cessation of waste acceptance at a facility typically initiates a review of the waste licence. This review allows the licence to be surrendered or amended to reflect the change in activities on site.

A closure plan requires assurance that funds are available to close the facility even if the facility owner starts bankruptcy proceedings. This assurance can be in the form of a bond, corporate guarantee, or some other financial instrument. The monetary amount is determined based on a cost estimate prepared as part of the closure plan. For example, the cost estimate may be equal to the maximum costs of closing all the waste management units ever activated at the facility.

Closure of a storage or treatment facility requires removal of all the remaining waste to another facility. All equipment and structures that had been in contact with waste must also be decontaminated. This may entail removal of concrete pads used to hold waste containers, as well as contaminated soil where leaks have occurred.

Users
Applicable to the whole WT sector.

2.1.7 Treatment of smalls

Purpose
The aim is to identify different types of wastes for their correct treatment.

Principle of operation
The substances that are to be treated are manually sorted and repackaged, crushed if necessary, conditioned and transferred to internal and/or external disposal plants.

Process description
The system is divided into three spatially separated parts:

- sorting of chemicals. This is carried out with a sorting cabin and an aspiration device for the separation of laboratory chemicals for different processing paths (e.g. recycling, disposal (incineration) and deposit in underground disposal)
- packing treatment for emptying fluid containers with a volume of 0.1 to 200 l. The small volumes are combined for the purpose of creating large batches (solvents or acids). These are disposed in the downstream high temperature incineration or recovered in the in-house physico-chemical treatment plant. A downstream facility crushes the emptied containers
- treatment of plant protection products, reactive and odour intensive substances in an special cabin.

Users
Treatment of hazardous wastes from private households, universities, laboratories and business enterprises.

2.1.8 Size reduction

Purpose
Adapt the waste solid granulometry for further treatments or to extract wastes which are difficult to pump or decant. Reduces the particle size.

Principle of operation
Techniques used in the installations are shredding, sieving, fractionating, conditioning and confectioning. Slow motion shredders, hammers and dedicated shredders are used.

Feed and output streams
Bins and aerosol cans are fed into the system. The gases are treated in a cleaning facility and the liquid and solid components are disposed of or sent for recovery.

Process description
Some examples are described below:

Bin shredder
The treatment facility consists of a shredder for the comminution of empty, half empty and full bins with sizes ranging from 1l to 1000 litres. The feed system works with an electronic wheel loader. The shredder itself is placed in a pressure surge-proof channel of 12 m high with an off-loading area on top. The bins are transported by the electric wheel loader through the open door to the shredder. Afterwards, the door closes and the shredding process starts automatically. In the next step the shredded material falls into a tank, which, after complete filling, is transported from the channel to further processing steps. The released exhaust gases are treated in a regenerative post-combustion facility. Other protection devices are a double-layered vacuum controlled polyethylene high density foil on the bottom and an automatic nitrogen and water flooding in the closed channel.

Aerosol can shredder

The treatment facility consists of a shredder for aerosol can crushing, two condensation units and one collecting tank. The collecting tank has a filling device for condensed and warmed (outside temperature) gases. This tank has also a nitrogen supply device for cooling the condenser and for the inertisation facility. Other parts of the facility are a collection tank for liquid waste solvents and a bin for scrap metal. The shredder crushes the aerosol cans batch-wise. The shredder works in a nitrogen environment (inert) and is gas-proof. The gases and other active agents that may still be contained in the aerosol cans are released within the shredder. These released gases (mostly propellants) are run over the condensation unit and condensed. The condensate is stored in a gas collection tank. In the next step the gases are filled into compressed gas cylinders and transported to an incineration facility for hazardous waste. The uncondensed gases are transported to a regenerative exhaust air cleaning facility, where they are combusted. The solid residues from crushing (scrap metal) are separated from the liquid substances. The liquid and the solid components are separately discharged over different locks. The solid components, e.g. metal fraction, are forwarded to recovery or disposal. The liquid compounds, e.g. paint and hairspray, are temporarily stored in a tank and then decanted into 800 litre bins. The 800 litre bins are transported to a combustion plant for hazardous wastes where the liquid waste is used for auxiliary firing (thermal recycling).

Users

Bin and aerosol can treatment facilities. Preparation of waste to be used as fuel. Applied to different types of waste as plastic or metal drums, oil filters, municipal solid waste, solid bulk waste, waste wood, aerosol and glass.

2.1.9 Other common techniques

This section contains generic techniques used in the waste treatment sector. They are mainly mechanical treatments. They are typically used as pretreatments but some are also used as post-treatments (e.g. sieves). They are shown in Table 2.3, which also states the purpose of the treatments and where they are used.

Technique	Purpose	Users
Cleaning	Remove contamination that would otherwise prohibit waste materials being recovered	PCB capacitators and transformers
Re-packaging (e.g. baling)	Due to the disaggregated nature of some types of waste, it is sometimes necessary to compact them to make them easier to use in the following process. Pressure machinery is used to pack the waste into a certain physical form	Used for municipal solid waste to be used as a fuel and for plastic, paper and metal bales The size and form of the bale is typically optimised for its transport and re-use
Screening		
Sedimentation	Solid components within the fluid wastes are separated and the wastes are pretreated for further processing	Preparation of liquid waste fuel
Sieving	Used to separate big particles. Vibrating sieves, static sieves and rotary sieves are used	Preparation of waste to be used as fuel
Sorting and scrapping		
Washing	One purpose for washing may be to enable the re-use of drums into the installation or for selling to other installations for re-use. Drum washing operations often include no real treatment other than washing and settlement. A number of reprocessors wash the oil filters and provide a semi-cleaned metal fraction for recycling	Most treatment plants incorporate a road tanker washing-out facility to enable the removal of residues from vehicle tanker barrels. May also be applied to storage tanks and drums. Ph-c treatment plants

Table 2.3: Common techniques applied in waste treatment
[86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

2.1.10 Examples of waste treatment installations where only the common techniques are applied

Some waste treatment activities are very specific and particularly related to the type of waste that is processed. Some examples are listed below.

Cleaning transformers containing PCBs
Technologies, for cleaning transformers can be divided into three main categories:

- draining of the PCB oil from the transformer, followed by decontamination of this oil, and reinjection of the cleaned product into the transformer for re-use
- extraction of the PCB oil, by solvent washing of the transformer, followed by dismantling and further decontamination of the components to allow recycling of the metal components
- after suitable pretreatment, PCB oils may be treated with hydrogen at elevated temperatures. Here, the transformers are not recovered as such.

One example of the second case is the following: Carcases of used transformers are cleaned by means of trichloroethylene (TCE) wash. Here, the carcase is filled with the solvent and allowed to stand for an extended period before the solvent is replaced with fresh TCE. This operation is repeated (typically three times) until the carcase passes the requisite 'swab test'. During the cleaning operation, the transformer carcase is left open to the atmosphere or loosely covered with a steel plate. As a consequence, the activity results in evaporative losses of TCE to the air.

Typically this activity is carried out at specialist sites, which clean the PCB contaminated transformers and bulk the PCB contaminated oils. Their wastes: oils, drums, cleaning waters and cleaning solvent sludge are all sent for off-site incineration.

Cleaned transformer carcases and windings are sent for reclamation after thorough cleaning with TCE.

Cleaning of capacitors containing PCBs
Capacitors are similar to transformers in that they are made up of an active core, held in a metallic casing. However, the active core is not copper windings, but instead consists of interwoven rolls of fine aluminium foil, separated by thin films of paper and/or plastic. The techniques used for cleaning these capacitors are:

- the casing of the capacitor is removed and decontaminated by solvent washing; this is a straightforward decontamination process since the casing is non-porous. The core is incinerated
- the possibility of going one step further and treating of the core after its removal from the casing. This decontamination step usually involves a shredding of the core, and treatment with a solvent. This allows the level of residual PCBs to be reduced
- the technology which allows the largest amount of recycling is similar to the above, but this also treats the mixed aluminium/plastic/paper residue to separate out these components, by solvent washing. The aluminium metal can then be re-used; the only component to be disposed of is the mixed paper/plastic shreds.

Aerosol crushers
The aerosol destructor may take manufacturing rejects or materials from collection banks. The potential contents are usually known. These can include propellant gases (this could be LPG, butane, propane, dimethyl ether or HCFC) and the active ingredients. A proportion of the aerosols are empty whilst others may still retain certain propellant gases, although this number is not quantified. Other rejects may have failed their pressure tests and will probably loose propellant on the way to the destructor unit. Any propellant still in the aerosol cylinders constitutes a risk of accident during the treatment.

At least one installation in France deals with aerosol treatment.

Glass crushing
Windscreen glass is laminated with polyvinyl butyrate, and this is removed in a preliminary crushing process and sent to landfill. The glass crushing operation handles municipal and industry glass. Sites typically do not take coated glass from electronic equipment.

Fluorescent tubes/lamp processing
Separate mercury from lamp tubes. Currently, this is a tiny activity in some countries, but existing operations are now experiencing an increasing demand for their services. At this time, most use a crushing process. However, another process recently developed is a process without crushing with a 99 % recovery of the mercury.

Treatment of wastes containing CFCs
In the EU, it is mandatory to collect CFCs for disposal. It is usual that the lubricating oil collected from the draining of refrigerants is also treated to remove residual CFC prior to being recovered. CFCs can later be incinerated. Few incineration plants in the EU have HF recovery.

2.2 Biological treatments of waste

[31, Greenpeace, 2001], [32, DETR and DTI, 2001], [33, ETSU, 1998], [51, Inertec, et al., 2002] [53, LaGrega, et al., 1994], [54, Vrancken, et al., 2001], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [80, Petts and Eduljee, 1994], [81, VDI and Dechema, 2002], [86, TWG, 2003], [114, Hogg, 2001], [117, DG Env, 2001], [132, UBA, 2003], [138, Lanfranchi, 2003], [150, TWG, 2004].

Biological treatment uses living micro-organisms to decompose organic wastes into either water, CO_2 and simple inorganics or into simpler organics such as aldehydes and acids. There are several biological treatments used for the treatment of wastes, however, not all are included in the Scope of this document. Table 2.4, together with information included in the Scope section, tries to clarify which treatments are included in this document.

Biological treatment	Brief description	Included in this document?
Activated sludge	Decomposes organic wastes in water by exposing waste to biological growth. Water is recycled and aerated to facilitate biological action and a sludge is generated. Two commonly applied systems: suspended growth systems and attached growth systems	Included as a waste water treatment (see Section 2.6)
Aerated lagoons	Large lagoons containing high concentrations of micro-organisms. The lagoon is aerated to encourage bacterial growth and decomposition of waste	Included as a waste water treatment (see Section 2.6
Composting	'Engineered' mounds of waste are built to encourage the biological breakdown of organic solids, producing a humic substance valuable as a soil conditioner	Not included in this document
Aerobic digestion	Reduction of the organic content of waste. Applied to solid waste, non-continuous waste waters, bioremediation and to sludge and soil contaminated with oil	Mechanical biological treatment (see Section 2.2.2 and Section 2.2.3) Only ex-situ bioremediation covered in this document
Anaerobic digestion	Decomposes organic matter in closed vessels in the absence of air. Uses two forms of bacteria: acid-forming and methane- forming. Applied to solid-liquid wastes, highly contaminated waste waters (e.g. chlorinated compounds), bioremediation and in the production of biogas to be used as a fuel	See Section 2.2.1 and Section 2.2.3 Only covered the ex-situ bioremediation

Table 2.4: Biological waste treatments

2.2.1 Anaerobic digestion

Purpose

Anaerobic digestion is used in industry to handle very high COD wastes and as a treatment process for sewage sludge after an aerobic treatment of the waste waters. The production of biogas from controlled anaerobic digestion is one of the principal advantages of the process.

Principle of operation

Anaerobic digestion involves the bacterial decomposition of organic material in the (relative) absence of oxygen. One of the main limits on the anaerobic digestion process is its inability to degrade lignin (a major component of wood). This is in contrast with the process of aerobic biodegradation.

Feed and output streams

Anaerobic processes may be used to directly treat liquid wastes, the biological sludge generated by an earlier aerobic stage, organic solids and sludges. The inclusion of other feedstocks, such as sewage sludge, alters the resulting digestate. However, it is important to note that the mixing of household waste with these feedstocks can improve both the environmental and economic aspects of the process and has already been adopted in a number of plants (particularly, co-digestion with slurries and manure at small scale farm-based plants).

In the process, carbon from incoming organics is mostly converted to methane and carbon dioxide, and then released as biogas, which is capable of being combusted to generate energy or be used as a fuel to abate VOC emissions for example. The proportion of methane to carbon dioxide will vary with the waste stream and the temperature of the system. The system needs to have a balanced feed to maximise methane production. Installations usually target carbon rich wastes, that will make use of the available nitrogen (and probably the extra required through bioaugmentation).

The anaerobic digestion process leads to a production of methane, with a theoretical methane production of 348 Nm^3/tonne of COD. In general, anaerobic digestion produces 100 – 200 Nm^3 of COD per tonne of biological municipal waste processed. Biogas generation is very sensitive to the feedstock, one plant found volumes ranging from 80 to 120 Nm^3 per tonne depending on the waste input. Biogas can be used to produce electricity (for internal consumption and/or for export) it can be burned in boilers to produce hot water and steam for industrial purposes, and it can also be used as an alternative fuel in light and heavy duty vehicles. Biogas has a typical composition of 55 – 70 % methane, 30 – 45 % carbon dioxide and 200 – 4000 ppm hydrogen sulphide.

The semi-solid residue, referred to as a digestate, is further treated normally through aerobic digestion. Some countries allow direct application of the digestate onto farmlands in certain circumstances (e.g. Sweden, Denmark). The risk of digestate application onto soil, mainly due to the heavy metals is typically controlled by national legislation in the different EU countries. As well as the main product from the process, i.e. a solid digestate, small quantities of surplus liquor are also available which can be dewatered to provide liquid fertiliser or sent to a waste water treatment plant (often following some separation of the solids).

Process description

The primary process variables are the methods of contacting the waste with the biomass (microbes), the moisture content of the waste (e.g. liquid, slurry or solid), and the method and degree of aeration. Anaerobic digestion generally involves the following stages:

Mechanical pretreatment

In order to improve the digestion process, materials, such as plastics, metals and oversized components are removed from the waste to be treated. Separation can be carried out under wet or dry conditions. Following this, a further process of size reduction is used to create a more homogenous material, which aids fermentation and facilitates processing. The size reduction could be brought about by screw-cutting, milling, drumming, pulping or shredding machines.

Digestion

There are a number of different techniques used to effect digestion. They are usually distinguished on the basis of the operating temperature (thermophilic plants operate at around 55 °C (50 – 65 °C), and mesophilic ones at around 35 °C (20 – 45 °C)) and the percentage of dry matter in the feedstock (e.g. dry systems with 30 – 40 % dry matter, wet systems with 10 - 25 % dry matter). Generally speaking, the higher the temperature, the faster the process, but the thermophilic process may be harder to control and will need more biogas for heating to keep them at the required temperature. Some common technologies currently available are listed in Table 2.5.

Technique	Description	Input
Wet single-step	Solid waste is slurried with the process water to provide a diluted feedstock for feeding into a mixing tank digester	The process can be used for MSW on its own, but the wet process lends itself to co-digestion with diluted feedstocks, such as animal manure and organic industrial wastes
Wet multi-step	Solid waste is slurried and fermented by hydrolytic and fermentative bacteria to release volatile fatty acids which are then converted to biogas in a high rate industrial waste water anaerobic digester	The system lends itself to the digestion of MSW and to the wet organic waste from food processors
Dry continuous	The digestion vessel is continuously fed with a material with 20 – 40 % dry matter through batch loading. In both mixed and plug flow variants, the heat balance is favourable for thermophilic digestion	
Dry batch	A batch is inoculated with digestate from another reactor and left to digest naturally. Leachate is recirculated to maintain moisture content and to redistribute methane bacteria throughout the vessel	
Sequencing batch	Essentially a variant of the dry batch process, in which leachate is exchanged between established and new batches to facilitate start up, inoculation and removal of the volatile materials from the active reactor. After digestion becomes established, the digester is uncoupled from the established batch and coupled to a new batch in another vessel	
Heap bioreactor		

Table 2.5: Anaerobic digestion technologies
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002]

Users
Anaerobic digesters are currently used for municipal waste (specifically biowaste separated at source) but have been tested for hazardous waste disposal as well. In some anaerobic digesters at sewage treatment works, spare capacity is being used for a range of industrial non-hazardous organic wastes. The anaerobic digestion of MSW has been commercially available for approximately 10 years and is utilised in Germany, the Netherlands and Denmark. There are developments in Spain, Portugal and Belgium, and it is used to a limited extent in other countries such as Sweden, the UK and France.

2.2.2 Mechanical biological treatments

Purpose
Mechanical biological treatment (MBT) is usually designed to recover materials for one or more purposes and to stabilise the organic fraction of the residual waste. The practical advantages of MBT plants are, above all, the reduction of:

- the volumes of waste
- the organic matter content of the waste, which are sent to final disposal (landfill or incineration).

Another purpose of MBT is material splitting for further processing (e.g. preparation of solid waste fuels). Biological digestion is intended to reduce the weight, and to render inert any biologically active organic materials (typically called ‘stabilised residue’).Typical values for the combined loss of water and biodegradable materials may be in the range of between 20 and 35 %, mainly depending on time the treatment occurs. Further reductions of the waste volume going to landfill may be achieved due to mechanical separation of the output and can then be finally even higher at 60 %.

Principle of operation
MBT plants significantly reduce humidity by extracting, reducing and stabilising the organic content in the waste. These treatments involve a mechanical separation of the waste, biological treatment (anaerobic and/or aerobic digestion) of the organic fraction, and a further mechanical separation if required.

MBT has to lead to a reduction of the contents of biodegradable organic substances, volume, water content, gas formation potential and respiration activity of the waste, as well as having a significant improvement in leaching and settlement behaviour.

Feed and output streams
In principle, many types of waste materials can be accepted at a MBT plant. The materials broken down and digested in the biological stage include paper and board, green/kitchen organics, and the organic content contained within nappies, packaging, textiles, some types of sewage sludge, etc. Generally, only mixed, unsorted waste enters the plant. However, some EC legislation and alterations in the treatment processes exclude or restrict some types of waste. Some examples are hazardous waste, waste for which a special treatment is obligatory because of EC legislation (e.g. Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption), waste for which a biological treatment is not appropriate and waste causing inhibition of the biological activity.

The output from MBT plants is greatly reduced in weight and stabilised (emission releases from the product compared with the non treated material could be reduced approximately 90 – 98 % under landfill conditions). Such figures are very variable and strongly depend on how reduction of emissions are calculated (e.g. gas generation and respiration activity) and typically can have significant variations in quality. In some countries, the waste OUT may be used as landfill cover if contamination is low enough (low grade compost, grey compost or stabilised biodegradable waste), or it may be landfilled. The quality of the waste OUT produced is generally not acceptable for widespread use because of the contaminants within related to both the inert content (glass, plastic, etc.) and also to the heavy metals content arising from other wastes entering the stream (batteries, etc). Other outputs are combustable fractions and recyclable materials (e.g. metals, plastic)

Process description
MBT plants are very flexible and they can be built on a modular basis. The mechanical treatment phase involves segregating and conditioning the wastes. The processes that may be involved are:

- open waste bags (where necessary) (e.g. shredders)
- extraction of undesirable components that might obstruct the subsequent processing (e.g. metal separators)
- optimising the particle size for subsequent processing (e.g. by sieves, or shredders)
- segregation of biodegradable materials in the underflows of primary screening, so that they can be sent to the biological treatment process (e.g. by sieves)
- segregation of materials with a high calorific value, such as textiles, paper and plastics, in the overflows of primary screening, so that they can be sent for use in the production of fuel. Also, segregation of those materials suitable for further material recovery (e.g. by air separation)
- homogenise materials destined for biological treatment.

Apart from these elements, the plant may include equipment for recovery of metals and for extraction of mineral fractions. The permutations regarding the design of an MBT plant are many and varied. Some plants are designed to separate and biologically treat the residual waste from MSW prior to landfill. A scheme of a MBT process is shown in Figure 2.6.

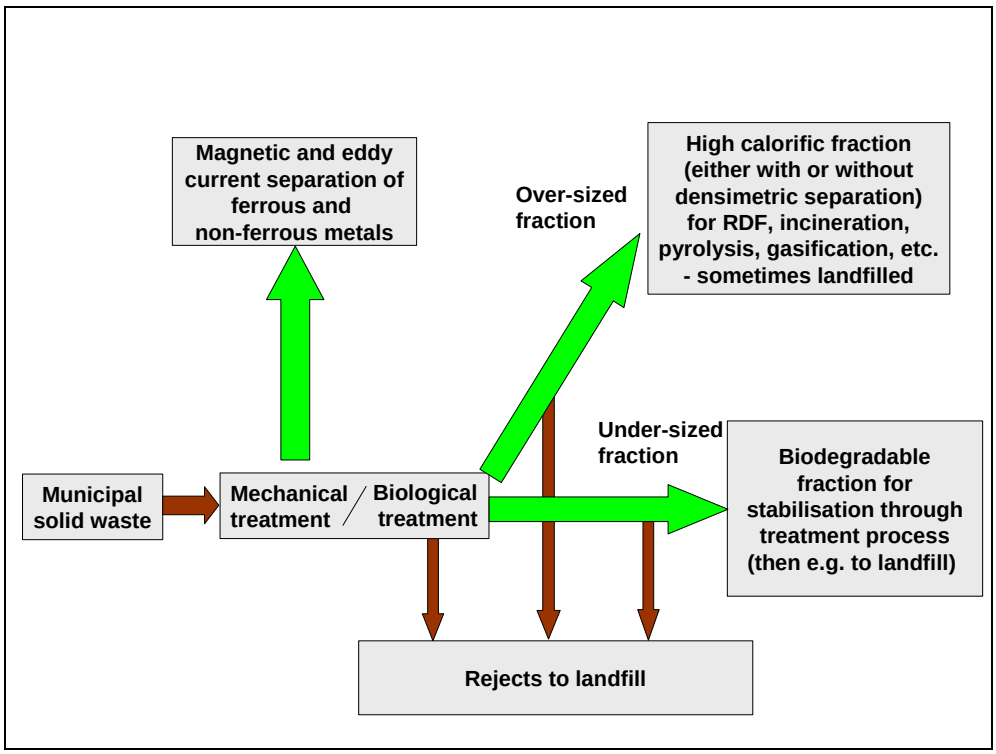


Figure 2.6: Schematic representation of mechanical/biological treatment inputs and outputs
Note: Brown arrows represent residual materials
Green arrows represent processed outputs
Mechanical treatment may be carried out before or after the biological treatment
[17, Eunomia Research & Consulting, 2002], [150, TWG, 2004]

Two types of systems exist: encapsulated and housed. *Encapsulated systems* (container, tunnel) are usually operated only under pressure with circulating air. Control is exercised through the parameters of temperature and oxygen content in the circulating air. The heat has to be led off from the system by cooling the circulating air. The condensate that is created may be used for watering the heaps or has to be disposed of as waste water.

Housed systems (wandering heap process) are operated both with pressure and with suction, in some plants both aeration methods are used alternatively. Circulating air systems are only possible to a limited extent in housed systems. In the suction operation, at least repeated re-use of the heap exhaust air is feasible. The heat generated can only be led off through water evaporation and exhaust air. In addition to specific aeration control, the periodic turnover of the biologically degraded material is of decisive importance for the progress of biological treatment. It serves the purpose of:

- mixing the material and making new surfaces accessible for the micro-organisms
- activating the biological degradation
- minimising the biological degradation times
- watering the heap evenly and compensating evaporation losses
- compensating for the volume loss of the biological degradation
- leading off heat from the heap.

So the biological process is optimised and the existing biological treatment capacities are cost-effectively utilised. In MBT plants with quasi-dynamical biological treatments according to the moving heaps process or the tunnel process, turnover usually occurs in weekly intervals. Some biological processes require two turnover cycles per week during the first three weeks. After this period, the material is turned over every five to seven days.

Users
Mechanical biological treatment is a tool for pretreating wastes prior to landfilling or for preparing solid waste (typically municipal solid waste) to be used as fuels. Although the popularity of mixed waste composting is declining, it is currently still carried out in Greece, Spain, and Portugal, whilst in Italy, Germany and Austria, it is being progressively or totally 'converted' to MBT of residual waste. These types of treatments are also emerging in the Netherlands and Belgium. There is currently a lot of interest in this technology in the UK with some plants currently being constructed and the UK Government sponsoring trials of such new technologies.

These plants tend to have large capacities because they treat large volumes of mixed waste. An average capacity of 50 – 100 kt/yr is quite normal, but they can be as large as 700 kt/yr, as is one in Milan in Italy and can be as small as 7 kt/yr. At least four examples exist in Europe with the purpose of achieving complete recovery of MSW in the form of recycling materials and energy recovery.

2.2.3 Biological treatments applied to contaminated soil

Purpose
To reduce the contamination of soil.

Principle of operation
Aerobic and anaerobic degradation of pollutants in the excavated soil.

Feed and output streams
The types of contamination to be treated are biodegradable pollutants, fuels (gasoline, kerosene, gasoil, heating oils, heavy fuels), mineral oil, waste oils and heavy organic oils. The main products of this type of treatment are decontaminated excavated soils.

Process description
The lack of oxygen is the most limiting factor of pollutant biodegradation in soil and lots of different processes have been developed to optimise soil oxygenation. The various biological treatments differ with the aeration techniques used. Two types of processes exist. *In-situ* and *ex-situ*.

In-situ biodegradation
In situ biodegradation is the term for biological treatment processes that are performed in the original place where the contaminated soil is. Such processes are not covered in this document.

Ex-situ biodegradation
Ex-situ biodegradation is the general term for treatment processes in which the contaminated soil or sludge is excavated and remediated through biological processes. Ex-situ bioremediation technology most often involves slurry-phase bioremediation where an aqueous slurry is created by combining contaminated soil or sludge with water and then the contaminants are biodegraded in a self-contained reactor or in a lined lagoon. Ex-situ biodegradation also encompasses solid-phase bioremediation, such as landfarming, composting, and biopiles. In these processes, the contaminated soil is excavated, and oxygen, nutrients, water, or micro-organisms are added to enhance the natural biodegradation of the contaminants.

Slurry-phase bioremediation
There are two main objectives behind using slurry-phase bioremediation: (1) to destroy the organic contaminants in the soil or sludge, and, equally important, (2) to reduce the volume of contaminated material. Slurry biodegradation has been shown to be effective in treating highly contaminated soils that have fuel or other organic contaminant concentrations ranging from 2500 to 250000 mg/kg. The slurry process has also shown some potential for treating a wide range of contaminants, including pesticides, creosote, pentachlorophenol, PCBs, and other halogenated organics.

Waste preparation is required before applying slurry biodegradation. The preparation may include excavation and handling of the waste material, as well as screening to remove debris and large objects. Particle size reduction, water addition, and pH and temperature adjustment may also be required to meet feed specifications.

Once biodegradation of the contaminants is completed, the treated slurry is sent to a separation/dewatering system. A clarifier for gravity separation can be used to remove the water from the soil.

Solid phase bioremediation
Solid-phase bioremediation involves the excavation and preparation of contaminated soil to enhance the bioremediation of contaminants in the soil. The techniques typically used for preparation of the soil to be bioremediated are sifting/riddling, homogeneisation, nutrient improvement and compost addition. The bioremediation is carried out in biopiles (soil turning or air injection).

Aerobic digestion involves the storage of biodegradable waste with a bulking agent to increase the porosity of the soil material. Bioremediation is similar to composting in that the contaminated soil is piled in large mounds. However, for these processes air is usually provided by pulling a vacuum through the pile.

Users
Contaminated soils.

2.3 Physico-chemical treatments of waste

[30, Eklund, et al., 1997], [51, Inertec, et al., 2002], [53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [89, Germany, 2003], [100, UNEP, 2000], [101, Greenpeace, 1998], [121, Schmidt and Institute for environmental and waste management, 2002], [123, Perseo, 2003], [124, Iswa, 2003], [136, Straetmans, 2003], [146, Galambos and McCann, 2003], [150, TWG, 2004], [152, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004].

This section details the physico-chemical (Ph-c) treatments of waste. Treatments such as precipitation, decanting and centrifuging, and thermal treatments not included in WI BREF are included here. Due to the fact that many of these treatments are common unit operations, the description of some operations will only be mentioned briefly in this section. For those techniques considered less common and that need extra explanations, an independent section within this section has been created. Techniques for the abatement of emissions are covered in Section 2.6. Common activities carried out in these plants (e.g. storage, handling) are covered in Section 2.1.

The structure of this section relates to the physical conditions of the type of waste. Treatments carried out on liquids and solids differ a lot and it has been suggested that considering these separately may give a good structure to such a long section. At the end of the section, some special physico-chemical treatments carried out on special wastes (e.g. destruction of POPs) have also been included.

Some of the techniques for the treatment of waste may make use, for example, of the acidic solution from the first scrubber in a wet air pollution control system when air pollution control waste treatment is being considered. Some techniques involve a return of the treated residues to the combustion chamber for sintering with bottom ash. These techniques are not included in this document because they are integrated measures of the combustion technologies. These issues can be found in other BREF documents.

2.3.1 Physico-chemical treatments of waste waters

Purpose
Ph-c plants are planned in such a manner that the maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials is used. The purposes of physico-chemical treatment plants are to:

- enable delivery of environmental protection goals, in particular, water quality management. In Ph-c plants, materials which may be hazardous to water are either treated, withheld and/or converted to a non-hazardous form
- enable the correct disposal of large quantities of, in general, aqueous liquid waste and waste requiring special controls
- separate the oil or the organic fraction to be used as fuel.

The procedures serve the specific application of physico-chemical reactions for material conversion (e.g. neutralisation, oxidation, reduction) and for material separation (e.g. filtration, sedimentation, distillation, ion exchange).

Principle of operation
During the physico-chemical treatment of contaminated waste water, water is separated and processed for discharge to sewerage systems or water bodies. This processed water becomes subject to various water legislation as soon as it is discharged.

Feed and output streams

The waste treated in Ph-c plants is aqueous liquid. Ph-c plants generally treat waste liquids or sludges with a relatively high water content (>80 w/w-%). Regardless of their origin and their relationship to their material characteristics, the wastes commonly treated by these plants are:

- emulsions/cooling lubricants
- acids (e.g. picking acids from surface treatments. Some information on STM BREF)
- alkaline solutions
- concentrates/saline solutions containing metals
- wash-water
- waste water containing a gasoline/oil separator
- solvent mixtures
- sludges
- aqueous liquid wastes with high concentrations of biodegradable materials
- aqueous marine waste.

An indication of the type of wastes accepted at sites in the UK is given in Table 2.6.

Waste stream	Percentage of sites accepting each type of waste (%)
Neutral aqueous inorganics	69
Acids	62
Oils	62
Alkalis	54
Neutral aqueous organics	54
Contaminated containers	23
Cyanides	23
Organic sludges	8
Water reactive chemicals	8

Table 2.6: Waste types accepted at physico-chemical treatment plants in the UK [56, Babtie Group Ltd, 2002]

Process description

Ph-c plants are configured on a case-by-case basis depending on requirements and/or application. Each Ph-c plant has a specific individual technological and operational concept; this is geared to the waste to be treated. For this reason, there is no 'standard' physico-chemical treatment plant. Although all plants have inspection and process laboratories and tend to have a neutralisation function, the range of pretreatment processes, sludge handling methods and the combination of input waste streams makes each a unique operation. The modes of operation of Ph-c plants are:

- continuous operation: particularly suitable for large throughputs, waste of relatively constant composition and for automated operation
- batch operation: particularly well suited to the very variable characteristics/reaction of the waste to be treated.

Table 2.7 shows some differences between different Ph-c plants.

	Treatment of				
	emulsions	**emulsions and oil/water mixtures**	**emulsions and waste with contents to be detoxi-cated**	**liquid and aqueous waste with some or-ganic solvents**	**liquid and aqueous waste containing or-ganic solvents and tensides**
Sieving	■	■	■	■	■
Sedimentation					■
Ultrafiltration					▒
Evaporation					▒
Heating up				■	▒
Stripping				■	
Acid splitting	■	■	■		
Organic splitting			▒		▒
Oxidation/reduction			▒		
Membrane filtration				▒	
Flocculation/precipitation	■	▒	▒	▒	▒
Sedimentation	■	▒	▒	▒	▒
Draining	■	▒	▒	▒	▒
Sulphuric precipitation	■				
Filtration	■	▒	▒		
Ion exchanger	■				
Neutralisation				▒	▒
Note: Dark grey: required process, light grey: Optional process					

Table 2.7: Analysis of some representative types of physico-chemical treatment plants
Based on [121, Schmidt and Institute for environmental and waste management, 2002]

The unit operations typically used are sieving, storage/accumulation, neutralisation, sedimentation, precipitation/flocculation, ion exchange, oxidation/reduction, sorption (adsorption/absorption), evaporation/distillation, membrane filtration, stripping, extraction, filtration/draining, acid splitting of emulsions and the organic splitting of emulsions.

Frequently several unit operations will have to be used to correctly treat a specific waste. The unit operations procedure combination (type of procedure, sequence of their application, controls) is specified by the Ph-c plant laboratory, on the basis of the composition of the waste and its reaction behaviour.

The following equipment is typically available for reactors in order to control reactions:

- storage vessels for separate storage, depending on the type of treatment
- reaction containers with adjustable agitators and temperature indicators
- sedimentation containers
- metering equipment
- receiver and storage tanks for chemicals
- storage tanks and reservoirs for the waste to be treated
- dosing equipment
- material resistant to acids and alkalis
- control of pH value for the chemicals
- containers for settling and mixing ancillary agents
- measurement and automatic controls
- ventilation and filtering of the reaction tanks with facilities for cleaning the exhaust air.

Users
From 25 to 30 % of all hazardous waste in Germany is disposed of by Ph-c plants. Some examples of the operations carried out via a Ph-c plant are:

- treatment of emulsions
- treatment of emulsions and waste with contents to be detoxified
- treatment of liquids, aqueous wastes with some organic solvents
- treatment of emulsions and oil/water mixtures
- treatment of liquids, aqueous wastes containing organic solvents and tensides
- detoxification (oxidation/reduction) of waste containing nitrites, Cr(VI), cyanide (as pre-treatment).

The wastes processed are usually from various industrial and commercial production processes, and from maintenance, repair and cleaning activities. Some specific industrial sectors served are the printing and photographic industries. These are an example of those sites, which provide a service to a particular industrial sector, taking away a wide range of wastes and transferring those that cannot be treated or recycled in-house.

Figure 2.7 shows the treatment of aqueous marine waste.

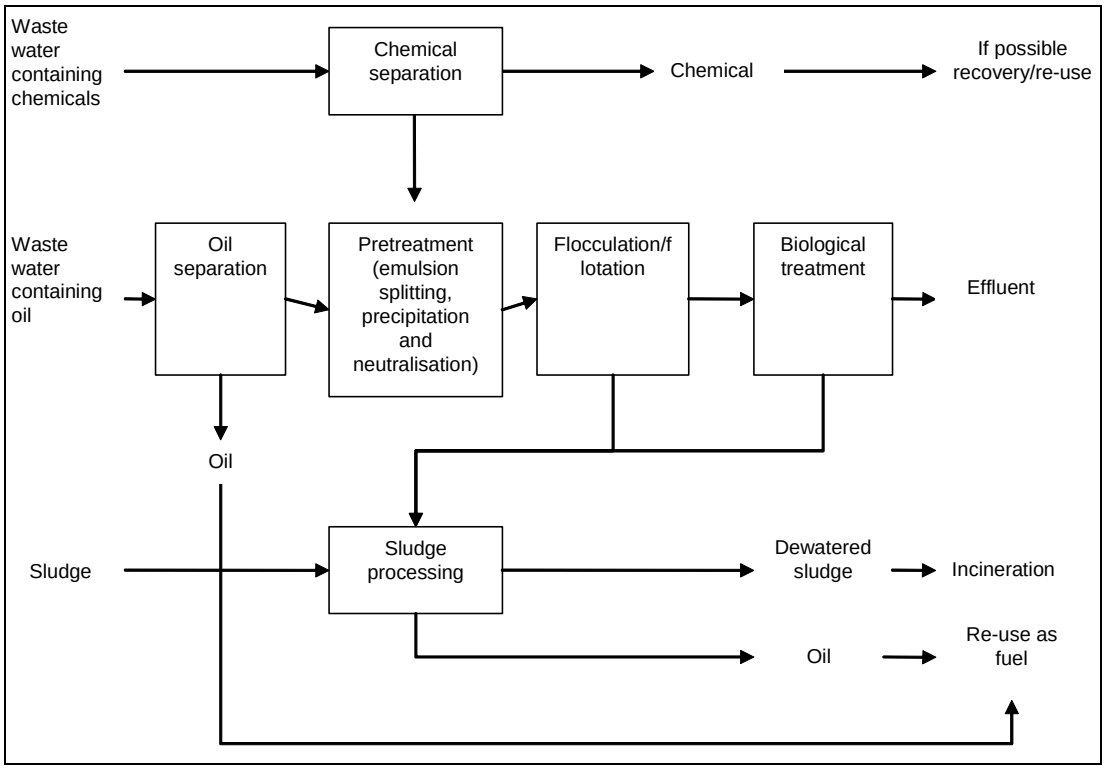


Figure 2.7: Treatment of aqueous marine waste
[156, VROM, 2004]

2.3.2 Unit operations used in Ph-c treatments of waste waters

Waste can be treated using any of a large number of commercially proven unit operations. The treatment methods fall into four categories:

- phase separation (e.g. sedimentation, steam stripping)
- component separation (e.g. ion exchange, electrodialysis)
- chemical transformation (e.g. chemical oxidation, incineration)
- biological transformation (e.g. fixed film aerobic treatment).

Table 2.8 summarises units operations used in physico-chemical treatments. Some more information on this issue can be found in the Common waste water and waste gas treatment BREF (CWW).

Unit operation	Purpose	Principle of operation
Separation operations		
Acid break-up of emulsions	The term 'acid break-up' is understood to be the treatment of emulsions. The aim of the treatment is the separation of the emulsion into waste water, oil/grease and undissolved metals as hydroxide sludge	
Centrifugation	Dewatering metal salt sludges from precipitation techniques	Separates solids and liquids by rapidly rotating the mixture in a vessel. Solids either settle at the bottom (sedimentation - type) or adhere to the inside wall of the vessel (filtration - type) through which the liquid passes
Evaporation and distillation	Evaporation and distillation are similar processes with different objectives. During evaporation the useful material in a mixture is evaporated through thermal effects and captured as vapour and generally condensed. Distillation is a separation process, which is used for the separation of mixtures, which obtains better separation ratios than evaporation	The aim of evaporation/distillation is to separate the oil into a good usable form. In the Ph-c plants, evaporation is used as a partition stage in order to separate vaporisable materials from the waste water. Depending on the ingredients of the waste water, evaporation can also be used as conditioning for a further preparation stage, such as membrane filtration. Evaporator technology is of great importance whenever organic solvents are to be separated from the waste to be treated
Extraction		Extraction is used for the specific separation of components from a mixture of substances. The mixture of substances is thoroughly mixed with a selective solvent. During mixing, the component from the mixture of substances migrate into the extracting agent. With the subsequent separation of the extracting agent from the substance mixture, finally the components of the mixture are also separated
Filtration/ dewatering	This is the most common operation applied, e.g. in drinking water treatment, industrial waste water treatment	Involves passing a mixture of liquid and solids (or gas and solids) through a filter medium to trap the solids. Different kinds of filters exist, such as gravel filters, sand filters and mechanical filters (e.g. waste water screen presses, chamber filter presses, membrane filter presses)
Filtration/ sieving	The sieving of the waste to be treated is essential for the protection and safety of functional units, such as pumps, sluice gates, valves	Sieving is a classifying/separating procedure with which the filtered material – liquid/solid mixture (slurry) – is separated into two mixtures, one with an average particle size smaller than the input, and another larger than the input

Unit operation	Purpose	Principle of operation
Filtration (by membranes)	Separation of substances/solids from liquid mixtures. Ultrafiltration can be used for break-up of emulsions	In membrane procedures the liquids to be treated are fed under controlled pressure and current conditions past a semi-permeable membrane. The separative power of the membrane is essentially based on the filtering effect and thus outputs are neither altered biologically nor chemically.
Flotation	Used by refining, meat packing, paint, paper milling and baking industries	Introduction of tiny air bubbles into a solution containing suspended particles. Particles attach to air bubbles and float
Ion exchange processes	Ion exchange is a process for the cleaning of liquid waste of dissolved electrically charged particles (ions) by means of ion exchanger materials. Can also be used in water-softening, as Ca and Mg ions are removed from the liquid stream. Some of substances suitable for ion exchangers are liquid waste from the electroplating industry, chromium electrolytes/chromating baths, phosphoric acid pickling, hydrochloric acid pickling and sulphuric acid anodising baths. Groups of material unsuitable for ion exchangers are: organic compounds as these can irreversibly block the resins in the exchanger or whose removal may be incomplete; strong oxidising agents, as these may damage the anion exchanger resins; metal cyanide complexes, as strong base anion exchangers damage the resins; aromatic and halogenised hydrocarbons, as they cause the exchanger resins to swell at times and thus can lead to interruptions in the exchanger availability.	Ion exchange resins have the ability to exchange their settled groups of ions (cations or anion) with ions contained in the water
Oil separation processes	Gravity settlement without heat to produce an oil rich layer, that is skimmed off and sent to oil recyclers for further processing, and an aqueous phase plus sludge that is processed through the main plant. At some plants, this is a major part of the day-to-day activities. At others it is an occasional batch process and only operated when needed to provide a full service to major customers but where the company does not actively seek oil/water streams for treatment. Some sites add acid to the oil to assist in the separation process (emulsion breaking)	Gravity separation of soluble oils and oil/water mixtures
Organic splitting of emulsions		For the destabilisation of the emulsifying agent, polyelectrolytes and/or similar products are used. These allow good splitting of the emulsion comparable to acid splitting

Unit operation	Purpose	Principle of operation
Reverse osmosis	Used to produce drinking water from brackish groundwater and seawater. Also for recovery of electroplating chemicals from plating rinse-water and sulphate from paper industry waste water. Used in leachate treatment	Uses a mechanical force, e.g. high pressure (17 – 100 atm) to drive solvent (usually water) through a membrane. This generate two fractions one that concentrate the dissolved components and another where the solvent is purified
Screening	Waste water containing solids, etc.	Removes large particles from waste water. There are three types of screens, rotating drums, vibrating and stationary
Sedimentation	Sedimentation is used in Ph-c plants specifically for the thickening of sludges, and the separation of heavy particles and suspended matter from the waste water and concentrate sludge	The forces of gravity cause the thicker phase of a suspension to separate. To this extent, the nature of the force determines the type of sedimentation: gravity sedimentation or centrifugal sedimentation
Sorption (absorption and adsorption)	If the waste water shows increased and/or inadmissibly high values of TOC, AOX or PCB, the organic materials generally separated using adsorption	Sorption is the uptake of a substance (gas, vapour, liquid) by another material, as a result of the contact of both materials. Absorption is designated as the penetration of a gas into a solid or liquid phase (absorbents) by diffusion. Adsorption is described as the accumulation of gases or solute materials at the surface of a solid or liquid material (adsorbents) by molecular forces. Adsorption is a physical process, and to this extent the chemical characteristics of the adsorbed material are unaltered
Stripping (by air or steam)	Stripping is used in order to be able to use the following procedures better and more effectively; or as a final stage to reduce the concentration of certain hydrocarbons (AOX). By stripping, volatile materials, for example hydrogen sulphide (H_2S), ammonia (NH_3), low boiling hydrocarbons and chlorine hydrocarbons (AOX) can be separated from aqueous solutions	Stripping is the driving out of easily vaporisable materials from liquid mixtures. Air or water vapour is used for stripping, with a simultaneous increase of the phase-boundary surfaces. Stripping is thus a separation process in which the separated material is in the exhaust air (stripping with air) or in the distillate (stripping with water vapour)
Chemical processes *		
Electrolysis	The recovery of metals from solutions (e.g. silver from photographic waste)	Use of electrical power to reduce metals from solution
Neutralisation	To neutralise the waste water or to recuperate some components from it by precipitation at a specific pH(s). Depending on equipment configuration, neutralisation and sedimentation can be carried out in the same container	Neutralisation is the adjustment of the pH values to a neutral level, for instance, pH ~ 7. Neutralisation is achieved by adding acids or alkalis to the material to be neutralised and/or by the mixing of acids and alkalis
Oxidation/ reduction	Redox reactions in connection with the Ph-c treatment of waste activity involve the detoxicating of nitrite and cyanide (oxidation) and chromium (VI) compounds (reduction). Other possible treatments are the destruction of sulphides or peroxides. Wastes are made less toxic, simpler and less volatile by subtracting or adding electrons between reactants	Oxidation and reduction are processes which are generally coupled. Oxidation is the release of electrons, and reduction is the uptake of electrons.

Unit operation	Purpose	Principle of operation
Precipitation/ flocculation	The separation of dissolved or suspended materials (e.g. metals) by the addition of chemicals	Precipitation is the conversion of a solute substance to an undissolved substance, in general by the addition of chemicals. Flocculation is the agglomeration of more or less fine particles (as well as solute substances) into larger flocs; these are separated by sedimentation or filtration
Wet air oxidation	Sewage sludge	Solids solubilised and oxidised under high pressure
* Some of these treatments induce separations (e.g precipitation)		

Table 2.8: Unit operations used in physico-chemical treatments
[80, Petts and Eduljee, 1994], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

2.3.3 Physico-chemical treatments of waste solids and waste sludges

The main goal in the physico-chemical treatments of waste solids and waste sludges is to minimise the long-term release by leaching out the primarily heavy metals and low biodegradable compounds. The available treatment options act to prolong the leaching time period by releasing, for example, heavy metals at lower and more environmentally acceptable concentrations for an extended period of time.

In principle, all treatment options can be applied to waste solids and waste sludges. However, the characteristics of the treated material and the effectiveness of a treatment technology can vary greatly depending on the specific properties of the original waste IN and on the type of cleaning system applied. The treatment options has been sub-grouped according to the following types:

- extraction and separation
- thermal treatment
- mechanical separation
- conditioning
- immobilisation (this treatment covers solidification and stabilisation)
- dewatering
- drying
- thermal desorption
- vapour extraction from excavated soil
- solvent extraction from solid waste (e.g. excavated soil)
- excavation and removal of excavated soil
- soil washing.

2.3.3.1 Extraction and separation

Purpose
To extract heavy metals and salts from solid wastes, using acid.

Principle of operation
Solubilises compounds and removes them with water.

Feed and output streams
Treatment options using extraction and separation processes can, in principle, cover all types of processes extracting specific components from the wastes.

Users
Several techniques have been proposed both in Europe and in Japan for air pollution control residues.

2.3.3.2 Thermal treatments

Purpose
Thermal treatment of FGT waste from combustion processes is used extensively in a few countries, mainly to reduce the volume and to improve their leaching properties.

Principle of operation
High temperature treatments use heat in order to melt waste and initiate vitrification and ceramisation processes. Thermal treatments can be grouped into three categories: vitrification, smelting and sintering. The differences between these processes chiefly relate to the characteristics and properties of the final material:

- vitrification is a process where wastes are mixed with glass precursor materials and then combined at high temperatures into a single-phase amorphous, glassy output. Typical vitrification temperatures are 1300 to 1500 °C. The retention mechanisms are chemical bonding of inorganic species in the waste with glass-forming materials, such as silica, and encapsulation of the constituents by a layer of glassy material
- melting is similar to vitrifying, but this process does not include the addition of glass materials and results in a multiple-phased product. Often several molten metal phases are generated. It is possible to separate specific metal phases from the melted output and recycle these metals, possibly after refinement. Temperatures are similar to those used in vitrifying
- sintering involves heating the waste to a level where a bonding of the particles occurs and chemical phases in the wastes reconfigure. This leads to a denser output with less porosity and a higher strength than the original waste. Typical temperatures are around 900 °C. Temperatures for sintering bottom ash from MSW incinerators can be up to 1200 °C.

Feed and output streams
Most commonly, FGT wastes are treated thermally in combination with bottom ashes.

Process description
Regardless of the process, the thermal treatment of FGT waste in most cases results in a more homogeneous, denser product with improved leaching properties. Vitrifying also adds the benefits of the physical encapsulation of contaminants in the glass matrix.

The thermal treatment of FGT waste requires substantial off gas treatment, thus creating a new solid residue to be treated. Also the high salts concentrations in FGT waste can cause corrosion problems in off-gas treatment systems.

Users
Sintering is not used as a dedicated treatment option for FGT waste, however some combined treatment methods may involve sintering.

2.3.3.3 Mechanical separation

Purpose
The aim of the treatment is to generate a material which is inert, does not negatively affect water bodies, and has the potential for safe recovery, e.g. as a soil substitute or in road construction. Such treatment reduces the mass of waste for disposal. Furthermore, the clean separated and collected ferrous and non-ferrous metal fractions can be re-used. In addition, the reduction in the amount of heavy metals, e.g. arsenic (salt) being emitted in the environment, is also a major benefit.

Principle of operation
In the case of bottom ash treatment, the bottom ash is separated into at least three fractions: mineral compounds, unburned material and scrap metal. A reduction of heavy metals and soluble compounds is required and is important for re-use of the material after treatment. The water soluble components are the most water-relevant ingredients of bottom ash.

Feed and output streams
One of the main products of waste incineration is the bottom ash generated through the burning process. An input of one tonne of household waste generates approximately 250 - 350 kg of bottom ash. The bottom ash is generally composed of components such as chloride, arsenic, lead, cadmium, copper, mineral materials and scrap metals.

Process description

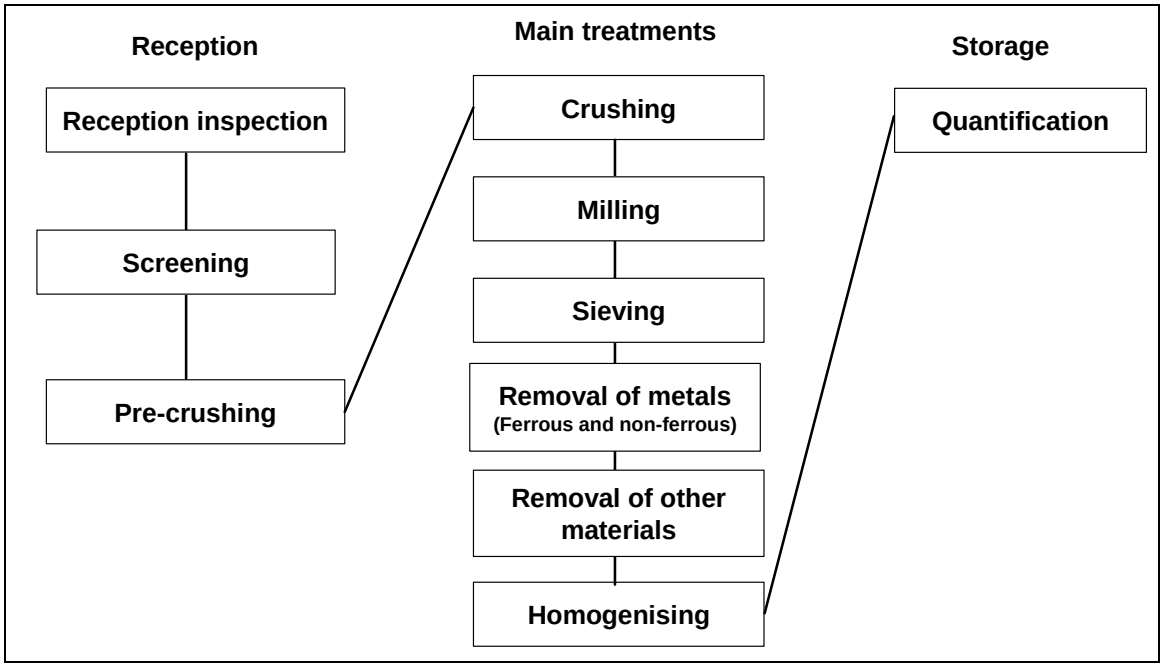


Figure 2.8: Example of some mechanical separations used for the treatment of bottom ashes [89, Germany, 2003], [150, TWG, 2004]

Users
Bottom ash and FGT waste.

2.3.3.4 Conditioning

Purpose
The aim is the treatment of the solid and paste like wastes for recovery/disposal in incineration plants or for landfilling.

Principle of operation
The substances that can only be incinerated or landfilled are conditioned by means of aggregates. Depending on the final disposal plant (e.g. incineration or landfill); diatomite, sawdust or other appropriate aggregates are added to the waste.

Process description
Wastes with certain resource contents may be passed on to the downstream plant for the recovery of recyclable substances. If necessary, the wastes may be run over a one step crushing, e.g. in order to crush the metal packaging such as paint cans, and transfer them via a conveyor system to the facility for recovery of recyclable material.

Wastes that are delivered in large capacity containers are pretreated in a second crushing facility. For dusty wastes, a third fully encapsulated two-shaft shredder is available. In the free-falling mixer, the pretreated wastes may be mixed with aggregates to produce a batch of maximum 10 m^3. The free-falling mixer consists mainly of an open cylindrical-conical container with a volume of 20 m^3. This container is filled via the last conveyor of the charging system. Rotation of the container produces a homogeneous mixture and the abrasive forces in the mixing drum cause a quasi-dry cleaning of metal and plastic components in the waste. The free-falling mixer is emptied into the loading facility which conveys the conditioned waste either to truck loading or to further treatment towards the facility for the recovery of recyclable substances.

Users
Preparation of waste to be used as fuel.

2.3.3.5 Immobilisation

Purpose
The aim of immobilisation is to minimise the rate of contaminant migration to the environment and/or to reduce the level of toxicity of contaminants, in order to alter or improve the characteristics of the waste so that it can be disposed of. The objective encompasses both a reduction in the waste toxicity and mobility as well as an improvement in the engineering properties of the stabilised material.

Principle of operation
Immobilisation relies on the properties of the reagent to produce an immobilised waste product, even where the waste product does not have a solid form. These processes retain substance(s) adsorbed to, or trapped within, a solid matrix. Some of these processes are reversible (i.e. the immobilised substances can be released), due to both poor process control and to subsequent mixing with other waste types. Two types of processes have been developed. These are commonly referred to as: stabilisation and solidification.

Stabilisation

This is a process by which contaminants (e.g. heavy metals) are fully or partially bound by the addition of supporting media, binders, or other modifiers. Stabilisation is accomplished by mixing the waste with a reagent (depending on the type of waste and reaction planned, this can be, for example, clay particles; humic organic substances, such as peat; activated carbon; oxidisers; reductors; precipitating reagents) to minimise the rate of contamination migration from the waste, thereby reducing the toxicity of the waste and improving the handling properties of the waste at the landfill. To achieve this, a process should include a physico-chemical interaction between the reagent and waste, rather than just a dilution.

These stabilisation methods make use of both the precipitation of metals in new minerals as well as the binding of metals to minerals by sorption. The process includes some sort of solubilisation of the heavy metals in the material and a subsequent precipitation in or sorption to new minerals.

The physical mechanisms used in stabilisation are: macro-encapsulation, micro-encapsulation, absorption, adsorption, precipitation and detoxification. There is an extensive range of sorbents and binders available for such purposes. Some of the most commonly used are: cement, pozzolans (alumino-silicious material that reacts with lime and water), lime, soluble silicates, organically modified clays or lime, thermosetting organic polymers, thermoplastic materials and vitrification (in-situ or in-plant).

In many cases, both types of reagents (chemical reagents as mentioned three paragraphs above) and sorbents and binders (as mentioned in the above paragraph) are used simultaneously.

Solidification

Uses additives to change the physical properties of the waste (as measured by its engineering properties such as strength, compressibility, and/or permeability). The term ‘solidification’ (and encapsulation or fixation) relate to the mixing of wastes with a reagent (pulverised fuel ash; cement, lime; blast furnace slag; cement kiln dust; organic binders such as bitumen/asphalt or paraffin; and polyethylene) to produce a solid waste form (with low porosity and low permeability matrix) for landfill disposal. Substances are either adsorbed to the reagent or trapped within the waste form. The output should possess a high resistance to chemical and biological degradation processes that could lead to the release of contaminants.

The addition of cement, for example, generally decreases the hydraulic conductivity and porosity of the material, and in addition increases tortuosity, durability, strength and volume. However, it usually increases the pH and alkaline capacity of the mixture, therefore improving the leaching behaviour of the product (e.g amphotheric metals, some organic compounds). In some cases, depending on the binder, solidification may result in chemical changes of the material matrix.

In summary, the fixation and insolubilisation of the pollutants is realised by means of four mechanisms: precipitation, complexation, encapsulation and adsorption.

Feed and output streams

This technology is applied for many inorganic wastes (typically hazardous waste) present in industry such as:

- pasty waste and slurries containing inorganic components (heavy metals, etc.) and small amounts of non-soluble organics (policyclic aromatics, fuel waste, etc.) For example, complex liquid and solid waste contaminated with heavy metals (Cu, Pb, Cd, Hg, Cr, etc.)
- solid and dry waste with inorganic components (in this case hydration water must be added). For example, contaminated soil and filter cakes; refuse with very few non-soluble hydrocarbons; bottom ashes and slag; FGT waste
- solidification is sometimes used for mixing various viscous liquids, such as glues and pastes, with sawdust to produce a solid crumb suitable for landfill. Such practice is not allowed, on landfill sites, in some countries, such as France, Germany and the Benelux Union. In some cases, such components are mixed with cement and lime or other suitable binder material.

Wastes that are legally not accepted by the Landfill Directive to be treated by immobilisation on installations located on landfill sites, are liquid wastes, waste containing toxic components, volatile compounds, foul smelling components or explosives. Key issues for immobilisation include: the suitability of the waste, the process control, the emissions generated and the output specification. Under the Landfill Directive (EC/33/2003) and its annexes, the output specification needs to be aligned with the acceptance criteria for the receiving landfill, which are developed by the European Technical Adaptation Committee and which will cover leachability, physical stability and reaction with other wastes. Their transcription into national legislation is due by the end of 2005.

The resulting output of solidification can either be landfilled or allowed to solidify in a holding area prior to landfill. The final stabilised/solidified waste is usually landfilled directly or sometimes cast into blocks (e.g. at a size of 1 m^3) before landfilling.

Process description

The process typically comprises storage of the reagents, a reaction vessel and in some cases the addition of water. Figure 2.9 shows a representation of a typical immobilisation process.

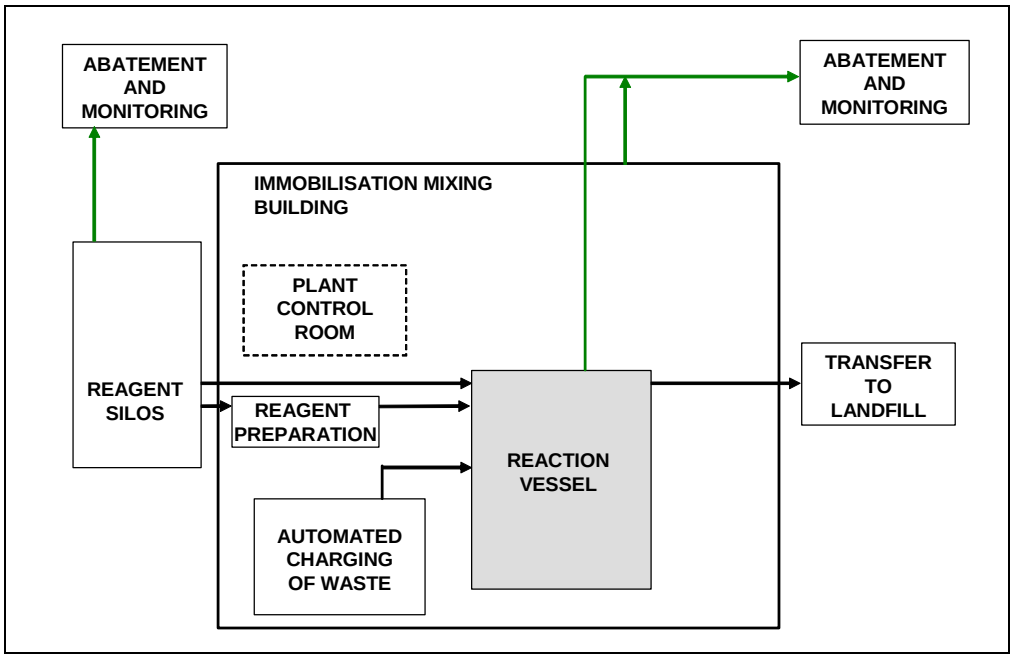


Figure 2.9: Representation of an immobilisation process [55, UK EA, 2001]

Several of the stabilisation methods have an initial washing step, where a major part of soluble salts and to some extent metals are extracted before chemical binding of the remaining metals. These methods are finalised by dewatering the stabilised product, which will then be ready for landfilling.

Two solidification processes are widely used: a) cement solidification (the most prevalent solidification technique), based on mixing waste with cement, and b) special hydraulic binder processes, which are chemical processes, aimed at developing bonds between the binder and the waste. Another technique, also in large-scale use, includes, e.g. the curing of fly ash waste with aqueous neutral or acidic liquors to give a granular output prior to landfill.

Users
Immobilisation treatments (both stabilisation and solidification) are applied to:

- remediation of hazardous waste sites
- treatments of waste from other treatment processes (e.g. ash from thermal treatments, residues from end-of-pipe techniques)
- treatment of contaminated land where large quantities of soil containing contaminants are encountered.

In several EU countries stabilisation/solidification is not an issue at all due to their national legislation. In these cases, a lot of wastes do not need any such treatments to respect the parameters of the annexes of the EU Landfill Directive or national legislation.

Radioactive wastes have been encapsulated using cement/pulverised fuel ash and bottom ash (slag) for more than 30 years. However, radioactive materials are explicitely excluded from the IPPC Directive.

2.3.3.6 Dewatering

Purpose
Sludge dewatering increases the dry solids content of sludge producing a ‘solid’ waste. It is a grey area as to when a liquid sludge becomes a solid waste; however, any sludge typically over 10 % dry solids becomes difficult and expensive to pump.

Principle of operation
Dewatering at ratios typically higher than 10 % will first require some form of chemical conditioning to assist in the separation of the bound and entrained water from within the sludge. There is a wide range of high molecular weight polymeric flocculants that are particularly effective at improving dewatering performance.

Feed and output streams
Dewatering produces a sludge ‘cake’, which may be between 20 – 50 % dry solids, and an aqueous waste stream. Overall disposal costs would be expected to be reduced in cases where the aqueous waste stream requires no, or minimal, additional processing to remove contaminants.

Process description
A number of sludge dewatering processes exist and selection depends upon the nature and frequency of the solids produced, and the sludge cake required, e.g.

- filter (or plate) presses, which are batch processes and can be manually intensive. A filter press can produce up to 40 % dry solids cake
- the belt press, which is a continuous process with the filter cloth continually running through rollers that forcefully dewater the sludge. A belt press can produce up to 35 % dry solids cake
- centrifuges, also continuous processes that can produce a cake of up to 40 % dry solids for certain sludges. Because of the shear forces, it can break up the solid particulates
- filter drums.

Users
The majority of sites use filter presses on the sludge from the treatment plant and then send the aqueous fraction through clarification or DAF units prior to sewer discharge. Excess solids are returned to the treatment tanks.

2.3.3.7 High temperature drying

Purpose
The aims of the process are the following:

- removal of the water content from the wastes; making recycling economically viable
- concentration of the waste components (e.g. metal compounds); the heating value is considerably raised
- elimination of the problems with handling paste-like substances, as drying the waste transforms it into granulate material
- use of the waste heat in other processes, e.g. distillation
- the dissipated plume gives the necessary moisture to the biofilter.

Principle of operation
The input substances that are to be dried are provided by the gathering chain conveyor and put into the revolving tube drum in single portions. The residence time of the input substances in the drier and thus the dryness of the granulated product can be regulated by hydraulic adjustment of the tube angle. The energy required for the drying process is drawn from the waste heat of the incinerator. The air needed for cooling the flue-gases is cooled down to 150 ºC in air-air heat exchangers.

Up to 30000 m^3/h drying air (maximum 100 ºC) flow through the revolving tube countercurrently to the moist input. The heat is used for the evaporation of the water. The plume is extracted by suction via a dust filter and directly transferred to the biofilter. Hereby, a slight negative pressure is created in the dryer who prevents effectively the leakage of dust into the environment. The granulated dry product is discharged automatically by the rotation of the drum and filled into big bags or other containers.

Feed and output streams
Sludges are dried and transformed into granulated material.

Process description
Drying consists of the following processes:

- warm air supply controlled by temperature and differential pressure
- hydraulically adjustable revolving tube drum
- gathering chain conveyor for charging
- dust filter with 300 m^2 filter area
- plume dissipation towards biofilter by means of induced draft fan
- measurement technique (e.g. dust, temperature, pressure, volume flow and moisture)
- process control system.

2.3.3.8 Thermal distillative drying plants

Purpose
To process materials which cannot be accepted by hazardous waste incineration plants or hazardous waste landfill sites without complex prior conditioning.

Principle of operation
The input material is first crushed in the plant under inert conditions and bunkered. The released propellants are transferred to the high temperature incineration plant or to the biofilter. Afterwards, treatment is carried out in order to distillate the fluids from the input material.

Feed and output streams
Solid/paste like hazardous wastes which contain considerable amounts of free or bound fluids are treated. Both the solid and the fluid products that leave this facility may be recycled, thermally used, incinerated or landfilled.

Process description
The process consists of two parts: materials handling and crushing; and thermal distillation.

- Material handling and crushing:
  - lift-tilt installation for containers
  - inertable crusher
  - gathering conveyor
  - CO_2 fire extinguisher and inerting facility
  - discharge of solids with load container and carrying chain conveyor.

- Thermal distillation:
  - reactor and vacuum slider
  - plume filter and circulation fan
  - plume superheater
  - condensers, product coolers, product containers and phase separation
  - vacuum pump station
  - vapour, inert gas and cooling water distribution
  - exhaustive security measures
  - control system with two work places and one computer for data collection.

The containers are transported from the high rack storage area to the facility and individually emptied into the feeding hopper of the crusher. After crushing, the input material is stored under a CO_2 atmosphere on an inerted gathering conveyor. This is carried out until the quantity necessary for processing is reached in the mixing reactor (maximum 3 m^3) and the reactor is prepared for take-up of the next load. The waste solvent vapours released at the crusher are specifically drawn off in order to prevent the production of explosive mixtures in the hall. The drawn off air is fed to the biofilter as well as the exhaust air from the vacuum pumps.

If the mixing reactor has been re-inerted after emptying of the previous load, it can be charged by the gathering conveyor. After charging, the mixing reactor and the pipe system are pressurised by the vacuum pumps to 400 mbar. Then, the circulation fan is powered up. The nitrogen from inerting and the created plumes can then be run over the superheater where they are heated up to 450 ºC. Afterwards, they flow into the reactor where they heat up and dry the input material. The heating period may, if necessary, be supported by fresh vapour from a boiler. Vacuum control keeps the maximum pressure in the facility approximately at 100 mbar, below that of the ambient air.

At the end of the drying process; i.e. when the maximum temperature of 180 to 200 ºC is reached in the reactor, in the plume filter or in the circulation fan; the facility is evacuated to a pressure of <100 mbar. This is carried out in order to evaporate the remaining solvent residues and to cool the dried material. To keep the emissions of the dried material low at discharge, cooling water is added directly to the dried material. Here, it immediately evaporates under vacuum and thus cools the dry product down to the discharge temperature of 50 to 60 ºC. The condensate is recovered by the in-house distillation facility directly after phase separation or after treatment. Solvent fractions that cannot be recycled may be thermally utilised or incinerated in the in-house high temperature incineration facility.

2.3.3.9 Thermal desorption

Purpose
To separate relatively volatile compounds from solid waste.

Principle of operation
In the thermal desorption process, volatile and semi-volatile contaminants are removed from soils, sediments, slurries, and filter cakes. Typical operating temperatures are between 175 - 370 °C, but temperatures from 90 to 650 °C may be employed. Thermal desorption promotes physical separation of the components rather than combustion.

Feed and output streams
Soils contaminated with non-biodegradable organic compounds, soil contaminated with petroleum fuels, soil contaminated with hazardous wastes and tar containing asphalt or similar waste are the types of waste processed by this treatment. The contamination is transferred to a further treatment.

Thermal desorbers effectively treat soils, sludges, and filter cakes and remove volatile and semi-volatile organic compounds. Some higher boiling point substances such as PCBs and dioxins may also be removed (if present). Inorganic compounds are not easily removed with this type of process, although some relatively volatile metals such as mercury may be volatilised. The temperatures reached in thermal desorbers generally do not oxidise metals.

Process description
After contaminated soil is excavated, the waste material is screened to remove objects greater than 4 to 8 cm in diameter. Direct or indirect heat exchange vaporises the organic compounds, producing an off-gas that is typically treated before being vented to the air. In general, any one of four desorber designs are used: rotary dryer, asphalt plant aggregate dryer, thermal screw, and the conveyor furnace. The treatment systems include both mobile and stationary process units designed specifically for treating soil, and asphalt aggregate dryers that can be adapted to treat soils. Mobile systems are most often used, due to reduced soil transportation costs and to allow for backfilling of the treated soil. However, stationary systems are also available and it may be feasible to provide regional services. The desorbed gases may be incinerated.

Users
Treatment of contaminated soils and tar containing asphalt and similar waste.

2.3.3.10 Vapour extraction

Purpose
Vapour extraction can be used as a method for treating solid waste, e.g. excavated contaminated soil, with volatile hydrocarbons.

Principle of operation
In general terms, vapour extraction removes volatile organic constituents from contaminated waste by creating a sufficient subsurface airflow to strip contaminants from the vadose (unsaturated) zone by volatilisation. As the contaminant vapours are removed, they may be vented directly to the air or controlled in a number of ways.

Feed and output streams
Vapour extraction has been widely used to treat excavated soil contaminated with gasoline or chlorinated solvents (e.g. TCE). It is also sometimes used to minimise the migration of vapours into structures or residential areas during some other in-situ remediation not covered in this document.

Spills or leaks of fuels typically involve liquids containing dozens of different constituents. For removal by this treatment to be effective, the contaminants must generally have vapour pressures greater than 1.0 mm Hg at - 7 °C. Complete removal of contaminants may not be possible with this technique alone.

Process description
The success of the treatment for a given application depends on numerous factors with the twoe key criteria being: the nature of the contamination and the nature of the waste (e.g. soil). The tendency of the organic contaminants to partition into water or to be adsorbed onto soil particles also affects its effectiveness, and hence the compound's water solubility, Henry’s Law constant, and the sorption coefficient to the solid waste are of interest. The temperature affects each of these variables and hence, the rate of vapour diffusion and transport. Increasing the temperature is one option commonly considered for enhancing the treatment performance. Solid waste can be heated in one of three ways: 1) introduction of heated air or steam, 2) input of electromagnetic energy through the waste, or 3) heat release through a chemical reaction. The use of heated air or steam appears to be the most widely used approach.

Typical systems include extraction, monitoring, air inlet, vacuum pumps, vapour treatment devices, vapour/liquid separators, and liquid-phase treatment devices.

Users
Vapour extraction has been used successfully for several years as a combined two-phase treatment of both groundwater and contaminated soil, and is increasingly being employed. Although this treatment may be used for a variety of soil types, its effectiveness depends on the ability of air to flow through the soil.

2.3.3.11 Solvent extraction

Purpose
‘Solvent extraction’ is much more effective for treating organic compounds than inorganic compounds and metals. It can be used in conjunction with other processes to reduce remediation costs.

Principle of operation
Solvent extraction differs from soil washing in that it employs organic solvents (e.g. propane, butane, carbon dioxide, aliphatic amines (e.g. triethylamine)) rather than aqueous solutions to extract contaminants from the soil. Like soil washing, it is a separation process that does not destroy the contaminants. It works as the contaminants will have a greater solubility in the solvent than in the soil.

Feed and output streams
Sediments, sludge, and soils contaminated with volatile organic compounds (VOCs), petroleum wastes, PCBs, and halogenated solvents can be effectively treated with solvent extraction. The removal of inorganic compounds such as acids, bases, salts, and heavy metals is limited, but these types of compounds usually do not hinder the remediation process. Metals may undergo a chemical change to a less toxic or leachable form, however their presence in the waste streams may still restrict disposal and recycle options.

Whilst these separation processes may be more effective in treating soils contaminated with petroleum fuels, they are generally employed to treat soils containing metals or heavy organic compounds.

The concentrated contaminants can be analysed and subsequently designated for further treatment, recycling, or re-use before disposal. While solvent extraction may improve the condition of the solids, often they may still need dewatering, treatment for residual organic compounds, additional separation, stabilisation, or some other treatment. The water from the dewatering process, the solids, and the water from the extractor will need to be analysed to aid in the choice of the most appropriate treatment and disposal.
Process description
The remediation process begins with excavating the contaminated soil and feeding it through a screen to remove large objects. In some cases, solvent or water is added to the waste in order to aid pumping it to the extraction unit. In the extractor, solvent is added and mixed with the waste to promote the dissolving of the contaminants into the solvent. Laboratory testing can determine which solvent adequately separates the contaminants from the soil. Generally, the solvent will have a higher vapour pressure than the contaminants (i.e. a lower boiling point) so that with an appropriate pressure or temperature change, the solvent may be separated from the contaminants, compressed, and recycled to the extractor.

Users
Treatment of contaminated soil.

2.3.3.12 Excavation and removal of contaminated soil

Purpose
Excavation activities may be carried out in isolation but are also typically carried out as part are of the on-site treatment processes such as incineration, thermal desorption, ex-situ biotreatment, and certain physico-chemical treatments.

Principle of operation
If removal of the contaminated soil is the selected remedy, the excavated soil is typically transported off site for subsequent disposal in a landfill.

Feed and output streams
Contaminated soils and decontaminated soil.

Process description
Typical civil engineering machinery is used.

Users
The excavation and removal of soils contaminated with fuels is a common practice.

2.3.3.13 Soil washing

Purpose
Soil washing is carried out to separate the decontaminated fractions and pollutants.

Principle of operation
Soil washing is an ex-situ process in which contaminated soil is excavated and fed through a water-based washing process. It operates on the principle that contaminants are associated with certain size fractions of soil particles and that these contaminants can be dissolved or suspended in an aqueous solution or removed by separating out clay and silt particles from the bulk soil. Additives such as surfactants or chelating agents are sometimes used to improve the separation efficiency (the treatment using additives may be referred to as chemical extraction). The aqueous solution containing the contaminants is treated by conventional waste water treatment methods.

The process is a water-based process and removes contaminants from soils in one of two ways:

a. by dissolving or suspending them in the wash solution (which is treated later by conventional waste water treatment methods)
b. by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition-scrubbing (similar to the techniques used in the mineral processing industry).

The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The silt and clay are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (i.e. clay and silt) particles from the coarser (i.e. sand and gravel) soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be easier further treated or disposed of.

Feed and output streams
Soil washing is effective for a wide range of organic and inorganic contaminants, including petroleum and fuel residues. Removal efficiencies range from 90 – 99 % for volatile organic compounds (VOCs) and from 40 – 90 % for semi-volatile compounds. Compounds with low water solubilities such as metals, pesticides or PCBs sometimes require acids or chelating agents to assist in the removal. Some pilot scale projects on radionuclides pollution treatment have been reported. The washing process is also applicable for contaminated sand and gravel from construction and demolition waste.

While these separation processes may be more effective in treating soils contaminated with petroleum fuels, generally they are employed to treat soils containing metals or heavy organic compounds.

Soil washing may can be effective for the remediation of soils with a small amount of clay and silt particles, but large amounts of clay and silt particles mitigate the effectiveness of soil washing.

Process description
The excavation and removal of debris and large objects precedes the soil washing process. Sometimes water is added to the soil to form a slurry that can be pumped. After the soil is prepared for soil washing, it is mixed with wash-water, and extraction agents are sometimes added.

After separation from the wash-water, the soil is rinsed with clean water and may be returned to the site. The suspended soil particles are removed by gravity from the wash-water as sludge. Sometimes flocculation is used to aid in sludge removal. This sludge is more highly contaminated than the original soil and undergoes further treatment or secure disposal. The spent wash-water from which the sludge is removed is treated and recycled. Residual solids from the recycling process may require further treatment.

Figure 2.10 presents a general flow scheme of a soil washing plant.

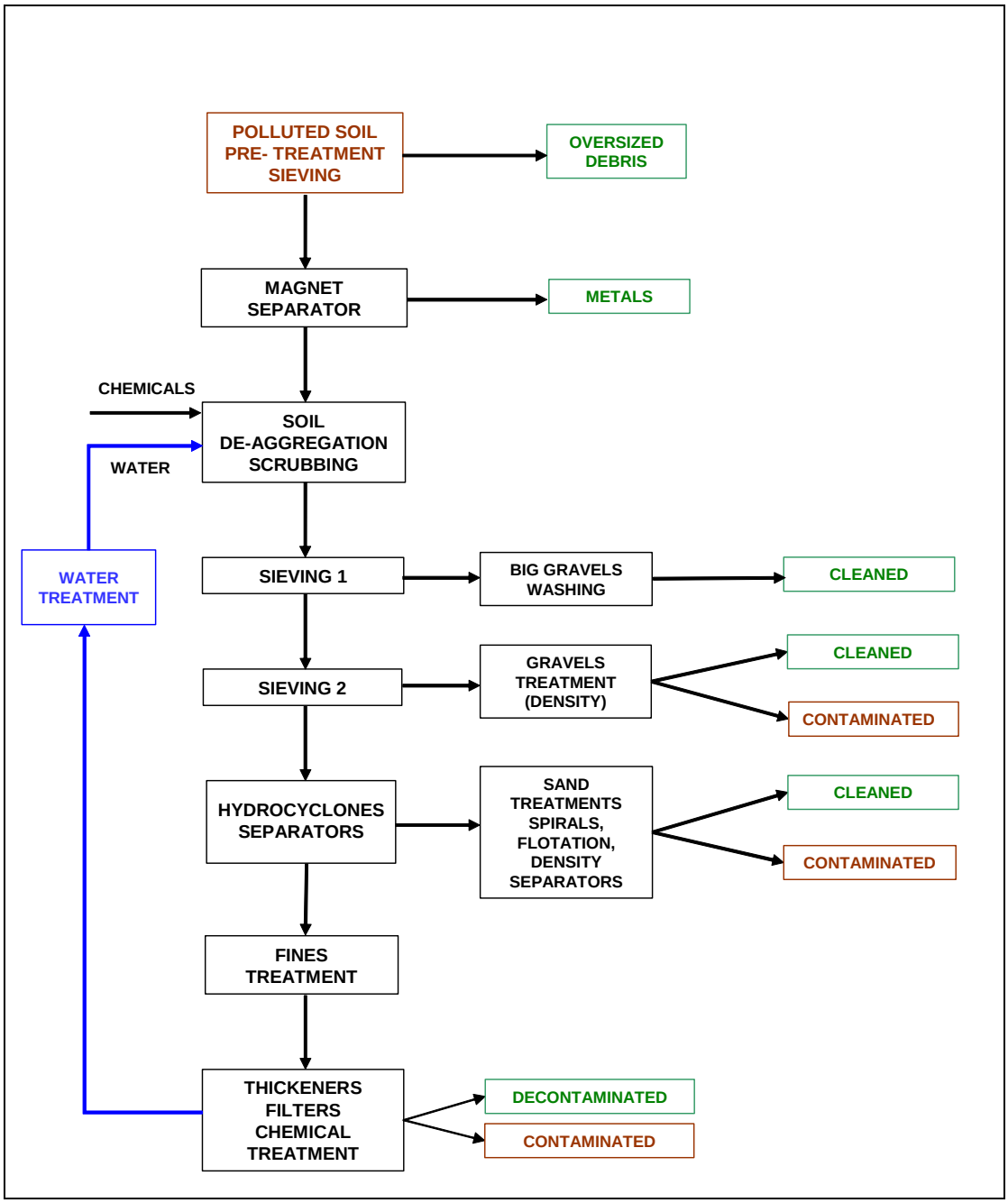


Figure 2.10: General flow scheme of a soil washing plant
[123, Perseo, 2003]

Typically, soil washing segregates a soil into a small volume of highly contaminated silt and clay and a larger volume of cleaned coarser soil.

Physical separation methods are mechanical methods for separating mixtures of solids to obtain a concentrated form of some constituents. Physical separations include screening, attrition scrubbing, or using hydrogravimetric separators as such hydrocyclones, jigs, spiral classifiers. In addition, in the majority of cases, the processes use water based chemical agents, which provide both dispersion and extraction. Chemicals (dispersants, collectors, frothers, etc.) may be added in some cases to enhance the quality of the separation.

Users
The soil washing technique is very well established in the Netherlands, Germany and Belgium, due to the sandy structure of the local soils. In 2003, eight plants in the Netherlands, six in Germany and six in Belgium were in operation. The technology is starting to become more developed in Switzerland and in northern Italy. Most plants have a capacity of 30 - 60 tonnes an hour. Furthermore, numerous on-site remediation projects have been performed with mobile plants, presenting usually smaller capacities (from 10 to 30 tonnes per hour).

2.3.3.14 Treatment of asbestos

Waste contaminated with asbestos are actually landfilled in the EU, however new techniques are appearing in order to treat them prior to landfill disposal.

2.3.3.15 Bottom ash treatment

Purpose
Improves the slag/bottom ash quality and therefore can help to improve its opportunities to be used as construction material.

Good bottom ash treatment facilities can produce a good quality material mainly scrap metal and mineral fractions. The residues from the treatment constitute 1 – 5 %. The residues are going back to the incineration. In addition, it is reduced the amount of heavy metals and e.g. arsenic (salt) that is emitted to the environment. Thus, the bottom ash treatment reduces the mass of waste to be landfilled.

Principle of operation
Bottom ash treatment plants exist in two types: wet and dry process.

Feed and output streams
Bottom ash from incinerators and other combustion processes.

Process description
The following points describe some general measures which can be taken to help to improve the quality of slag for re-use after it has been generated (i.e. after the incineration and after the drying process). These include (no order is suggested with this list):

- separating the bottom ash from all other burning products, such as filter and boiler dust, with the intention to reduce the leaching possibilities of the waste (e.g reducing leaching of heavy metals)
- avoiding mixing bottom ash from different sources
- removal of some of the organic material that it has not been entirely incinerated. Afterwards, incinerating this organic material removed. It is typically applicable when the waste OUT is used as a building material
- dewatering the bottom ash (it is commonly dried by storing it for a period of 2 - 4 weeks); this process requires a solid base (such as a concrete surface) and a collecting system for the effluent
- utilising a preliminary washing process to reduce the easily water soluble fraction of the bottom ash
- separating the scrap metal fraction from the bottom ash
- classifying and excluding the fine fraction from the bottom ash (the fine faction is the most problematic fraction for the environment as it leaches out easily). Excluding the small fraction from the bottom ash leads to more landfilling, since there are no real alternatives for such fraction
- ageing the bottom ash. This improves the consistency and reduces adverse leaching effects. A ventilation system and an installed water circulation system can allow a better bottom ash quality
- analysing the eluate and the solids to assess the recovery possibilities of the material.

The ageing processes require a solid base and a collecting system for effluents. The common aging time is up to 3 months. The end of the ageing process is noticeable by specific temperature changes. The sieving, separation and wet preparation of the bottom ash are important steps to achieve a good result.

Two different types of bottom ash analysis are possible. The first method analyses the available mobile compounds (eluate analysis (i.e. leachate)) of the bottom ash fraction. The second method analyses the complete compounds of the bottom ash (solid analyses). It is common to use both methods in parallel to define the environmental effects of the bottom ash. However, the eluate analysis is more important with assessing the possibility of material recovery.

Users
These techniques are seen by some Authorities as an important step to decrease the use of landfill. The amount of bottom ash from burning processes will rise, as probably the incineration of waste in Europe will become more common. Not only is the reduction of waste to disposal an environmental benefit, but it is also considered the re-use of the metal scrap fraction.

The wet process shows advantages concerning chloride-salts and final copper leaching, but is not compulsory in order to reach a bottom ash quality that allows re-use as a construction material in e.g. NL and DE.

2.3.4 Unit operations used in the physico-chemical processing of waste solids and sludges

This section contains common physico-chemical techniques used in the waste treatment sector. They are mainly common unit operations. They have been tabulated in Table 2.9, which gives the purpose and principle of the treatments and their main users.

Technique	Purpose and principle of operation	Users
Adsorption	See Table 2.8	
Centrifuging	See Table 2.8	Applied to liquid waste. Centrifuging is typically used together with recovery of the organic phase
Decanting	The principle of operation is the density difference of the different components to separate	Applied to liquid waste (e.g. separation of two inmiscible liquids, recovery of liquid layers after separation of suspended solids or biological/chemical flocs)
Drying	Thermal drying as evaporation	Applied to contaminated soils, sludges
Extraction	See Table 2.8	
Filtration	See Table 2.8	
Flotation	See Table 2.8	Flotation is used on liquid waste when gravity settlement is not appropriate. It occurs when: • the density difference between the suspended particles and water is too low • there is a space constraint at the site • the waste contains oil or grease that needs to be removed before treatment • recovery of the sludge is required
Metal recovery		
Oil separation processes	See Table 2.8	Gravity separation of soluble oils and oil/water mixtures
Oxidation	See Table 2.8	The chemical oxidation of wastes is a well-established technology that is capable of destroying a wide range of organic molecules, including chlorinated organic carbons, VOCs, mercaptans, phenols, and inorganics such as cyanide. The most common oxidising agents used for hazardous waste treatments are ozone, hydrogen peroxide, and chlorine. Ultraviolet (UV) light is usually added along with ozone and/or hydrogen peroxide to accelerate the oxidation of chlorinated VOCs. It is a very common pretreatment operation at many plants, but has a variety of technologies
Scrubbing	Air scrubbing	
Sedimentation (settlement)	See Table 2.8	Applied to liquid waste. Sludges liberated from a settlement stage are typically around 1 % dry solids content
Stripping	See Table 2.8	*Air stripping* is one of the most commonly used processes for separation of waste water contaminated with VOCs, such as solvents. It can be used to remove the halogenated or non-halogenated hydrocarbons from dilute aqueous solution. Solutions high in ammonia can also undergo such pretreatment to reduce the concentration of ammonia. *Steam stripping* is utilised for the removal of volatile and sometimes semi-volatile compounds from waste water.

Technique	Purpose and principle of operation	Users
Supercritical treatments	Extraction and/or oxidation of pollutants from contaminated water or sediments. Supercritical fluids (e.g. carbon dioxide, water, ammonia, cyclohexane) are materials at elevated temperature and pressure that have properties between those of a gas and a liquid. In extraction, the organics in soils, sediment or water are dissolved in the fluid at elevated temperatures and pressure conditions and are then released from the extraction at lower temperatures and pressures. In supercritical water oxidation, air and contaminated water are brought together above the critical point of water and the complete oxidation of organic compounds occurs rapidly	Treatment of POPs
Water reactive chemicals pre-treatment	These are scrubbed in a caustic solution and both treated liquors and scrubber liquors are treated in the main plant	The pretreatment of materials such as thionyl chloride, acetyl chloride, silicon tetrachloride with water to liberate acid gases
* The thermal treatments covered are those not included in the WI BREF		

Table 2.9: Common unit operations used in physico-chemical treatments
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

2.3.5 Physico-chemical treatments of other wastes

Physico-chemical treatment of wastes containing POPs
Three ways have been identified for the destruction and irreversible transformation of the POP content in wastes [154, UNEP, 2004]. One is the incineration on land (not covered in this document but in the waste incineration BREF that also covers plasma techniques), another is the use of waste as fuel (e.g. co-incineration in cement kilns not covered in this document) and last one is the physico-chemical treatment of waste. This section concentrates on those physico-chemical treatments related to these very specific types of waste (e.g. waste containing PCBs, dioxins, furans) and they are summarised below in Table 2.10.

Technique	Principle of operation	Feed and output streams	Process description
Dechlorination with metallic alkali	Reaction of metallic alkali with chlorine atoms contained in the chlorinated compounds	Waste IN: PCB oils Waste OUT: organic compounds (oil which may be re-used) and salt	The dispersion is carried out at a temperature above that of the melting point of the sodium, i.e. 98 °C. Being liquid, the metal surface can be renewed continuously. In this way a reasonable reaction rate can be achieved, thus decreasing the cost of the decontamination process. The process must avoid the formation of polymer (which occurs in one or two of the technologies identified) or must take the formation of this solid into account and introduce a separation step to yield the pure re-usable oil
Hydrogenation of POPs	Hydrogen reacts with chlorinated organic compounds or non-chlorinated organic contaminants, such as (PAHs), at high temperatures	Waste IN: transformer fluids; bulk PCB solids, including electrical capacitors; and high strength DDT waste pesticide mixtures Waste OUT: primarily methane and hydrogen chloride for PCBs and methane and minor amounts of light hydrocarbons for PAHs	Typical process used in mineral oil refineries and carried out at temperatures of 850 °C and higher. This technique converts approximately 40 % of the methane produced to hydrogen, via the water shift reaction, and the remaining part to hydrogen in the catalytic steam reformer. In this way, the process can operate without an external supply of hydrogen. For highly concentrated wastes, the process produces an excess of methane. It uses draw combustion air from off-site or ambient air on-site after first filtering it through active carbon, for the combustion process
Solvated electron process	Free electrons in a solvated electron solution convert contaminants to relatively harmless substances and salts	Waste IN: halogenated organic compounds, including PCBs, dioxins, pesticides, chlorofluorocarbons (CFCs) and chemical warfare agents. Waste OUT: decontaminated soils are said to be suitable for returning to the site, and as an additional benefit enriched in nitrogen from the trace amounts of residual ammonia	This technique uses an alkali or alkaline earth metal dissolved in a solvent such as ammonia, or certain amines or ethers to produce a solution containing free electrons and metal cations. Destruction efficiencies vary from 86 to 100 %. Chlorine and other halogens are selectively stripped from organic halides by free electrons and captured by the metal cations to form salts (e.g. $CaCl_2$). For example, a PCB molecule can be converted to biphenyl in a rapid reaction at ambient temperatures.
Supercritical water oxidation	A high temperature and pressure technique that uses the properties of supercritical water in the destruction of POPs	Waste IN: wastes containing organic compounds and toxic wastes Waste OUT: carbon dioxide; hydrogen to water; the chlorine atoms derived from chlorinated organic compounds to chloride ions; nitrocompounds to nitrates; sulphur to sulphates; and phosphorus to phosphate	Supercritical conditions
Note: Some other treatments outside the scope of this document are available for the treatment of wastes contaminated with POPs. These identified are co-incineration in cement kilns, hazardous waste incineration and plasma treatments			

Table 2.10: Some specific treatments for waste containing PCBs and/or POPs [100, UNEP, 2000], [154, UNEP, 2004]

Physico-chemical treatments of CFCs

The aim is to treat the waste to transform the CFC in hydrochloric acid and hydrofluoric acid. An example of such plant is shown in Figure 2.11.

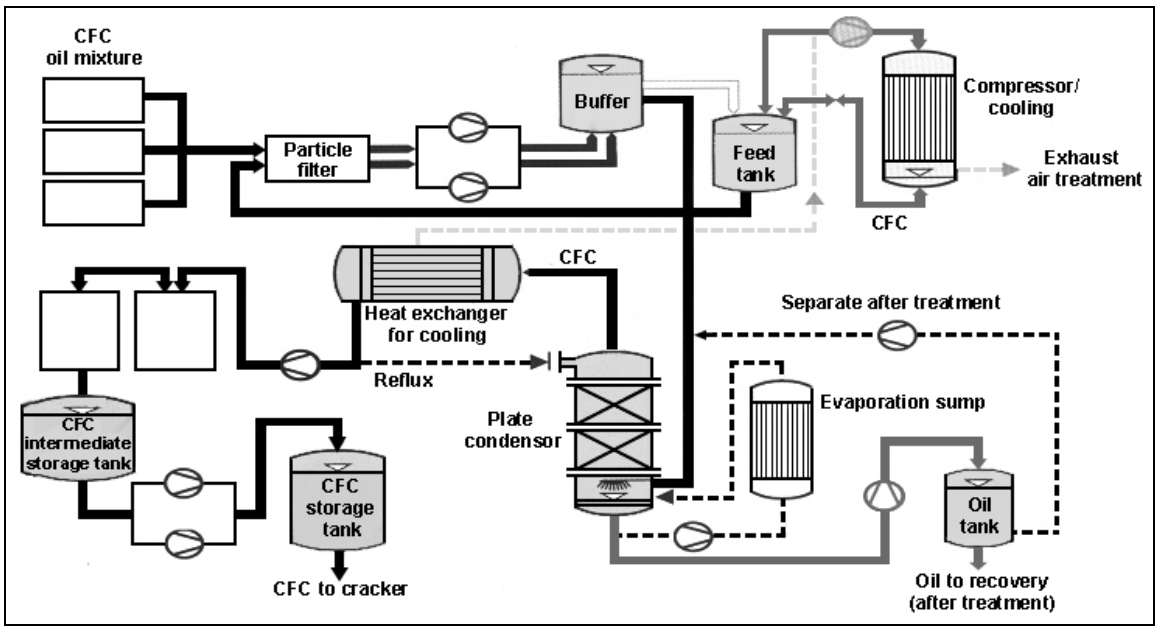


Figure 2.11: Treatment of CFCs to generate hydrochloric acid and hydrofluoric acid [150, TWG, 2004]

Physico-chemical treatment of waste containing mercury

Purpose
The aim is to treat the waste to separate the mercury.

Principle of operation
In the process of vacuum distillation, waste containing mercury is evaporated under vacuum conditions at approximately 300 to 650 ºC. The liquid components (e.g. mercury, water and oil) are distilled from the waste and condensed. In the condensation, a separation is established between the mercury and the distillate. The metallic mercury is drained and possibly refined. The mercury is recycled as a secondary raw material.

Feed and output streams
Sludge containing mercury from the oil and gas production industry, batteries, catalysts, activated carbon filters, thermometers, waste from the dental sector, fluorescent tubes, blasting grit and soil.

The destination of the residue from the vacuum vessel depends on the waste treated. It can be used as a secondary raw material (e.g. for batteries) or landfilled (e.g. in the case of sludge containing mercury).

Process description
The process is shown in Figure 2.12.

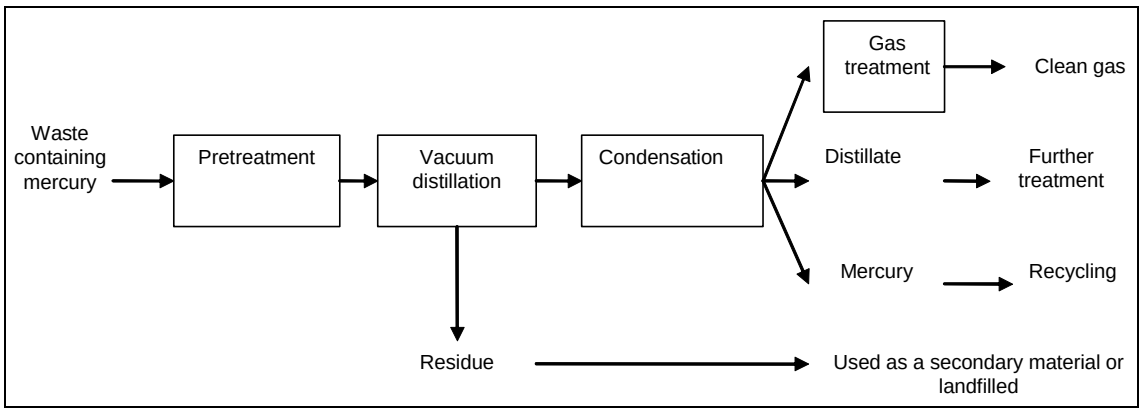


Figure 2.12: Vacuum distillation of waste containing mercury [156, VROM, 2004]

Users
Used in Sweden, Netherlands and Belgium.

2.4 Treatments applied mainly to recover the materials from waste

This section includes those treatments and processes mainly designed to recover the materials or portions of materials contained in waste. Typically these processes are very dependent on the type of waste treated and the materials that are wanted or that need to be produced. The materials produced from these treatments are materials that can be re-used for the same purpose (e.g. lubricant oils) or recovery for other non-energy purposes (e.g. recovery of metals from catalysts). When the material is treated to be used subsequently as fuel, this is included in the Section 2.5.

'Regeneration' is the term used in this document to describe these treatments except in the case of regeneration of waste oils where the term 're-refining' is used. This is not an attempt to make any kind of definition. This should be taken only as a convention to aid reading this document.

2.4.1 The re-refining of waste oils

[5, Concawe, 1996], [7, Monier and Labouze, 2001], [11, Jacobs and Dijkmans, 2001], [13, Marshall, et al., 1999], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [96, Straetmans, 2003], [150, TWG, 2004], [152, TWG, 2004]

There are two main options for the treatment of waste oils. One is the treatment of the waste oil to produce a material that will be used mainly as fuel or for other uses (e.g. absorbant, mould release oil, flotation oil). These include treatments as cleaning of waste oil, thermal cracking and gasification for example and are covered in Section 2.5.2.4. The other way, is to treat the waste oil to reconvert it to a material that can be used as a base oil to produce lubricants. This latter way is referred to as 're-refining' in this document. This section details the different treatments that are actually applied to waste oils for clean-up and re-refining. As it is the case in the whole document, this classification has been adopted for this document and it is not intended to provide any attempt to define any of the 'R' codes from EC waste legislation.

A lot of treatment processes exist (or are currently under development) today in Europe. The most significant ones are listed below in Figure 2.13. This figure also gives an overview on how these treatments have been included in this document.

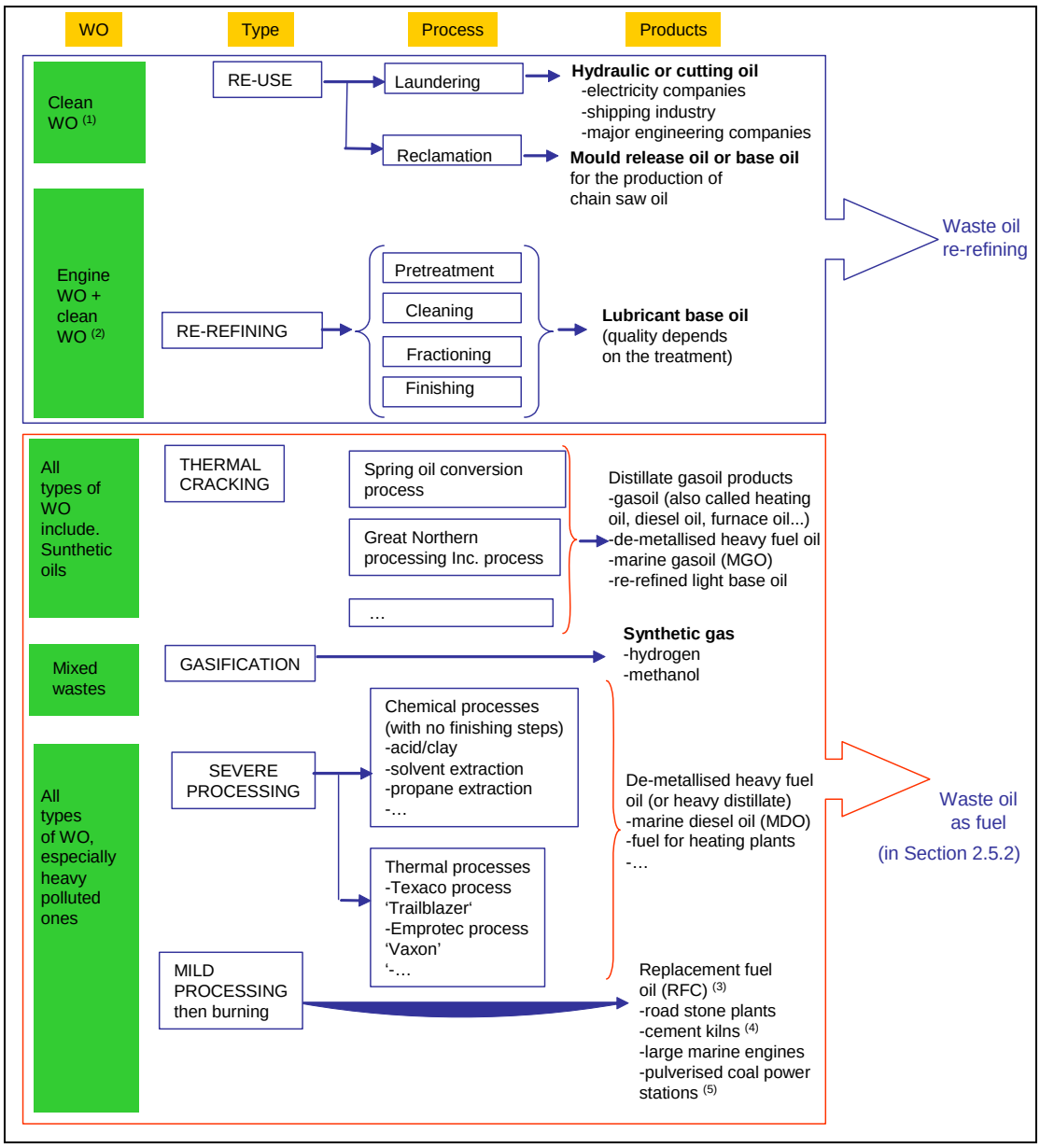


Figure 2.13: Waste oil treatments and division approach used in this document
[7, Monier and Labouze, 2001], [86, TWG, 2003], [150, TWG, 2004]
Note: (1) Especially hydraulic or cutting oil
(2) Engine oils without chlorine + hydraulic oils without chlorine + hydraulic mineral oils + mineral diathermic oils (according to the API classification)
(3) Treated oil still containing the heavy metals, halogen and sulphur contained in the original waste oil (WO)
(4) Substitutes other secondary liquid fuel (SLF) or heavy fuel or coal or petroleum coke
(5) As a furnace start up fuel

To re-use a waste oil to make a lubricant requires cleaning or re-refining in order to make it into a product suitable to be re-used as a base oil to produce a lubricant. These processes involve the removal of impurities, defects and any leftover products from its old use. Generally, this type of process removes all impurities and additives and only base oil then remains. Subsequently, lubricant producers add substances to attain the specifications of a virgin product.

The main processes used in oil recovery plants are shown in Figure 2.14. This is an amalgamation of unit operations. Not all operations are applied in every plant. In practice, most plants only use a few of the processes shown, and usually there are two or more parallel streams from each process.

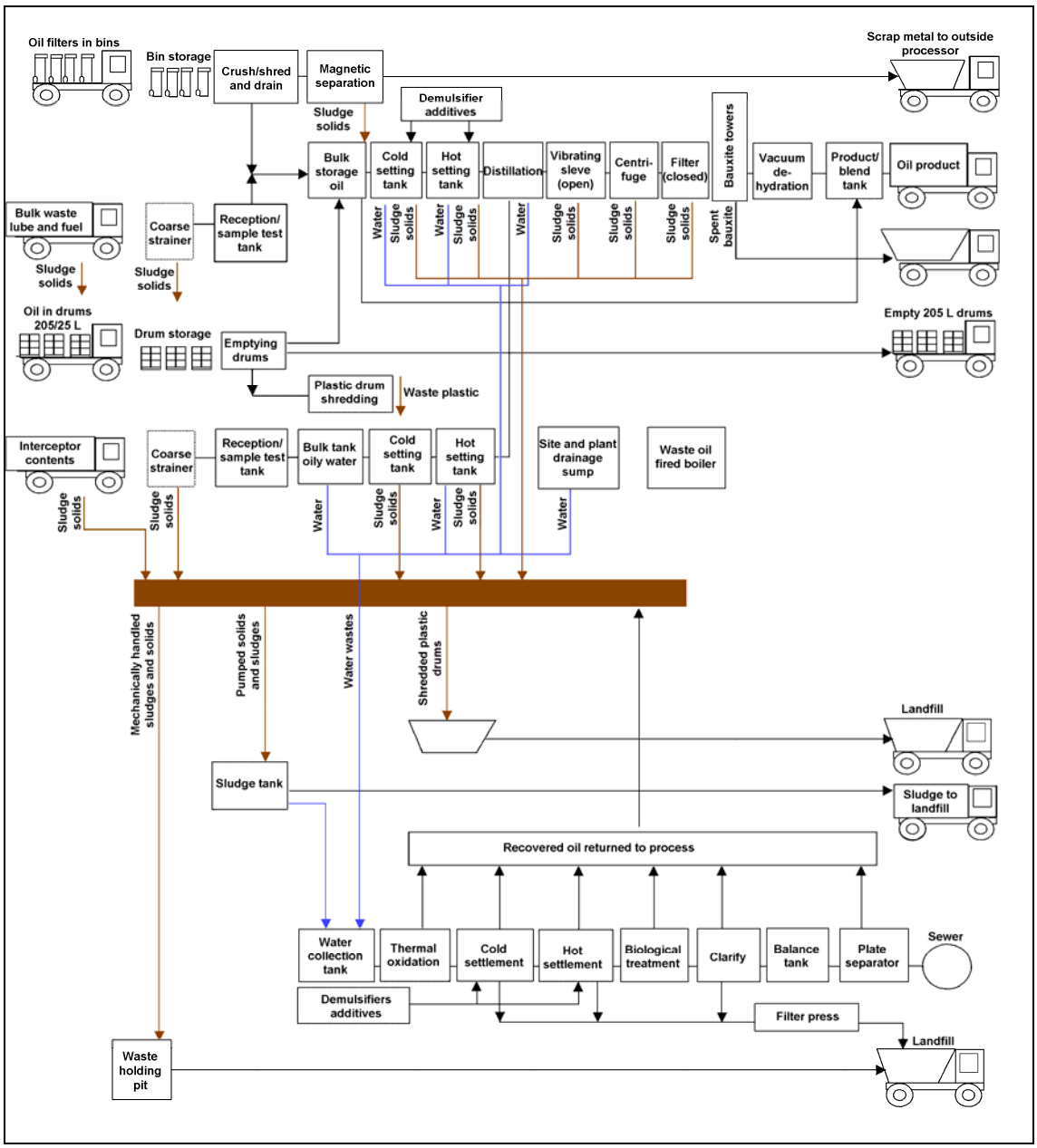


Figure 2.14: Generic flow diagram of waste oil treatment plant
Note: The diagram indicates common treatment elements. Some of these are alternatives and do not all occur in a single installation. Brown lines correspond to waste or sludges and blue lines to waste water.
Based on [56, Babtie Group Ltd, 2002]

Re-refining treatments may differ depending on the technology used for one or several of the following operations: pretreatment, cleaning, fractionation and finishing. Each of these processes are briefly described in the following sections.

2.4.1.1 Pretreatment of waste oil

Purpose
To dewater (removal of water), de-fuel (removal of light ends and fuel traces such as naphtha, etc.) and remove sediments. This pretreatment process is not compared with the other oil treatment systems because it does not yield an end-product, nor does it achieve the final aim of treatment.

Principle of operation
Water and sediments are removed from the waste oil by a simple physical/mechanical treatment. Settling is used in some cases to remove water and sludge from waste oil and in the effluent treatment systems for removing oil and solids from the effluent. Generally, settling takes place using the gravity effect in settling tanks, clarifiers or plate separators, but centrifuges or distillation can also be used.

Feed and output streams
The typical feed is collected waste oil. The product is cleaned waste oil. After this treatment the cleaned oil can be used in one of the options described below (Sections 2.4.1.2 to 2.4.1.4).

Process description
The main techniques used are settling, sedimentation, filtering and centrifuging.

Settling
A tank is filled and left until it settles, the upper oil strata is skimmed off and similarly the water layer is drawn off. Depending on how dirty the feedstock is, the sludge might be left at the bottom of the tank to accumulate over several settlement cycles before it is removed. The settling process is often aided by heating, to reduce the viscosity. In many cases, an interface layer of an oil/water emulsion remains. This can be encouraged to separate by the addition of heat and chemicals. Further settling processes applied to the 'water' layer can separate the oil/water phase even better.

Sedimentation

Filtering/straining
Particulates are removed by strainers, filters or sieves.

Centrifuging

Distillation
Water may be removed by this technique.

Users
Used in many of the waste oil re-refining technologies (see Table 2.12)

2.4.1.2 Cleaning of waste oil

Purpose
Cleaning includes deasphalting and the removal of asphaltic residues: heavy metals, polymers, additives, other degradation compounds.

Principle of operation
Distillation and the addition of acids are the most typical ways to achieve the above results.

Feed and output streams

Process description
Acid cleaning: additives, polymers, oxidation and degradation products are removed by contact with sulphuric acid or precipitated as sulphates (e.g. metals). Clay cleaning is also considered, where the clarified oil is mixed with clay by absorption to remove any polar and undesirable compounds still present.

Users
Used in many of the waste oil re-refining technologies (see Table 2.12).

2.4.1.3 Fractionation of waste oil

Purpose
This involves a separation of the base oils using their different boiling temperatures, to produce two or three cuts (distillation fractions).

Principle of operation
This physical separation process utilises the boiling point differences of components.

Feed and output streams
Typically pretreated waste oil.

Process description
Vacuum distillation units can range in complexity from a simple splitting column to a full fractional distillation column, as used in mineral oil refineries.

Users
Used in many waste oil re-refining technologies (see Table 2.12).

2.4.1.4 Finishing of waste oil

Purpose
Final cleaning of the different cuts (distillation fractions) is carried out to achieve specific product specifications (e.g. improve colour, smell, thermal and oxidation stability, viscosity, etc.). Finishing may also include the removal of PAHs in the case of a severe (high temperature and high pressure) hydrofinishing or solvent extraction (low temperature and low pressure).

Principle of operation and feed and output streams

Technique	Principle of operation	Feed and output streams
Alkali treatment	KOH or NaOH is used	Colour properties are enhanced.
Bleaching earth	This is a tertiary treatment, to remove the black colour from the oil (caused by the carbon breakdown from the additives), so it can visually be compared with virgin base oil.	The new goals, set up by the implementation of upcoming specifications for passenger car motor oils, cannot be achieved. In particular, the colour of the produced oils is darker than required.
Clay polishing	This is a process similar to the acid/clay process but acid is not used. Bentonite is the clay typically used. The clay is then separated from the oil using a filter press.	Generally, clay polishing does not produce the high quality base oils of solvent extraction or hydrotreatment.
Hydrotreatment	Chlorine and sulphur are removed from the waste oil fraction at a high temperature under a hydrogen atmosphere and in contact with a catalyst, being converted into HCl and H_2S. Phosphorus, lead and zinc are also removed in this process. PAHs can be removed by severe hydrofinishing (high temperature and with hydrogen under high pressure)	The quality of the distillates is very high and the petroleum fractions are immediately marketable. Hydrogen is needed for the process. Hydrogen sulphide is formed, which can later be reduced to sulphur.
Solvent cleaning	PAHs are removed from the base oils by extracting them into the solvent (into ppb range). The solvent extraction also improves the colour and viscosity index.	The feed into the extraction must be a good quality base oil with all heavy metals etc. removed and already fractioned into wanted cuts. The products are a high quality base oil, the used solvent which is regenerated, and a small stream of base oil (c. 3 % of the total base oil stream) with a high PAH concentration, which is used as a fuel product.

Table 2.11: Finishing techniques used for the treatment of waste oils [7, Monier and Labouze, 2001], [86, TWG, 2003], [139, UBA, 2003]

Process description
The hydrotreatment process can be found in the Refinery BREF.

Users
Used in many waste oil re-refining technologies (see Table 2.12)

2.4.1.5 Technologies used for the re-refining of waste oils

Table 2.12 summarises the different technologies used for the regeneration of waste oil.

Technology	Feed and output streams	Process description			
		Pretreatment	**Cleaning**	**Fractionation**	**Finishing**
Laundering	Transformer oils, industrial lubricants (e.g. hydraulic and cutting). Product: clean industrial lubricant returned to users	Adsorption Heating Filtration Vacuum dewatering			
Reclamation	Industrial oils (especially hydraulic oils). Product: clean industrial lubricant returned to users	Centrifugation and/or filtering			
Clay processing	Product presents poor characteristics in terms of viscosity and volatility. It can only be employed in the formulation of a limited type of industrial lubricant	*Pre-flash unit* Atmospheric vacuum stripping	*Clay treatment* By contact with a large quantity of adsorption clay		
Acid/clay + distillation		*Atmospheric or vacuum flash stripping*	*Acid or clay treatment* Removal of waste oil contaminants by acid treatment (typically sulphuric acid) or clay treatment	*Distillation* The cleaned oil is then distilled to recover two or three cuts, plus an overhead gasoil	*Neutralisation and filtration* The lubricating oil cuts, along with the gasoil, are neutralised with calcium hydroxide and filtered
Acid surfactant flocculation					
Distillation/ chemical treatment or solvent extraction		*Vacuum distillation* The 1st stage removes the water, naphtha and light end. The 2nd stage removes the gasoil, spindle oil or light fuel oil	*Vacuum distillation* The 3rd/4th stages separate the different lubricating oil cuts from the residue (in which all the metals, additives and degradation products are concentrated)		*Chemical treatment is* carried out in a blocked operation, followed by a distillation/stripper to correct volatility and the flashpoint. Alternatively, a *solvent extraction stage* can be supplied to remove the PAHs
Distillation and solvent extraction (Vaxon process)			*Vacuum distillation*		*Solvent extraction*

Technology	Feed and output streams	Process description			
		Pretreatment	**Cleaning**	**Fractionation**	**Finishing**
Solvent extraction and distillation (Sener-Interline process)	The recovered base oils have a good quality.	*Chemical pretreatment*	*Extraction with propane.* Liquid propane extracts the base oils and rejects water, asphalt, additives, and other non soluble contaminants.	*Atmospheric and vacuum distillation* The extracted oil is firstly distilled in an atmospheric distillation column to separate light hydrocarbons and some propane. The remaining oil is fractioned in a vacuum distillation column to recover lubricant base oils.	
Propane deasphalting and hydrofinishing	The technology produces good quality base oils and an alphaltic residue (suitable as bitumen)	*Pre-flash* In a distillation column	*Extraction with propane* Propane deasphalting	*Atmospheric vacuum distillation*	*Hydrofinishing with a NiMo catalyst*
Distillation and alkali treatment (Vaxon - C.F.T. – Cator)	Motor and industrial waste oils, all types of synthetic lubricants except PAG water-soluble, silicon oils and some type of esters. Base oils and asphatic residue are the main products Impurities and sediments remain in the final solid waste, which has an asphaltic nature.	*Distillation* Throughout the process, pretreatment forms part of the same process, since the first phase produces a dewatering through whole distillation with all used oil types.			*Alkali treatment*
Thin film evaporators (TFE) and different finishing processes *	Heavy metals, polymers, additives and other degradation products are removed as an asphaltic residue.	*Pre-flash and chemical treatment (1^{st})* Water, light ends and fuel traces contained in the used oil are removed. Atmospheric vacuum stripping + chemical treatment (optional) to minimise the corrosion and fouling of downstream equipment.	*TFE(2^{nd})* Performed at very high temperatures and vacuums.	*Distillation (4^{th})* The lubricating oil fraction is separated into different oil cuts in a vacuum column.	*One of the following (3^{rd})* *a) Hydrotreatment* *b) Clay treatments* *c) Solvent extraction* *d) Solvent extraction + hydrotreatment*

Technology	Feed and output streams	Process description			
		Pretreatment	**Cleaning**	**Fractionation**	**Finishing**
Thermal de-asphalting process (TDA)		*Pre-flash* Atmospheric vacuum stripping + chemical treatment. The last treatment is used to minimise the corrosion and fouling of downstream equipment and to facilitate the subsequent deasphalting step.	*Settling + TDA* Deasphalted by settling. Residue removal is achieved by flashing at the bottom of the distillation column, which performs the fractionation of the different lubricating oil cuts.		*a)Clay* *b) Hydrotreatment*
Direct contact hydrogenation process (DCH)	Waste oil and hot hydrogen gas pass the process as a mixture It produces good quality base oils (group II)	*Pretreatment* Not necessary	*Guard hydrogenation reactor (1^{st})* Hydrogen and oil vapour is routed to a two stage fixed bed catalytic reactor. The guard reactor removes any trace metal contaminants, following by a cracking of any sulphur, nitrogen, halogen compounds in the conversion reactor.	*Fractionation (3^{rd})* The lubricating oil fraction is separated into different oil cuts in a vacuum column	*Hydrotreatment (2^{nd})* High pressure flash separator. Fixed bed catalytic reactor
Caustic soda and bleaching earth treatment (ENTRA)	Waste oil and caustic soda. The base oil produced is of good quality (group II) with good yields	*Pre-flash* Dewatering. Feed with the addition of caustic soda (3 % referred to dry used oils) and bleaching earth (2 % referred to dry used oil)	*Tubular reactor* Break-down of the undesired metallorganic, sulphur, nitrogen and halogen compounds takes place. An advanced control of temperature and retention time in a linear tubular reactor minimises the break-down of those organic molecules which are still viable as lubricating oil components	*Fractionation* The lubricating oil fraction is separated into different oil cuts in the linear tubular reactor	*Neutralisation* Neutralisation with acid, clay treatment
Integration in a base oil production of a refinery	Oil produced represents a good quality of re-refined base oil.	a) Pre-flash in a distillation column b) Atmospheric vacuum stripping.	*TFE*	*Aromatic extraction unit* of the refinery to remove PAHs and other undesirable compounds.	*Hydrofinishing*

Technology	Feed and output streams	Process description			
		Pretreatment	Cleaning	Fractionation	Finishing
Integration in a refinery after pretreatment	Waste oil is reprocessed in a refinery to allow blending into fuel products. Contaminants within waste oils normally preclude their use as catalytic cracker feedstock or in lubricant oil production.	Water and sediments are removed from the waste oil by a pre-flash step	The pre-flashed waste oil is directly blended with the regular atmospheric residue of a refinery.		
* *1st, 2nd, 3rd, 4th* stands for the sequence of when the operations are carried out within the process. When no such numbers are present, the sequence is the most common one, i.e. pretreatment, cleaning, fractionation and finishing.					

Table 2.12: Waste oil re-refining technologies
[5, Concawe, 1996], [7, Monier and Labouze, 2001], [86, TWG, 2003], [139, UBA, 2003], [150, TWG, 2004]

2.4.2 Regeneration of waste solvents

[53, LaGrega, et al., 1994], [83, Indaver, 2002], [129, Cruz-Gomez, 2002], [130, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

Purpose

Once the waste solvent is passed to a waste manager, there are two main options for its treatment:

- utilisation of the calorific value by using them directly as a fuel or blended with other fuels. The use of the waste solvents as fuels is covered in Section 2.5.2.1
- treatment of the waste solvent to reconvert it to a material that can be re-used as solvent. This treatment is referred to in this document as 'regeneration'. This section details different treatments that are actually applied to waste solvents for their clean-up and to regenerate them to produce solvents.

The solvents and organic acids can be treated to a degree such that they can be returned into the production cycle as secondary raw material.

Principle of operation

Clean-up is achieved by different types of distillations which are the main types of separation process used.

Feed and output streams

Solvent regeneration is common practice in many industries, with a wide range of solvents currently being regenerated, the more common of which are shown in Table 2.13.

Hydrocarbon family	Chemicals
Alcohols	Ethyl, isopropyl
Aliphatics	Hexane, heptane
Aromatics	Benzene, aromatic naphtha, toluene, xylene, turpentine
Chlorinated	Trichloroethylene, perchloroethylene, methylene chloride
Esters	Ethyl acetate, butyl acetate
Ketones	Methyl ethyl ketone, methyl iso-buthyl ketone
Mixtures of solvents	Toluene/xylene, ketones, alcohols, phenols, toluene/heptane

Table 2.13: Commonly regenerated waste solvents
[53, LaGrega, et al., 1994], [150, TWG, 2004], [152, TWG, 2004]

Process description

Figure 2.15 and Figure 2.16 give examples of flow diagrams of waste solvent regeneration plants.

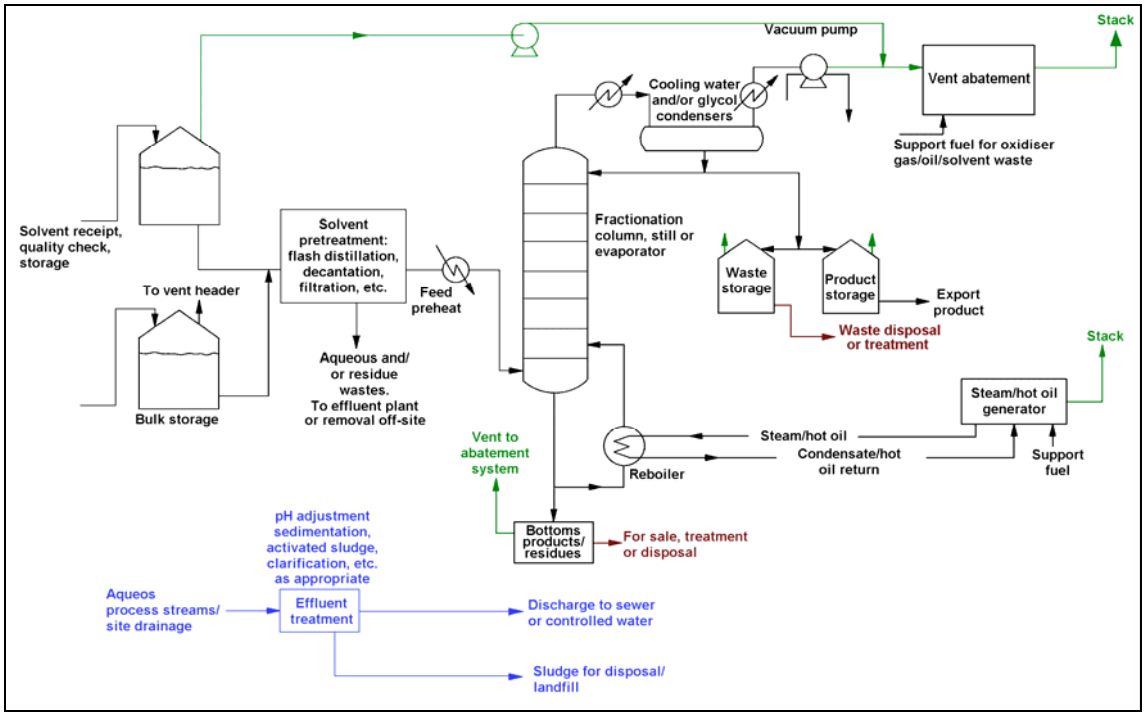


Figure 2.15: Example of waste solvent regeneration installation
[129, Cruz-Gomez, 2002]

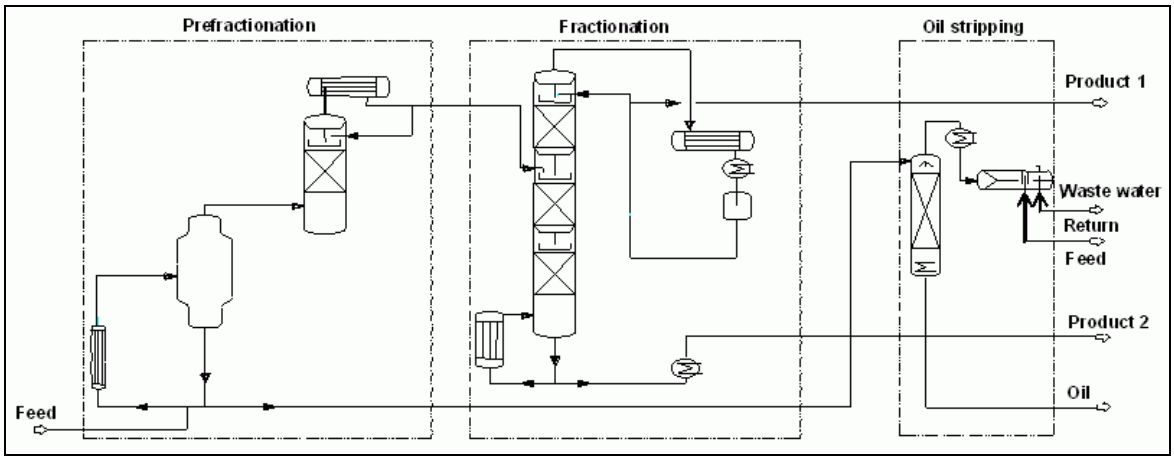


Figure 2.16: Example of chlorinated solvent regeneration flow diagram
[150, TWG, 2004]

Table 2.14 shows the techniques typically used for the regeneration of waste solvents.

Technique	Purpose and principle of operation	Users
Absorption	Transfer solvent from a gas to a liquid	
Adsorption	Recover solvent from solvent laden air	
Centrifugation	Removes suspended solid or separates two distinct (or insoluble) liquid phases, one phase is, for instance, the solvent being recovered	
Condensation	Eliminates solvent vapours from gas streams	
Decantation	Phase separation due to different densities. Separation of liquid solvent and water	
Distillation	Separation of liquid mixtures. Thin film evaporators. Rectification. Fractionation	The distillation of contaminated solvents for partial subsequent use as a fuel in boilers is one technique used (for reducing metal levels in the solvent), (some plants exist in Belgium, Italy, Spain)
Evaporation	Removal of solvent as a vapour form from a solution or slurry	
Filtration	Separation of solid particles from liquid solvent	
Liquid-liquid Extraction	Applied to liquid solvents	
Membrane separation	Recovery of solvents from liquid or gas streams	
Neutralisation	Applied to liquid solvents	
Salting out	Applied to liquid solvents	
Sedimentation	Applied to liquid solvents with a high level of solids	
Storage	See Section 2.1.4	
Stripping	Transfer of solvent from a liquid stream to a gas stream	

Table 2.14: Unit operations used for the regeneration of waste solvents [129, Cruz-Gomez, 2002], [130, UBA, 2003], [150, TWG, 2004]

Users

This activity is carried out in the chemical, pharmaceutic and painting industries. Five plants are currently in the Netherlands. An example is described below:

The evaporation capacity depends on the specific evaporation heat of the distilled solvents and amounts to up to 1.3 t/h. The use of a reflux separator can further improve the separation; however, the flowrate is then reduced. Multiphase distillates are cooled and then separated in heavier and lighter phases which are then collected in different containers. Distillation can be performed both under ambient pressure and under vacuum. Furthermore, the facility can carry out other processes such as azeotrope solvent drying or azeotropic esterification. Additionally, organic acids may be treated in a specific ceramics bubble.

The input material containing solvents is pumped into the distillation containers. These containers are heated indirectly by fresh vapour of maximum 6 bar at approximately 158 ºC. For heavily contaminated solvents, distillation bubbles of steel are available which are equipped with stirrers for homogenising the contents. Waste solvent mixtures containing only small quantities of residues, or highly corrosive substances such as organic acids, can be distilled using enamelled bubbles. The resulting plumes are transported through a packed column and condensed at the pipes of the overhead cooler.

2.4.3 Regeneration of waste catalysts and recovery of components from abatement techniques

[86, TWG, 2003], [125, Ruiz, 2002], [150, TWG, 2004]

As mentioned in the Scope, this section covers the regeneration of waste catalysts and the recovery of components from abatement techniques. Alternative ways to regenerate spent catalysts exist, such as the recovery of the metals from catalysts (some precious metals recovery treatments are already covered with in the Non-Ferrous-Metals BREF), regeneration of catalysts (covered in this document) and the treatment of spent catalysts as raw materials for other processes, which are not covered in this document (e.g. the treatment of spent alumina-supported catalysts in the cement industry which is covered in the Cement and Lime BREF). This document only includes ex-situ regeneration installations. In-situ regeneration is typically part of a production process where a catalyst is used, thus is not covered in the scope of this document.

This section is intended as well to include information on the recovery of components from waste generated from abatement techniques (see also Section 1.2.8)

Purpose

Waste catalysts and waste from abatement techniques are typically disposed of. However, most catalysts used in abatement techniques (e.g. NO_x abatement) are regenerated.

Principle of operation

Regeneration of precious, platinum and noble metal catalysts to remove coke deposits can successfully restore the activity, selectivity, and stability performance of the original fresh catalyst. Coke deposits are removed by controlled combustion.

Feed and output streams

Catalysts from the refinery industry such as used in hydrotreating, hydrocracking, reforming and isomerisation are typically regenerated. Noble metal catalysts are also regenerated. The metals that are typically economically interesting to be recovered are Rh, Cd, Pt, Ir, the Nickel Raney and some petroleum catalysts with Ni-Co, Co-Mo, Co.

Process description

Ex-situ thermal regeneration is performed in specially designed equipment as well as in standard equipment, e.g. moving-bed belt calciners or rotary calciners.

The regeneration of precious, platinum and noble metal catalysts to remove coke deposits can successfully restore the activity, selectivity, and stability performance of the original fresh catalyst. Coke deposits are removed by controlled combustion.

As an example, after the coke is burned off, a catalyst containing platinum can be regenerated by chlorine treatment at an elevated temperature. The chlorine treatment causes redispersion of the platinum by converting it to a volatile platinum chloride, which is then transported through the gas phase and deposited on the pore walls, where it is treated in H_2 and reduced. The result is an increased dispersion of the platinum and a reactivated catalyst.

The common unit operations used in this sector are dryers, furnaces, leaching equipment and solvent extraction. Some end-of-pipe processes used to control air emissions are dust removal techniques (e.g. electrostatic precipitators, cyclones, fabric filters, ceramic filters, scrubbers, flares), gas scrubbing systems (e.g. scrubbers, dioxins capture systems, VOC abatement systems), and waste water treatments.

Users
There is a very precise process in France (Eurocat) which is applied to the recycling of one specific catalyst family (hydrotreatment) coming mainly from refineries. There is only one moving belt calciner process plant in the EU, which has been located in Luxembourg since 1979.

2.4.4 Regeneration of activated carbon

[29, UK Environment Agency, 1996], [41, UK, 1991], [42, UK, 1995], [150, TWG, 2004]

Purpose
To treat the spent activated carbon to produce a material with properties and qualities very similar to the original activated carbon.

Principle of operation
Thermal treatments are the main processes used for regeneration. During the process, drying, thermal desorption and heat treatment are carried out.

Feed and output streams
Activated carbon is commercially available in three forms: extruded, granular and powder. Since powdered carbon is extremely difficult to regenerate, this activity is not carried out on powdered carbon. Only the first two forms are therefore considered in this section.

Process description
Regeneration is normally carried out thermally and is typically composed of the following operations:

Receipt, handling and dewatering
Spent activated carbon is normally received on site as a drained solid in tankers. Water is added at the regeneration site in order to turn the carbon into slurry, which is fed to a tank where it is dewatered and charged into a kiln to be regenerated.

Thermal regeneration
After separation from the water, the moist carbon is fed into the furnace for regeneration. During thermal regeneration, drying, thermal desorption (i.e. removal of the organic chemicals) and high temperature (650 to 1000 °C) heat treatment in a slightly oxidising controlled atmosphere are carried out.

The types of equipment generally used are multiple hearth furnaces, directly fired rotary kiln furnaces and indirectly fired rotary kiln furnaces. Fluid bed furnaces and infrared furnaces may also be used.

Flue-gas treatment

Users
The most common use of these techniques is in the thermal regeneration of activated carbon, especially in facilities regenerating industrial or potable water/food grade carbons. This is because of the potential for carbons from a variety of sources to be contaminated with a range of organics. The other methods, such as steam regeneration, tend to be applied in specific areas and typically undertaken on-site.

Multiple hearth furnaces are used extensively worldwide. In conjunction with multiple hearth furnaces, rotary kilns (directly and indirectly fired) are one of the most common types of furnaces employed. Fluid bed furnaces are mainly used in Europe on potable water applications and also in North America for waste water and decolourising.

Other treatments are available as steam, chemical and biological regeneration. However they are only used for in-situ regeneration on-site and not at separate facilities. Steam regeneration is a non-destructive technique and is primarily used where the spent carbon contains highly volatile compounds. The resulting steam/VOC vapours are condensed. Chemical regeneration is a non-destructive technique that uses a variety of gaseous or liquid desorbants. There are numerous regenerant materials available, many of them highly specific to the individual application.

2.4.5 Regeneration of resins

[41, UK, 1991], [42, UK, 1995], [150, TWG, 2004]

Purpose

To regenerate ion exchange resins for their re-use.

Principle of operation

Thermal regeneration may be accomplished by using hot water or steam.

Feed and output streams

The feed corresponds to spent resin with the output of the process being regenerated resin. The attractive forces encountered in resin adsorption are usually weaker than those of granulated activated carbon adsorption. Due to this, regeneration of resins can be achieved by simple, non-destructive methods such as solvent washing, and the solute can be recovered. Thermal regeneration of resin adsorbents is generally not possible due to their temperature sensitivity, although in recent years some new products are becoming available that can be regenerated by hot water.

Process description

Steam regeneration

Steam regeneration is only possible if the temperature limits of the resins are within those of the available steam pressure. For example, styrene based polymeric adsorbents are usually stable to 200 °C, whilst acrylic based resins are only stable up to 150 °C. The adsorbed solvent and other organic constituents can cause the resin matrix to swell and weaken. It is important therefore, that removal of these constituents by steaming does not result in disruption and breakup of the resin matrix.

Hot water regeneration

Users

This technique is not widely used, but it may be applied to the desalination of brackish water for a cleaner process water usage. It would not be used for deionised water applications.

2.4.6 Regeneration of waste acids and bases

[40, Militon and Becaud, 1998], [86, TWG, 2003], [144, TWG, 2002], [150, TWG, 2004]

As described in Section 1.2.10, only waste sulphuric and hydrochloric acids are regenerated.

2.4.6.1 Regeneration of spent sulphuric acid

As mentioned in Section 1.2.10, two alternative methods for regenerating spent sulphuric acid exist. One is the thermal decomposition of spent sulphuric acids to give SO_2, achieved in a furnace at temperatures of around 1000 °C. The SO_2 produced is then used as a feedstock in the production of H_2SO_4. Both processes (thermal decomposition and SO_2 conversion to H_2SO_4) are covered in the LVIC-AAF BREF [62, EIPPCB, 2003]. There are some industrial processes where sulphuric acid is used (e.g. production of titanium dioxide). In such cases, the recycling of the spent sulphuric acid is an integral part of the process and will be covered in the BREF where that industrial process is covered. The second alternative process to regenerate spent sulphuric acid is based on the reconcentration of weak/spent/waste sulphuric acid, with or without a separation of the potential impurities (e.g. salts). This is also included in this BREF document.

Purpose
To re-use the spent sulphuric acid for the same purpose as it was originally used for or for a new use.

Principle of operation
Reconcentration of the weak sulphuric acid by evaporation.

Feed and output streams
Spent/weak sulphuric acid is concentrated to a stronger acid solution.

Process description
Concentrations close to 70 % H_2SO_4 have been achieved and the process consists of water evaporation, without too much H_2SO_4 in the vapour phase. The range of temperatures vary with the processes. There are many processes but the most common are based on the forced circulation evaporators, which allow a very stable operation; due to the big circulation, any solid in the acid will remain in the suspension and can be separated out in the concentrated acid, if necessary.

Because of the cost of the process is very dependent on energy, (medium pressure steam), a multiple effect evaporator can reduce the operating costs very much; vacuum operation allows lower operation temperatures and the use of more standard materials for equipment construction.

Another process for weak acid concentration uses hot gases (from sulphuric acid or any other process), by contacting hot gases and weak acid, the water will be evaporated towards the water saturation; the process takes place at atmospheric pressure but, due to the relatively high gas volume, some acid carry over must be prevented, by demisters or other similar devices.

Submerged combustion processes consist in the production of flue-gases at very high temperatures, (in excess of 1500 °C), directly over the spent acid level; the flue-gas passes through the spent acid allowing water evaporation from it, suffering an adiabatic cooling down to 150 – 250 °C; before being to discharged into the air, the gases need to be cooled and scrubbed out; in general, no especially high SO_2 emissions will be expected but NO_x levels should be important.

Other processes, such as Chemico, have been used for 70 years for sulphuric acid concentration; the principle is quite the same, except that the combustion does not take place within the vessel and the temperature is considerably lower (in the range of 600 °C).

Users
The metal industry.

2.4.6.2 Regeneration of spent hydrochloric acid

Most often, HCl is produced as a by-product from chlorination processes. HCl is generally produced in the gaseous phase and directly re-used in a chemical process. It can also be dissolved in water and used as a raw material for the production of other chemicals, such as water treatment product (e.g. $FeCl_3$) in electrolysis or as a neutralisation agent. HCl can be used in applications such as metal pickling or ion exchange regeneration.

Afterwards, spent hydrochloric acid is neutralised rather than regenerated. Then, reference to Sections 2.3.1 and 2.3.2 needs to be made. Some other regeneration treatments exists, for example, re-use as a picking acid. However, in this use, no treatment is carried out to these streams, so these are not covered in this BREF document.

2.4.7 Treatment of solid photographic waste

Purpose
Separate the waste in two main streams: one containing some valuable components (e.g. Ag) and the other to be used as fuel.

Principle of operation
The silver containing fixer is desilvered by means of electrolysis (see Section 2.4.8 on treatment of liquid photographic waste). The chemical reaction for dissolving silver from film is: $Ag + Fe^{3+} \leftrightarrow Ag^{+} + Fe^{2+}$.

Feed and output streams
Silver and energy.

Process description
The film waste is cut into little pieces by a shredder. The shreds are washed with a desilvering liquid and rinsed with water. Possible desilvering agents are desilvered bleach-fix (contains iron) or iron chloride. When desilvered bleach-fix is used, the consumption of raw materials is reduced. When iron chloride is used, silver chloride is separated and then dissolved again by means of a fixer. The plastic shreds are dried, after which they can be incinerated with energy recovery or used as a secondary fuel in a cement kiln.

Users
Photographic industries.

2.4.8 Treatment of liquid photographic waste

Purpose
Separate the waste stream into valuable components (e.g. Ag).

Principle of operation
Desilvered liquids and photo processing waste with a low silver content, such as developers, are treated by means of sulphide precipitation and membrane filtration. By adding a sodium sulphide solution, silver ions and other metals are precipitated. By pressing the solution through membranes the solid particles are filtered out. The permeate from membrane filtration undergoes further treatment. The silver contained in the sludge is recovered by means of pyrometallurgic treatment and refinement. These treatments are described in the Non Ferrous Metals Industries BREF. Photo processing liquid wastes with a low silver content are treated by chemical removal. By adding sodium borohydride, metallic silver is precipitated. The silver is recovered from the containing sediment. The desilvered liquid undergoes further treatment.

Feed and output streams
Silver.

Process description
The treatment of the desilvered liquid photo processing waste with a high silver content consists of the following steps:

- silver is removed from photo processing waste with a high silver content (>100 mg/l) by means of electrolysis. After refining, the silver is re-used
- for a concentration of concentration of silver of 5 to 100 mg/l, desilvering by electroflocculation or sulphide precipitation and membrane filtration is applied. The created sludge is sent for incineration
- colour processing waste water is, prior to further treatment, evaporated in a vacuum evaporator because of the presence of toxic and not easily degradable organic compounds
- treatment in an activated carbon filter, where large organic and metal containing complex agents are absorbed by the carbon. When the carbon is saturated, it is regenerated and re-used
- purification by means of flocculation and flotation
- biological treatment
- evaporation in a vacuum evaporator. The condensate can be used as processing water or discharged
- the sludge from the flocculation/flotation and biological treatment and the residue from the evaporator are incinerated or landfilled.

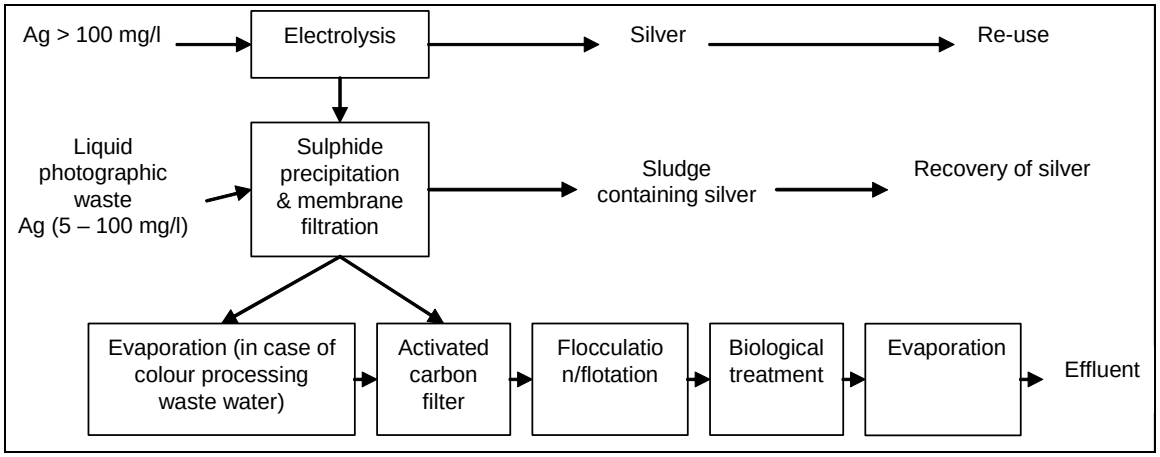


Figure 2.17: Treatment of liquid photographic waste
[156, VROM, 2004]

Users
Photographic industries.

2.5 Treatments primarly aimed at producing material to be used as fuel or for improving its energy recovery

[5, Concawe, 1996], [7, Monier and Labouze, 2001], [8, Krajenbrink, et al., 1999], [11, Jacobs and Dijkmans, 2001], [13, Marshall, et al., 1999], [21, Langenkamp and Nieman, 2001], [40, Militon and Becaud, 1998], [50, Scori, 2002], [52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [57, EIPPCB, 2001], [58, CEFIC, 2002], [59, Hogg, et al., 2002], [64, EIPPCB, 2003], [81, VDI and Dechema, 2002], [86, TWG, 2003], [114, Hogg, 2001], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004].

This section covers those treatments and processes which are mainly applied to obtain a material, prepared from waste, to be used as fuel or to change its physico-chemical properties to allow a better recovery of its calorific value. Some treatments may produce some outputs that may be used for other proposes other than as fuel. These processes are very similar and only depend on the physical properties of the starting waste and the physical properties that the waste OUT needs to have to be able to be burned in a combustion chamber. Discussion of the actual combustion of the waste is not in this document as it is covered in the individual sectorial BREFs (e.g. waste incineration, cement and lime, large combustion plants, iron and steel, etc.).

Waste which has some calorific value is currently used as a fuel in certain combustion processes, e.g. waste incineration, in cement or lime kilns, large combustion plants, heating plants, chemical works, industrial boilers, ceramic plants, brick production, iron and steel production, non-ferrous metal production. Some of the sectors using waste as a fuel are directly linked to the production of that waste. This implies that some wastes, produced in stable processes (therefore of a certain consistency), may not need any further preparation for their onward use in that sector and therefore they are often delivered directly to the plant where they will be used (e.g. used oils, used solvents). In these cases, no treatment is carried out on the waste, so consequently this activity is not included in the scope of this document (these ones represented in the following Figure 2.18 as brown arrows). The type of waste streams that are technically suitable for use in co-incineration plants is an issue that will be tackled in individual sectorial BREFs. This document considers and analyses the environmental issues involved in handling and transforming different types of waste into a material suitable to be used as fuel in different processes as represented by the blue arrows in Figure 2.18.

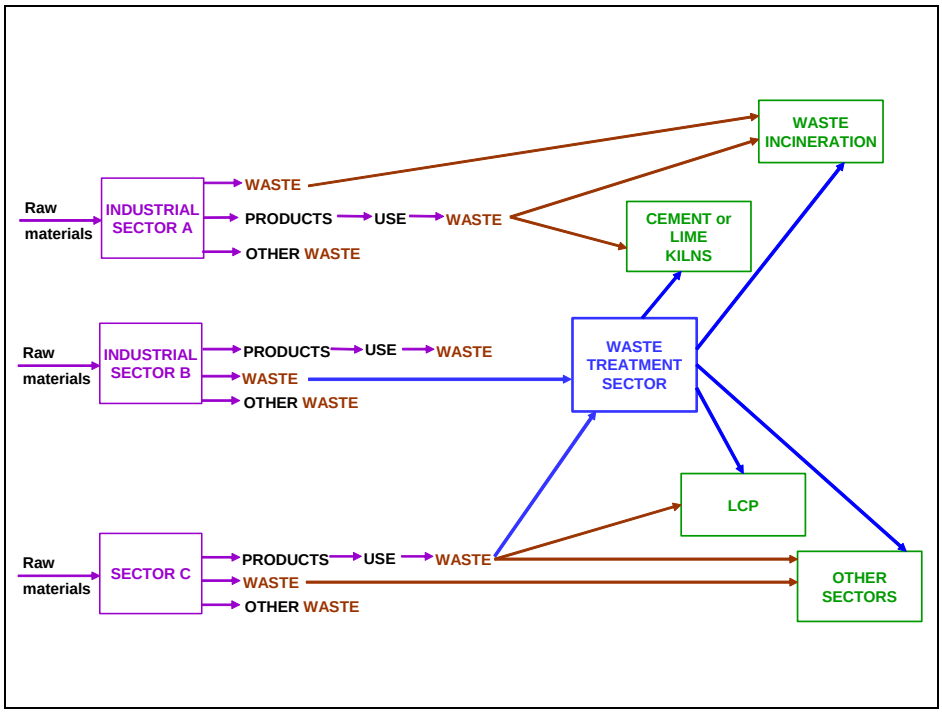


Figure 2.18: Some current possibilities for the use of waste as a fuel in different sectors
Note: This figure does not intend to show all the possibilities that may appear. Some options are not shown in the figure to increase its readability

To cite a few instances, the use of waste oil as a substitution fuel without any treatment is one option that is used across Europe, varying in popularity depending on local economic and legislative circumstances. Most national regulations allow the burning of waste oil in cement kilns. Waste oils are accepted under special conditions as cement kiln fuel in France, Germany, Italy, Spain and the UK, but seem to be banned for that use in the Netherlands, for instance. In other countries they are simply not used.

Common techniques used in the production of these materials for their use as a fuel are described in Section 2.1.

2.5.1 Preparation of solid waste fuel mainly from solid waste

2.5.1.1 Preparation of solid waste fuel by mechanical (and biological) treatment from non-hazardous wastes

Purpose
The main purpose is to prepare a combustible material out of municipal solid waste (MSW). Other purposes are mentioned in Section 2.2.2. The main function of the fuel preparation is to upgrade selected materials into a specified fuel. This section also covers the preparation of solid fuels by blending/mixing. Broadly, it is possible to distinguish two types of MBTs:

- 'separation' facilities -which seek to split residual waste into 'biodegradable' (that may be dried and used as fuel) and 'high calorific' fractions, and
- 'dry stabilisation' processes, which are less concerned with the splitting into fractions, and more aim towards the use of heat from a 'composting' process to dry the residual waste and increase its calorific value, therefore making it suitable for use as a fuel as well as to improve the separation of fractions.

Principle of operation
This type of fuel is manufactured by sorting wastes mainly to leave a combustible material, by mainly removing wet putrescibles and heavy inerts (stones, glass, scrap metals, etc.) from the wastes. Other operations used are for example sieving, separators, crushers, screening and picking.

Solid fuel preparation technologies vary considerably depending on the source and type of waste, and on the user requirements of the customer/combustion installation.

It is very important to bear in mind that waste is a heterogeneous mixture of materials, especially municipal solid wastes. Therefore, in producing the fuel, the producer makes a fuel more homogeneous by utilising preparation technology and specific waste processing.

Feed and output streams
See Section 2.2.2. This activity is commonly used for the treatment of non-hazardous waste. Solid fuel can arise from many different sources, such as pre-use of industrial residues, post-use of industrial waste, selected fractions from commerce and households, and from construction and demolition activities. The input to the process then may be either direct industrial waste or mixed waste (typically as the level of mixing increases, the need for waste preparation increases). Depending on the source, the composition and amount of contamination of the waste OUT will differ.

MSW, 'commercial' waste, and construction and demolition waste are the most common sources. The most common waste materials are paper, plastic, wood and textiles. Another type of waste typically used is the paper fraction (paper + plastic + rubber) from oil filters. This contains a high calorific value.

It is possible to distinguish two major fuel types: shredded or fluff-like material and densified fuels, such as pellets, cubes and briquettes. Densified recovered solid fuel can have lower heating values (LHV) i.e up to 30 MJ/kg depending on composition. The reported minimum calorific values vary from 3 to 40 MJ/kg. Other data report that the input, which may typically have a starting calorific value of c. 8.4 MJ/kg can increase its calorific value to c. 17 MJ/kg mainly by separating out the non-combustable fractions (e.g. inorganic materials and water).

Waste plastic can be substituted for other solid fuels, such as coal, peat, wood, petroleum coke, etc. There are a number of developments currently being carried out on fuel substitution, as well as some demonstration plants currently operating using solid waste plastic.

The treatment to produce solid waste fuel divides the MSW into two fractions. The calorific value and the composition of these fractions are different and also differs from the MSW treated. The fraction that remains after the extraction of the solid waste fuel may represent a high percentage of the MSW treated.

Process description
See Section 2.2.2. Depending on the source and the use, these wastes are shredded, separated, blended and pelletised. A typical example of a flow sheet is: input (waste), mechanical transport (e.g. conveyer belt), separation (e.g. by drum sieves, air classifiers, handpicking, magnets, dryers), size reduction (e.g. by crushing, shredding), size increasing (e.g. baling, pelletising), and finally output (fuel). Several examples applied in this process are known: reducing/removing/changing physical and/or chemical contaminants. Figure 2.19 only shows one main characteristic - automatic picking. Near infrared spectroscopy or metal separation also influences such properties as for example heavy metal contents. Figure 2.19 presents an overview of some common process units, which may be applied for solid waste fuel production. The number and kind of processing steps applied depend on the waste composition and the desired waste OUT qualities.

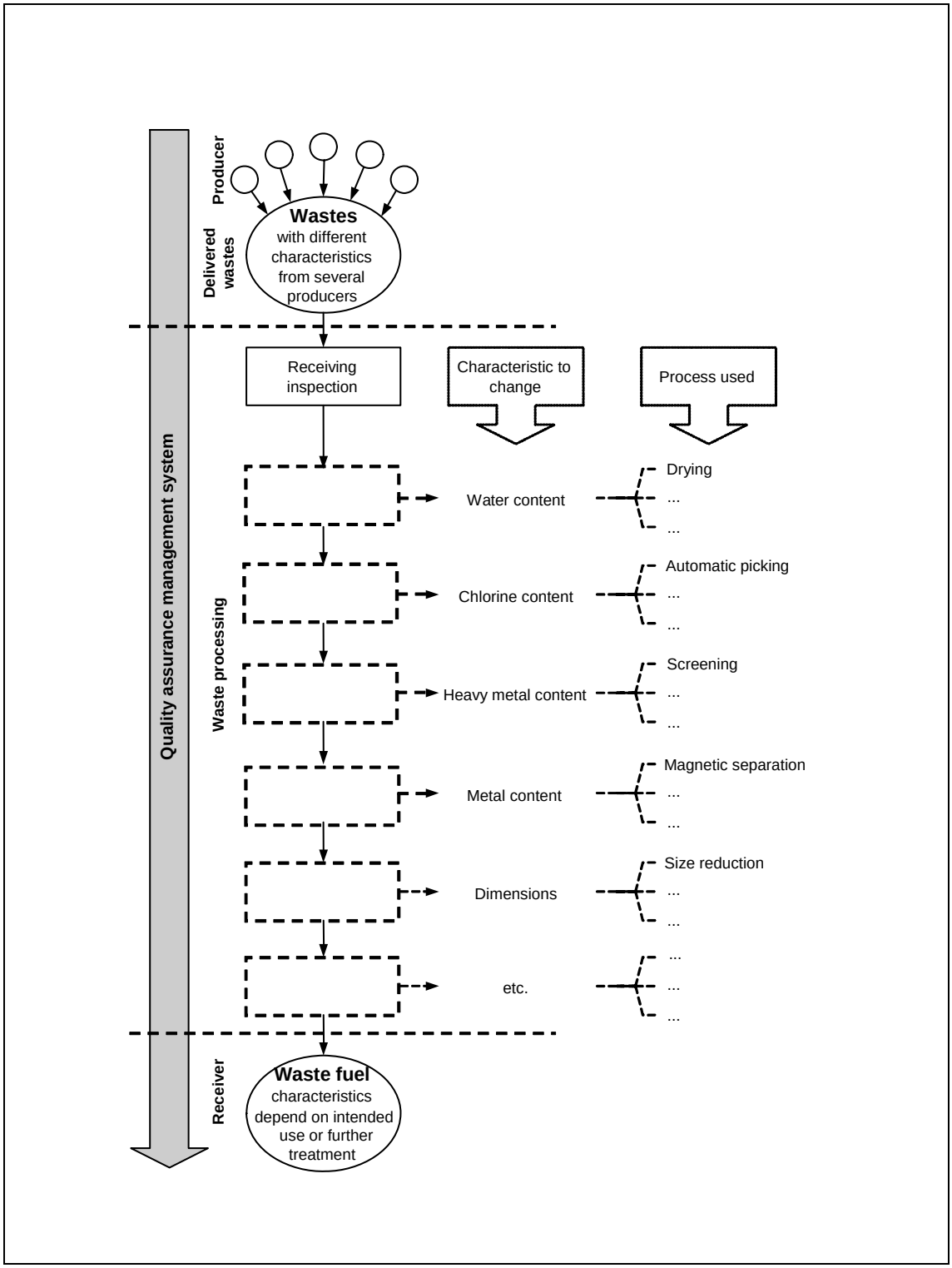


Figure 2.19: Process scheme of solid waste fuel production [126, Pretz, et al., 2003]

Source selection may be the first action to take into account for monostreams. Preselection may be incorporated in the collection system for mixed commercial wastes. The waste receiving area is the first important facility with regard to the quality assurance management system and this is where a receiving inspection is carried out. All kinds of disturbance materials which might cause operational or quality problems, need to be sorted out at this early stage.

The production of solid waste fuel can be divided into several steps which are listed below. However, this list only presents an overview of possible techniques; each technique is not necessarily part of each process:

- receiving area/bunker
- presorting/contaminants selection
- feeding equipment - wheel loaders or cranes are usually applied for the feeding of the process
- size reduction - comminution can be achieve by hammer mills, shear shredders, single shaft shredders, rotary cutters, cam shaft shredders and cascade mills
- metal separation - to separate, for instance, ferrous metals out of the solid waste, it is possible to use a number of techniques based on the different properties of the material. The most important characteristics in waste treatment are density, shape, magnetic susceptibility and electric conductivity. The type of systems mostly used in this sector are magnetic separators (overband magnetic separators, magnetic drum separators, magnetic pulleys) or Eddy current separators (to separate out non-ferrous metals)
- classification - classification can be carried out by drum screens, linear and circular oscillating screens, flip-flop screens, flat screen, tumbler screens and moving grates. A very important processing step, within classification is the screening step, before and after grinding. Screens are applied to allow mass and volume division by particle size. It is noticeable that in small particle size mixtures, the content of hazardous substances accumulates compared to the amount found in the screen overflow. A classification with sieves is applied in waste treatment processing when:
  - materials from an upstream process need to undergo some kind of conversion to make them suitable for further processing steps, i.e. separation into defined size fractions
  - a separation of coarse or fine particle sizes is required
  - a comminution material has a high content of particles of the final particle size and only oversized particles should be reduced in size again
  - certain materials need to be concentrated. In this case, the processing is called sorting classification. This also includes separation of the small size fractions, which often contains a high content of heavy metals substances
- air classification (e.g. by air classifiers or aeroherds)
- near infrared spectroscopy
- automatic picking
- compacting/pelletising can be carried out by flat bed presses, ring die presses, or disc-agglomerators
- storage/storage area/hopper
- biological degradation/thermal drying - If the water content has to be reduced to increase the calorific value, a drying process step is necessary. This can be implemented as a thermal or biological drying step. It may be necessary to dry the waste in order to achieve higher sorting/classification ratios of waste
- exhaust gas collection and cleaning
- waste water treatment
- loading and transportation.

After the final processing step, a solid waste fuel is obtained. In some cases additional processing steps may be required to design the solid waste fuel according to the consumers' wishes. For example, further compacting or further size reduction may be requested. Table 2.15 shows the correlation between different fuel preparation processes and the end application for different purposes.

Prepared fuel in form of	Co-combustion process			
	Cement kiln	**Circulated fluidised bed**	**Pulverised coal power plant**	**Gasification and pulverised coal power plant**
Bales	Shredding (fluff), covered storage	Shredding (fluff), covered storage	Pelletising, storage, pulverisation	Shredding (fluff), covered storage
Soft pellets/fluff	Covered storage	Covered storage	Covered storage	Covered storage
Hard pellets	Covered storage, simple crushing	Covered storage	Covered storage, pulverisation	Covered storage
Chips				
Powder				

Table 2.15: Additional processing steps required according to the physical form, to deliver waste fuel to consumers' specifications
[126, Pretz, et al., 2003], [150, TWG, 2004]

Once the combustible material has been separated, it is then shredded and either sent to the customer, or pelletised before it is sent for combustion (this usually occurs when the material is burned off-site, as a densified fuel reduces transport costs).

Users
The combustible material is typically incinerated in dedicated facilities or co-incinerated in plants where a combustion process is carried out. The major fuel application is in cement/limestone production and power generation. Depending on the end application, there are different requirements for waste fuels.

This type of installation can be found in the Netherlands, Italy, Germany, Austria and Belgium, and constitutes a basic template for some 'integrated facilities' planned in the UK. The blending of large volumes of solid wastes is common practice in a number of EU states (e.g. Belgium, France, Germany, Denmark, etc.).

The processing of solid waste fuel is not a standardised process. The extent of processing carried out depends to a certain degree on the type of waste being received (input) and to the actual application of the solid waste fuel.

In mechanical biological treatment, the process used in the production of solid waste fuel is a kind of mechanical upstream facility, because the high calorific wastes are separated out before the rest of the material is fed into the biological degradation step to lower its organics content. In some cases, the biological degradation step is part of the production of solid waste fuel, with the main focus being on lowering the water content. In other cases, the biological degradation step is also arranged in the production of solid waste fuel, but the main focus may be on lowering the organics content, to maintain the respective disposal criteria for any material which is not part of the solid waste fuel and which needs to be disposed of. Depending on the applied process, different regulations for emissions may apply.

In some cases, the entire waste is dried by physical and biological processes for several days (e.g. in Germany, 7 days) under high aeration rates in a closed bio-reactor. Within this process, the organics content is reduced only slightly, and the separation behaviour is improved significantly. This is followed by a separation into a heavy and light fraction. The light fraction is used as RDF after further separation of the metals. The heavy fraction (about 15 %) is separated into metals, glass, batteries and mineral components for re-use.

2.5.1.2 Preparation of solid waste fuel mainly from liquids and semi-liquid hazardous waste

Purpose
The goal of the preparation of such fuel is to make a tailor-made, homogeneous, and free flowing waste fuel, which can be used in combustion processes and this may also make it easier for it to be traded/used.

Principle of operation
Mechanical preparation of solid waste fuel including, for instance, the impregnation of waste over a support (e.g. sawdust, crushed paper or cardboard, adsorbents).

Feed and output streams
The types of wastes used are pasty, powders and solid waste, mainly hazardous. In some specific cases, some liquid wastes may be used.

Process description
An example process of a layout for the production of solid waste fuel is presented in Figure 2.20. The design of the layout, as well as the selected installation, is chosen according to the type of waste, the availability of the waste, as well as the end specification of the waste fuel.

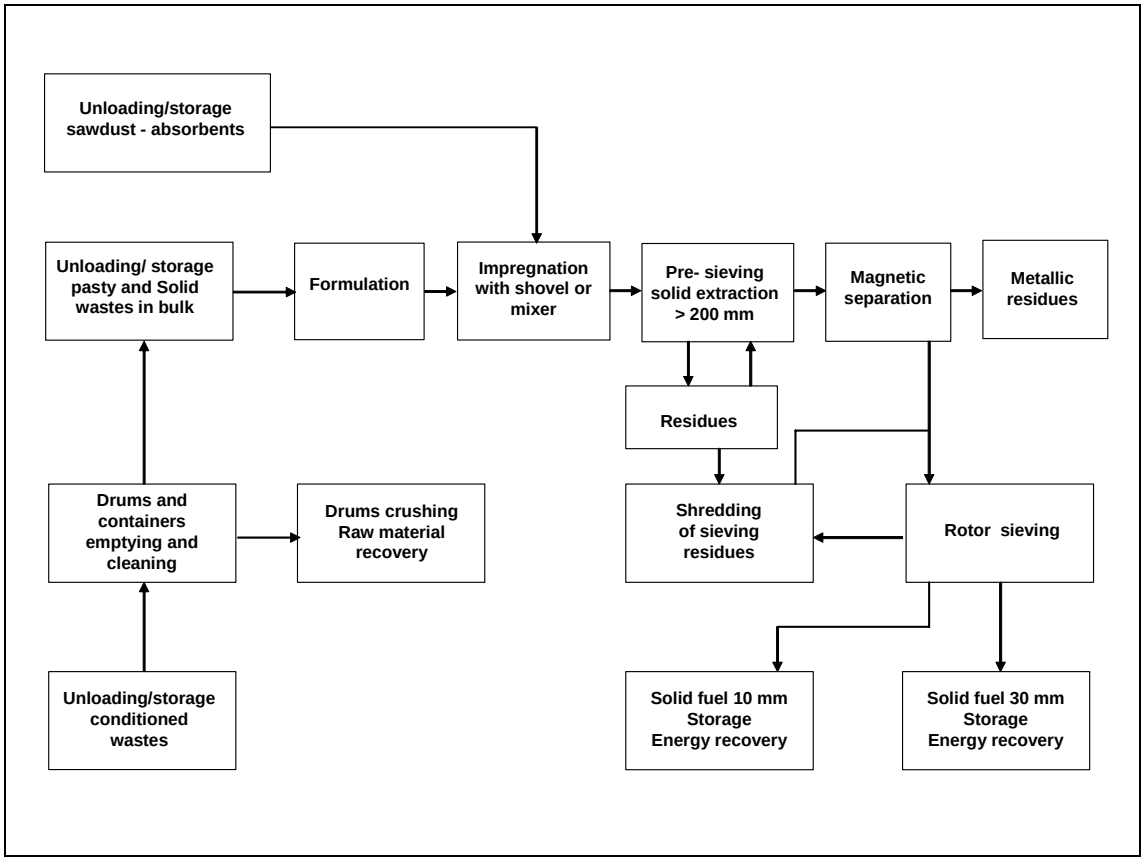


Figure 2.20: An example of the production of solid fuel from liquid or semi-liquid hazardous waste [122, Eucopro, 2003]

The main processes and production steps are:

- feeding of the waste from the storage to the production units. Pre-homogenisation of the incoming wastes is based on physico-chemical characteristics. This step is critical for ensuring the compliance of the waste fuel with the final users specifications
- shredding and/or sieving of coarse particles. Wastes that contain big particles need to be shredded or sieved before introduction into the mixing unit
- feeding of the mixing unit
- mixing operations. Materials can be fed directly or through a hopper to stabilise, regulate and control the quantity of waste introduced in the mixing unit. A conveyor belt is used after the mixing operation to transport the material to the sieve
- scrap extraction by magnetic separators or Foucault (Eddy) current systems to remove non-ferrous metals
- sieving operations by rotary or vibrating sieves. The dimensions, as well as the design of the sieve mesh depend on the granulometry specifications and the off-specification waste fuels (different fractions are possible on some installations, depending on the re-use possibilities of the big particles). Off-specification fractions can be reprocessed in the production, treated in a dedicated shredder, and/or treated in incineration or dedicated co-processing units
- storage of waste fuel before loading
- dispatch of the waste fuel. Loading of the trucks (or potentially trains or ships) is carried out by cranes, conveyor belts or bulldozers
- cryogenic crushing and separation of used packaging of paint, ink, and similar substances.

Users
Co-incineration plants (e.g. cement kilns).

2.5.1.3 Preparation of solid waste fuel by the carbonisation of contaminated wood

Purpose
Carbonisation of contaminated wood can be carried out to obtain a vegetal carbon to be used as fuel.

Principle of operation
Carbonisation of wood at a relatively low temperature (300 – 400 °C).

Feed and output streams
Contaminated wood is converted to coal, that can then be used as fuel. The metals are recovered and valorised in the metallurgic works.

Process description
The process is divided into three types of operations:

a. cutting of the wood in order to obtain a material with homogeneous granulometry and composition
b. carbonisation of the wood shavings in order to obtain a vegetable coal concentrating all of the metals. The carbonisation is carried out at temperatures between 300 and 400 °C in a low oxidant atmosphere. In this way, the organic compounds are gasified and the heavy metals are concentrated in the carboneous residue. This residue is then extracted from the oven and the gas is treated at 850 °C for two seconds
c. extraction of the heavy metals. This is an essential step to obtain pure carbon (with a calorific value of 27000 kJ/kg). A fine crushing is undertaken in order to separate the metal crystals of the carbon structure. The metals (3 w/w-%) are separated by centrifugation and the carbon is aspirated from the centre through a bag filter. The metals are recovered in metallurgic processes.

Users
One installation in France.

2.5.2 Preparation of liquid waste fuels

In this section, treatments carried out to prepare liquid fuels from liquid or semi-liquid materials are covered. The liquid waste fuel produced has properties enabling it to become fluid and move when a difference of pressure or gravity is applied. Some of the materials produced may be very viscous and can be very difficult and expensive to pump, however they still maintain fluid properties. The waste OUT of these treatments are referred to in this section as 'liquid waste fuel', regardless whether the fuel is semi-liquid or liquid. Those processes that start from liquid or semi-liquid waste and end up as a solid waste fuel are included in Section 2.5.1.2.

Typically, the materials prepared by these types of treatments are hazardous wastes. Several liquid waste fuels can be prepared according to the different wastes and market requirements:

- organic liquid preparation by blending
- fluidification
- emulsions
- sludges (the preparation of these types of waste is considered as an emerging technique).

The main processes used in the preparation of wastes to be used as fuel are:

- knowledge, controls, follow-up and traceability of wastes (a common technique as described in in Section 2.1)
- transport of wastes (a common technique as described in in Section 2.1)
- reception of wastes (a common technique as described in in Section 2.1)
- unloading of wastes (a common technique as described in in Section 2.1)
- storage units used before treatment
- reconditioning
- homogenisation and blending
- crushing
- sieving
- fluidification
- phase separation for liquid wastes: settling, centrifugation, extraction, …
- drying
- washing.

2.5.2.1 Preparation of organic liquid waste fuels by blending mainly hazardous wastes

Purpose
The aim of this operation is to blend and homogenise compatible wastes from several producers and/or sources. The purpose of this operation is to:

- provide a nearby service to producers with only small quantities of organic liquid wastes
- rationalise the logistic organisation (transports, etc.)
- develop an adapted solution for packed wastes with several phases (liquid/pasty or solid)
- separate the different phases (water, organic liquid, sludges or solid) from a composite waste in order to optimise the recovery
- prepare the homogeneous and stable wastes in accordance with specifications.

Principle of operation

These operations may involve the grouping of small quantities and/or pretreatment activities such as phase separation or settling. Blending and homogenisation are the main operations.

Feed and output streams

Liquid and semi-liquid waste with a high organic content. The wastes utilised include solvents, oils, oil sludges, emulsions, distillation residues, tank bottom sludges, oil emulsions from mechanical and metallurgy industries, wastes and sludges containing oil from petroleum refining and from the collection and storage of oil materials, waste from oil distillation and regeneration from production failure; pasty wastes such as grease, ink and adhesives wastes; pulverulent wastes such as paint powder, washing powder wastes, etc.

Process description

An example of a process layout for the preparation of liquid fuel from waste is presented in Figure 2.21.

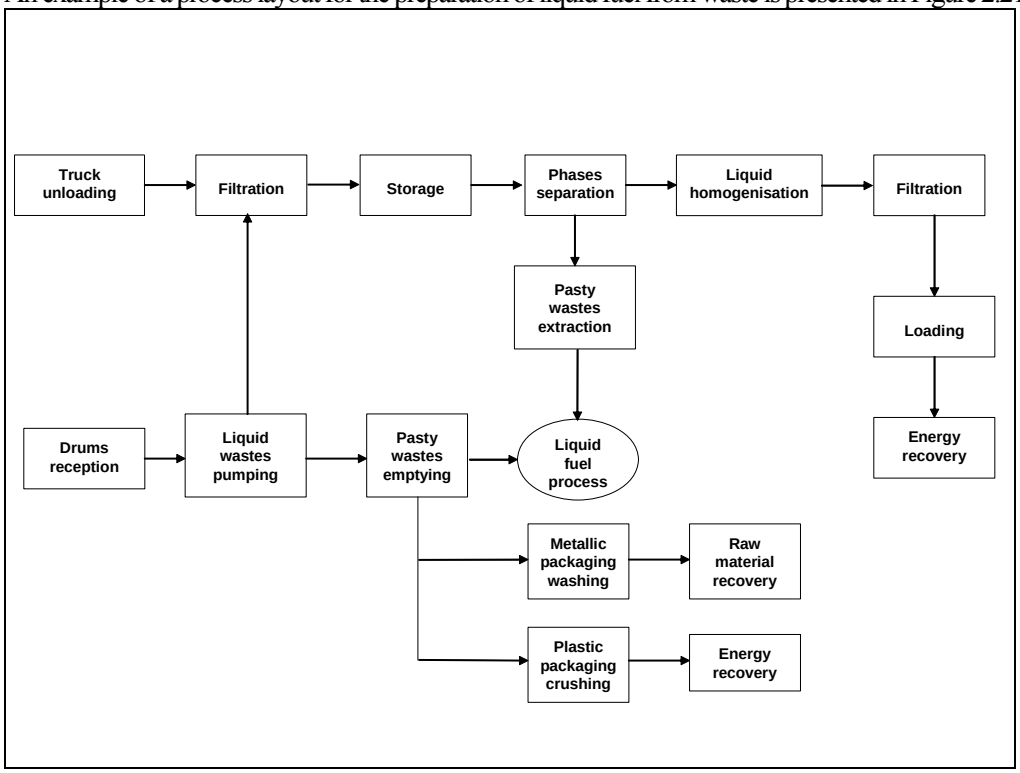


Figure 2.21: An example of the process layout for the preparation of organic liquid waste fuel [122, Eucopro, 2003], [150, TWG, 2004]
Note: 'Liquid fuel process' uses pasty waste to produce other liquid fuels

The main processes and production steps are:

Unloading and grouping

- liquid wastes in bulk. After filtration and/or settling, organic liquids are sent with a centrifuge or membrane pump to metallic cylindro-conical tanks equipped with a blending device in order to avoid settling or phase separation (consisting of a pendular mixer or pumping system which blends the top and the bottom of the tank by continuous circulation)
- packed wastes (drums, etc.). Before grouping, the packagings are emptied with techniques adapted to their physico-chemical characteristics. Generally, two phases exist: a liquid one and a pasty (and sometimes solid) one in the bottom of the drum.

Preparation

This step consists of operations such as settling, grinding, filtration and blending. A stirring propeller or a recirculation system is used in order to keep the wastes homogeneous. Sometimes, a grinding system is used with a recirculation technique in order to decrease the granulometry of any solid particles which may be in the liquid waste.

Dispatch
Before loading, the liquid preparation is filtered through a 3 mm filter. The loading of the trucks is carried out with all the security systems necessary.

Users
Co-incineration plants (e.g. cement kilns).

2.5.2.2 Preparation of liquid waste fuels by fluidification of hazardous wastes

Purpose
The aim of this operation is to blend and homogenise compatible wastes from several producers and/or sources.

Principle of operation
Fluidification means processes where liquid, pasty and solid wastes are homogenised and shredded together in order to produce a liquid fuel which can be used as fuel.

Feed and output streams
Typically hazardous waste such as oil residues, used solvents, residues from organic chemical synthesis, oil and grease, etc.

Process description

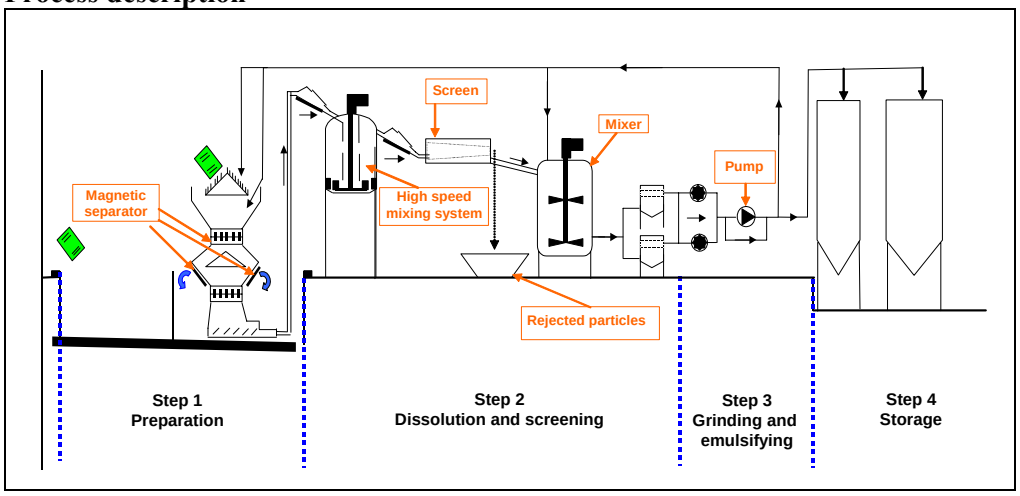


Figure 2.22: An example of the process layout for the production of liquid waste fuel by fluidification
[122, Eucopro, 2003]

The main processes and production steps are:

Pre-homogenisation
Pre-homogenisation of the incoming wastes is based on the physical-chemical characteristics. Pre-homogenisation consists of producing a premix with physical characteristics acceptable for the fluidification process. This step prevents different kinds of problems arising inside the process, such as blockages in the hoppers/pipes/machinery.

Feeding of the waste from the upstream storage facilities to the fluidification process
Solid wastes are handled with a mechanical shovel, hydraulic arm, crane bridge or hydraulic loader. They are transferred to the fluidification process with a screw conveyor or a reddler conveyor. Sludges are handled with hydraulic shovels, crane bridges and/or hydraulic piston pumps able to handle high viscosity materials. Liquid wastes are handled by pumps. Pumping technologies must be able to accept fluctuations in the quality and presence of particles in suspension.

Fluidification process
This is composed of four main steps:

'Calibration' of the pasty part
This step consists of shredding coarse particles, extracting any foreign metallic parts blended accidentally with chemical wastes and then transfering this pasty material into the mixing tank. The shredders used are slow motion shredders, used for flammable and low flashpoint wastes (e.g. mono-rotor or bi-rotor rotary shears) and dedicated shredders for specific wastes (e.g. cryogenic shredders). Technologies for the extraction of undesired solid portions include ferrous and non-ferrous metal separators for metals and vibrating sieves and/or static grates for bigger particles. The transfer of the material is carried out by screws and pumps (e.g. concrete pumps).

A simplified design is also possible for lower investments: this consists of a smaller capacity unit, which is dedicated to less difficult wastes (i.e. that free of coarse pieces). In this case, the material may be transferred into the mixing step by shredding. A rotary filter may be installed to remove large quantities of useless materials

Dissolution and screening
his second step dissolves and emulsifies the pasty parts into a solvent phase, to obtain a homogeneous material.

The dissolution of solid organic compounds in a liquid phase composed of solvents and/or waste water is carried out by special mixers, rotary screens and buffer tanks. The mixers must respond to the constraints of the sticky material containing strong and voluminous solids in suspension. They pulverise the solids between rotor and stator and blend them into the liquid phase. Next, the liquid mixture is admitted inside a rotary screen, which extracts the pieces of plastic lining fragmented by the shreddinig in the previous step. A buffer tank collects the material in the course of preparation at the end of this step

Grinding and emulsifying
This third step consists of finely grinding any solid particles remaining in suspension in the liquid phase. It also consists of making a fine emulsion between the aqueous phase and the hydrocarbons phase constituting the liquid waste fuel. The stability and the quality of combustion of the waste fuel depends directly on both its homogeneity and the size of fragmentation of the solids in suspension.

These criteria require high velocity technologies of grinding/emulsifying protected by magnetic separators and mechanical filters. The equipment must be flexible enough in order to accept fluctuations in viscosity, density and the nature of the solids in suspension.

The liquid waste fuel is controlled at this step, during the filling of the buffer tank. Some parameters such as pH and viscosity can be controlled continuously in process. Other parameters such as LHV, composition and flashpoint, are controlled from samples taken during the production. If the quality does not meet the specification, the fuel must be reprocessed before being transferred to the storage unit.

A simpler design is possible for small capacity units: here steps 2 and 3 may be carried out at the same time. In this case, the mixing and buffer tank will be the same and the grinding line will run into the mixing tank.

Storage and dispatching
Once a high level is reached inside the buffer tank, the material can be transferred by pump into the final storage. During this transfer, a latter adjustment of the quality of the fuel can be carried out by means of grinders and filters operating on the transfer line. The storage capacity is generally composed of vertical cylindrical-conical tanks with blending equipment. Two technologies of blending are appropriate to homogenise the liquid fuel:

- a long marine mixer installed on the roof of the tank
- a pumping system which blends the top and the bottom of the tank by loop circulation.

Dispatching to the customer is carried out by a truck loading station. This loading station is fed by the storage unit mentioned above.

Users
Co-incineration plants (e.g. cement kilns).

2.5.2.3 Preparation of emulsions from liquid/semi-liquid hazardous waste

Purpose
The aim is to produce a homogeneous and stable waste fuel from liquid and semi-liquid waste.

Principle of operation
This process is based on the control of blending by means of the addition of selected chemicals or tensides.

Feed and output streams
Emulsions are typically produced from hazardous wastes such as oils and emulsions from the mechanical and metallurgy industries, wastes and sludges containing oil from petroleum refining, production failure, etc.

Process description
Installations are similar in design and layout to those used for the pasty raw meal preparation for clinker production in cement kilns.

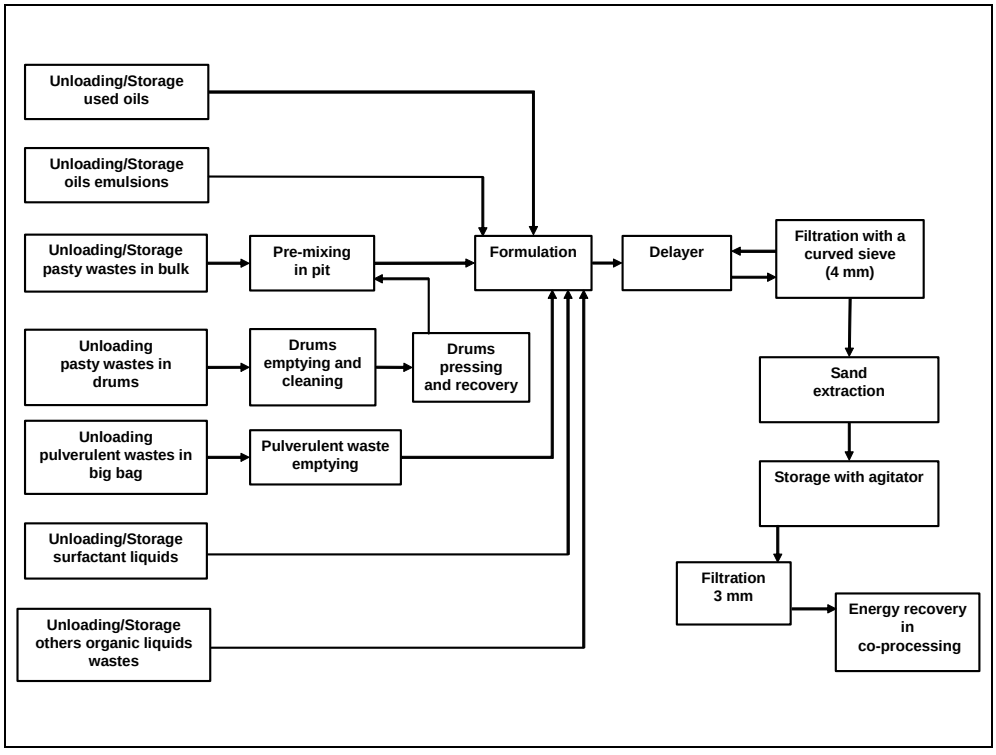


Figure 2.23: An example of the process layout out for the preparation of emulsions [122, Eucopro, 2003], [150, TWG, 2004]

The main processes and production steps are:

Feeding of the waste from the storage to the production units
Before introduction into the production process, wastes are deconditioned with equipment adapted to their physical characteristics. Pasty wastes extracted from drums are put in special pits. They are first handled by mean of a mechanical shovel to a homogenisation pit. Then, they are transferred to a hopper in order to be introduced to the production process by a screw conveyor or a concrete pump. Pulverulent wastes, such as paint and washing powder, are received in big bags. They are directly put into the production process with equipment adapted to capture dust emissions. Liquid wastes are handled by pump. Pumping technologies (centrifuge pump, volumetric pump with out-rotor, etc.) must be able to accept a viscosity fluctuation and the presence of particles in suspension

Formulation
According to the physical-chemical characteristics of the waste stored, the laboratory defines the specifications, including the nature and quantities of wastes, which can be put into the production processes. Compatibility tests are also developed. Such tests are carried out at any operation, in order to comply with the waste fuel specifications

Production process
The production process which is a batch process is carried out by special mixers (called 'delayors'), closed in order to prevent VOC emissions. The different components are introduced in the mixer according to laboratory specifications. An agitator provides for stable emulsion production. During this step, several parameters are monitored, such as viscosity, pH, temperature and motor specification. One of the purposes of this monitoring is to detect any polymerisation reactions, as these could cause production problems

Screening
Once the emulsion is achieved, it is circulated again with a centrifuge pump to the mixer and through a curved screen providing particle retention above 4 mm

Sand extraction
When the mixer is emptied and before being sent to the storage capacity, the material is pumped to a concrete pit with a sedimentation area. The aim is to separate through density any mineral solid particles (e.g sand) which may be present in the material

Storage and dispatching
The material is transferred by centrifugal pump to storage. The capacity of the storage is generally composed of concrete or steel vertical cylindrical tanks with blending equipment.
Three technologies for blending are appropriate to keep the homogeneity:

- a submerged agitator
- a low agitator with a scraper in order to avoid sedimentation
- a pumping system which blends the top and the bottom of the tank with high flow (around 250 m^3/h) loop circulation.

The waste fuel quality is controlled in order to be sure that its characteristics comply with customer specifications. In some specific cases, the addition of waste with a high calorific value may be made if the calorific value is considered too low.

Dispatching to the co-processing factories is carried out by a truck loading station. A final screening (through a filter of 3 mm size) is undertaken whilst loading.

Users
Co-incineration plants (e.g. cement kilns).

2.5.2.4 Treatments of waste oil where waste OUT is basically used as a fuel

There are two main options for the treatment of waste oils (see Figure 2.13 in Section 2.4.1). One way is to treat the waste oil to reconvert it to a material that can be used as a base oil to produce lubricants. This is referred to as 're-refining' in this document and it is covered in Section 2.4.1. The other way is the treatment of the waste oil to produce a material that will be mainly used as fuel or for other uses (e.g. absorbant, mould release oil, flotation oil). These treatments are covered in this section. As is the case in the whole document, this classification has been adopted for this document and it is not intended to provide any attempt to define any of the R codes from EC waste legislation.

The calorific value of waste oils can be utilised. When used as a substitute fuel, principally for coal, diesel and light fuel oil, used oil has an economic value. A number of different burning applications for used oil exist, distinguishable partly by the temperature at which they burn, and partly by the control technology they use to reduce environmental effects. Before its use as fuel, several cleaning or transformation treatments may need to be applied. These are summarised in the Table 2.16.

Type of treatment	**Changes that occur in the waste oils after treatment**	**Fuel use**	**Industrial sector use**
No treatment. Used directly in a combustion process (Not covered in this document)	No change	Directly used as fuel in kilns, furnaces, etc.	Waste incinerators, Cement kilns, Space heaters (garages, green houses, workshops, etc.) [1], On-board ships (typically using marine oils), Quarry stone industries.
Mild re-processing	Removal of water and sediments	Waste fuel blend to fuel oil (replacement of fuel oil)	Cement kilns, Road stone plants, Large marine engines, Pulverised power plants
Severe reprocessing (chemical or thermal processes)	Demetallised heavy fuel oil (or heavy distillate)	Waste fuel blend to fuel oil (replacement of fuel oil)	Marine diesel oil, Fuel for heating plants
Thermal cracking	Demetallised and cracked material	Distillate gasoil	Gasoil (also called heating oil, diesel oil, furnace oil, etc.), Demetallised heavy fuel oil, Marine gasoil, Rerefined light base oil not used as fuel
Hydrogenation	Reduction of sulphur and PAH contents		
Gasification [2]	Converted to synthetic gas (H_2 + CO)	Fuel gas	Chemical production of methanol Large combustion plants (e.g. gas turbines)
[1] Forbidden in some MSs [2] More information in Section 2.5.3			

Table 2.16: Treatments applied to waste oils before their use as fuel
[5, Concawe, 1996], [7, Monier and Labouze, 2001], [86, TWG, 2003], [150, TWG, 2004]

2.5.2.4.1 Direct burning of waste oils

Burning waste oils without any treatment is one disposal/treatment option that is used across Europe, varying in popularity depending on local economic and legislative circumstances. There are four sectors identified where waste oils are directly burned: cement kilns (see Cement and Lime BREF); waste incinerators (see Waste Incineration BREF); as a reducing agent/fuel in blast furnaces (see Iron and Steel BREF), and in large combustion plants (see Large Combustion Plant BREF). As these are already covered in other BREFs, they will not be included under the scope of this document.

2.5.2.4.2 Mild reprocessing of waste oils

Purpose
To clean the waste oils to improve the physical properties, so that they can be used as a fuel by a wider variety of end users.

Principle of operation
The treatments involve the settling of solids and water, chemical demineralisation, centrifugation and membrane filtration.

Feed and output streams
Waste oils in general. A simple cleaning process is applied to waste oil destined for asphalt drying or for fuel blending before further use.

Process description

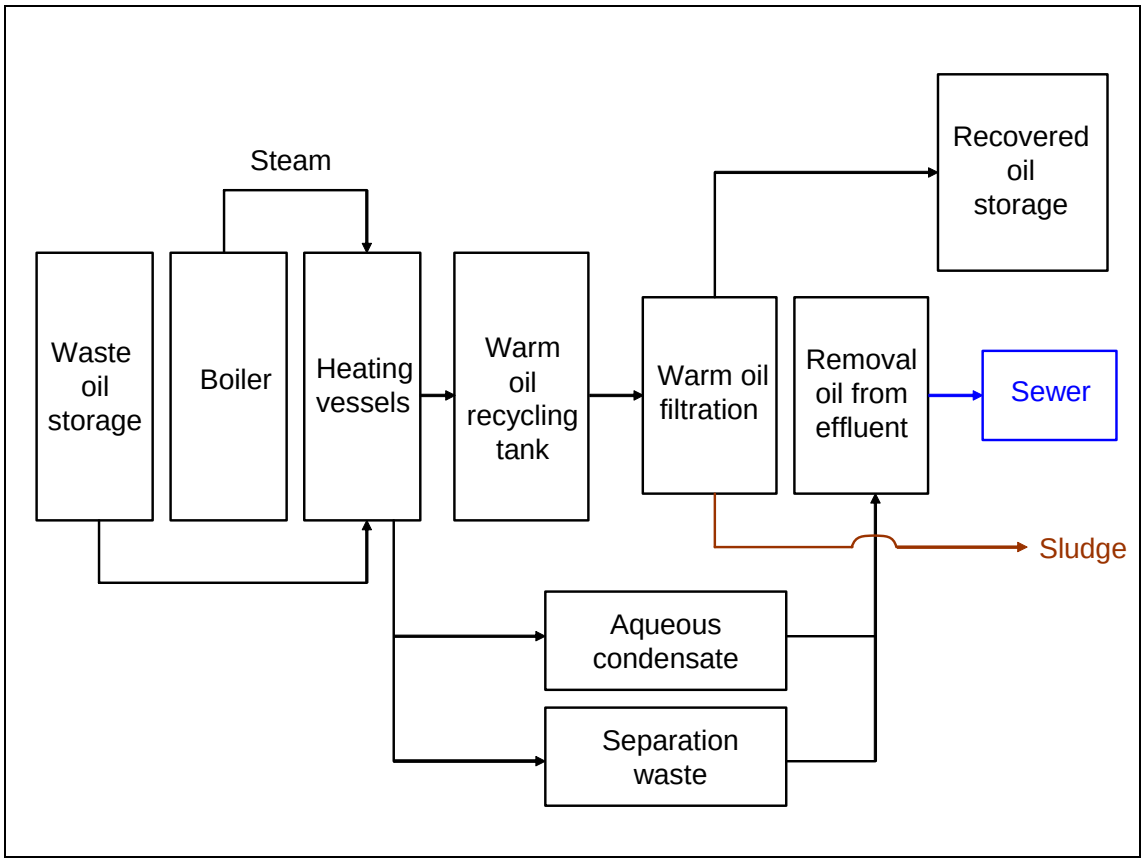


Figure 2.24: An example of a mild reprocessing of waste oil
[55, UK EA, 2001]

Settling
Water and sediments are settled in a tank after mixing the used oil with a demulsifier. Settling is facilitated by heating the tank up to 70/80 °C. If necessary, the clear oil is decanted and passed through a series of filters. The waste water and sediments are treated. A simple cleaning process to remove water and sediments (althought typically, this does not deal with the heavy metals, halogens and sulphur), is given before the further use of the waste oil as a replacement for fuel oil.

Chemical demineralisation
This process is used to clean metallic contaminants and additives. The chemical process relies on the precipitation of salts such as phosphates, oxalates and sulphates. The waste fuel is suitable for burning as 'black oil' and produces less air pollutants because of its pretreatment. Water is usually removed by demulsification and heating. The precipitate is removed by settling and filtration. Unfortunately, the chemicals and plant required are quite expensive when compared to the value added to the waste fuel produced. Also, a concentrated hazardous waste is generated.

Membrane filtration
Produces high grade recycled oil, a concentrated waste oil, and waste water.

Users
Used oil has been a substitute for light gasoil for several years. It provides a lowering of operational costs and useful a disposal route for used oil. Details of the extent of this route in Europe are unclear but it is likely that the combined fuel oil may be sold as bunker fuel, for use in asphalt plants and power stations. The material, after membrane filtration, is suitable for power station ignition fuel or as a diesel extender. Concentrated waste oil, after membrane filtration, can be used as coal spray, where contaminants are bound with silica compounds upon burning. Table 2.17 summarises some of the uses of waste oil after a mild reprocessing.

Sector where treated WOs is used	Comments	Countries where it is used
Road stone plants or asphalt mixing plants	Reprocessed WOs are burned to dry hard stone for the manufacture of road surfacing materials. The stones are dried, then sized, after which they are mixed with bitumen and filler	Common in Belgium and the UK. However, in Italy some environmental authorities do not permit this use
Dry limestone	Reprocessed WOs are burned to dry limestone. Some acid contaminants are likely to be captured by the solid material	
Blending into fuel oil	The processed oil may be blended into fuel oil. In this case, the maximum amount of processed used oil which may be blended with other heavy streams is limited by specifications on the ash content (generally about 0.1 % max.), and sulphur content and may be subject to meeting a viscosity range specification	
Power stations	Reprocessed WO is utilised in pulverised coal power stations, mainly as a furnace start up fuel, but it is also used sometimes as an addition to the main fuel where heat input is restricted. See the LCP BREF [64, EIPPCB, 2003]	
Burning used oil in space heaters	After a separate pretreatment step where water and sediments are removed, the cleaned waste oil (see Section 2.4.1.1) is burned in small space heaters in garages, workshops and greenhouses. Special standalone heaters are manufactured for this purpose. In this type of burner the exhaust gases are not usually scrubbed and emissions of harmful and polluting substances to air are likely. This route is usually carried out on a small scale (typically <10 MW_{th}). This use provides an economic heating source and the used oil is disposed of at the point of generation	Such burning is said to account for approximately 40 kt of used oil in the UK per year. In Belgium and Denmark it is illegal in most cases to use it in garages, workshops and greenhouses (it is necessary to have a permit to dispose of it as a hazardous waste)
On-board ships	Typically this involves used marine oils. The waste oil originating from shipping and from land sources is mixed in order to obtain better treatment and separation parameters. The oil is used as a finished waste fuel or as cutterstock, which means that different streams are blended in order to meet a viscosity range specification. The combined fuel oil is sold as bunker fuel. For the removal of the water the waste oil is decanted, if necessary demixing can be improved by adding emulsion breakers and/or raising the temperature. The oil is then filtered and centrifuged. The resulting oil goes to a storage tank and is sampled. Some cleaned waste oils are currently used in marine motors for electricity production	Some examples are in Spain

Table 2.17: Use of mild reprocessed waste oil (WO) as fuel
[55, UK EA, 2001], [86, TWG, 2003]

2.5.2.4.3 Severe reprocessing

Purpose
Burning after 'severe' reprocessing aims to separate the combustible WO portion from the less desirable bottoms fraction which contains the metals, the non-combustible ash, grit and dirt. The 'severe' reprocessing transforms the used oils into fuels which can be burned with similar conditions to those for burning other oil fuels.

Principle of operation
Uses of flash column and (vacuum) distillation columns to produce a cleaner waste fuel suitable to be used as fuel. Several commercial processes exists (see process description below).

Feed and output streams
The demetallised waste oil produced (also called heavy distillate or heavy fuel oil) is burnt as a marine diesel oil or as fuel for heating plants.

Waste OUT from the 'Trailblazer' process (see process description below)
- light hydrocarbons consisting of gasoline, kerosene, etc.
- vacuum distillates. These comprise ash-free hydrocarbons in the diesel range and meet the fuel oil specification for several applications, including for use as a marine diesel oil
- asphalt extender. This material is the residual bottoms from the vacuum tower. The metal, additives and degradation compounds are contained in the asphalt extender. The metal encapsulated in the finished asphalt material shows low leachability under a variety of tests.

Waste OUT from the propane de-asphalting process (see description below)
The base oil produced is only suitable as a diesel extender because they produce unfinished lube basestocks which are not marketable. The 'bottoms' produced are suitable as bitumen. This process yields more marketable materials than regeneration by chemical treatment or by hydrogenation. This is the reason why sometimes this process under certain operational conditions may be seen as a re-refining process because a high percentage of base oils are produced. More information can be found in Table 2.12.

Process description
Some chemical treatments exist (acid/clay, solvent extraction, propane extraction, etc., with no finishing step) as do thermal treatments ('Trailblazer' process, 'Vaxon' process, etc.). A short description of the processes currently available in the market follows:

'Vaxon' process
This consists of a series of vacuum cyclone evaporators, followed by a chemical treatment of the distillates obtained. There are several stages:

- the first stage removes water, naphtha and light ends
- the second stage removes gasoil, spindle oil or light fuel oil from the bulk of waste oil
- the third and fourth stages separate different distillate cuts from the residue (in which all the metals, additives, sediments, heavy hydrocarbons and degradation compounds are concentrated).

The resultant distillates are then available as good quality industrial fuel. This process has been modified to create re-refined base oils (see Table 2.12).

'Trailblazer' process
In this process the used oil is dehydrated in a flash tower, heat soaked and then processed by vacuum distillation to produce three output streams. The ash-free distillate oil yield with this process is 80 % on a dry basis.

Propane de-asphalting process (PDA)
Two types of process exist. These are called 'single-stage' and 'two-stages'. More information can be found in Table 2.12. Oil is mixed with liquid propane at a high pressure and ambient temperature in the de-asphalting unit for the separation of the residual asphaltic fraction. The components of waste oil that are not soluble in propane (i.e. the asphaltic fraction containing carbon, metallic additives, resins, additives, polymers, degradation compounds and asphalt), precipitate and can be removed via settling. The process consists of the steps shown in Table 2.18:

Dewatering and de-fuelling	Pre-flash. Water, light ends and fuel traces contained in the used oil are removed by atmospheric or mild vacuum stripping; one or two columns may be used for this operation
De-asphalting	PDA, fractionation and hydrotreating. Asphalt is separated by extracting the recoverable fractions of the used oil with liquid propane. Two versions exist: 1) single stage: downstream of the PDA extraction unit, the clarified oil is separated from the propane and fed to the hydrotreating. Finally, fractionation in a vacuum column produces the desired lubricating oil cuts 2) two-stages: the clarified oil coming from the first PDA unit is distilled and fractionated in a vacuum column. The bottom fraction, still containing impurities, is fed to a second PDA unit; the resulting asphaltic fraction is recycled back to the first PDA unit. The oil fractions coming from the side cuts of the vacuum column, along with the heavy cut clarified in the second PDA stage, are hydrogenated separately in the hydrotreatment. The two-stage process, compared to the single stage, provides an extended life for the hydrotreating catalyst, but has higher investment and operating costs
Fractionation	Vacuum distillation
Finishing	Clay or hydrotreatment: after the subsequent distillation steps, the chlorine content of the distillates is lowered by treatment with metallic sodium
Yield	74 % in dry basis for IFP process (97 % dewatering de-fueling, 80 % de-asphalting), 95 % hydrofinishing (medium pressure) 80 % in dry basis for the Snamprogetti. 5 % fuel, 9 % gasoil and 6 % residue
Common plant size	
Advantages	High yield and good waste fuel quality (if hydrotreated)
Drawbacks	More or less expensive according to the number of stages for the PDA. Significant amount of residues to be disposed of
Comment	Single-stage: IFP was the first company to apply this technology in 1968 at Pieve Fissiraga in Italy (Viscolube plant). One plant in Italy producing 57 kt/yr Two-stages: Snamprogetti installed this technology in 1982 at the Ceccano plant (Viscolube) in Italy.

Table 2.18: Information on the PDA process
[7, Monier and Labouze, 2001], [86, TWG, 2003]

Users
A 'trailblazer' process plant with a capacity of 150 kt/yr used oils is in operation in Louisiana, US. Some of those processes are similar to the ones used within refineries. The waste fuels of those processes are typically used as marine diesel oil or a fuel for heating plants.

2.5.2.4.4 Thermal cracking

Purpose and principle of operation
Thermal cracking uses heat to break down long-chain hydrocarbon molecules (e.g. the ones found in waste oils) into shorter ones thus generating lighter liquid fuels. In this way, larger molecules of more viscous and less valuable hydrocarbons are converted to less viscous and more valuable liquid fuels.

Feed and output streams
Thermal cracking can accept various types of hydrocarbon feedstock: waste oils, waste marine fuels, deep frying oils and, possibly with design considerations, waste plastics (e.g. waste oils returned in their original container). The strategy of thermal cracking is to crack viscous large molecules into more valuable shorter molecules ranging from demetallised heavy fuel oil to re-refined light industrial lube oil, including gasoil products as well as other materials for other uses. According to this, the thermal cracking can be configured to give the following set of outputs (Table 2.19).

Plant configuration	Outputs	%
1	Off-gases	5
	Naphtha	8
	Demetallised heavy fuel oil or marine gasoil	77
	Heavy residues	10
2	Off-gases	10
	Naphtha	15
	Gasoil (also called diesel fuels, heating oil, furnace oil)	65
	Light lube oil	Small fraction
	Heavy residues	10
3	Off-gases	5
	Naphtha	10
	Gasoil	30
	Re-refined light lube oil [1]	45
	Heavy residues	10
[1] Sometimes this configuration is enclosed as a re-refining process because of the high percentage of re-refined lube oil. Some cracked materials are used as flotation oil, mould release oil or as naphthalene absorbant in coke oven gas cleaning.		

Table 2.19: An example of outputs under appropriate operating conditions [7, Monier and Labouze, 2001], [86, TWG, 2003], [150, TWG, 2004]

If the configuration for gasoil production is desired, this is the most severe cracking mode and thus heat input is maximised and the throughput is at the design capacity. If demetallised heavy fuel oil or light lube oil is preferred as the primary output from the plant, the process operating conditions can be changed to achieve this. Due to these variability facts, thermal cracking offers a big opportunity to adapt to fluctuations in the market values of products.

Process description

The process operates at very high temperatures (thus evaporating all the water present). After removal of the water, much of the heavy metal content is removed as a sludge or via an acid treatment prior to the cracking step. The pretreated waste oil is thermally cracked at 420 °C at low pressure (without a catalyst). The subsequent distillation and stabilising steps yield a marketable fuel (gasoil). Depending on the intensity of the cracking, the material may either be a fuel oil, a fuel suitable for blending with diesel (diesel-extender) or materials used as light lube oil and for other uses. Several processes exist today, such as:

SOC processes

- SOC1: dewatering is followed by thermal cracking, performed in fired heater coils with soaking drums or heated kettles. This process is suitable to small plants, in the 6 to 15 kt/yr range but it has only a limited feed acceptance
- SOC2: dewatering is followed by thermal cracking, performed in an indirectly fired rotary kiln. This process is suitable for large capacities and can also process more refractory oils than thermal cracking (such as synthetic oils) and higher carbon residues (bunker fuels, etc.).

GNP processes

This thermal cracking of waste oils, utilising 'refinery calibre' systems and equipment, is a relatively recent development. The process consists of a screening and dewatering stage; followed by a thermal cracking stage; a separation or distillation stage, depending on the output mix desired; and finally a purification and stabilisation stage. This technology is characterised by large operational and output flexibility and adaptability to the changing market values of materials. It can also be manipulated to maintain output quality even with wide feed variability. As a matter of fact, the process operational conditions (temperature, pressure, residence time, etc.) can be varied to produce a primary output (be it heavy fuel oil, gasoil or base oil) that can be maximised, whilst minimising the secondary output streams (consumed in the process for calorific value or sold).

Thermally cracked gasoil is unstable if not further processed. It can discolour rapidly and precipitate gums and tars. A stabilisation and purification operation supplementing the thermal cracking can produce a gasoil which is not odorous, meets regulatory and consumer colour criteria, minimises the formation of gums and tars during storage and which is not highly acidic. For this, several methods are available:

- the 'Robys[th]' process
- several chemical stabilisation methods (clay absorption, solvent extraction)
- hydrotreatment. Except for a standalone WO thermal cracking plant, this treatment might not be feasible due to the very high capital costs and the requirement for hydrogen gas.

The typical yield for thermal cracking is 71 %, this resulting from the partial yields in the processes of 95 % dewatering, 90 % thermal cracking, 83 % distillation and 99.5 % purification/stabilisation.

Users
Thermal cracking is a common mineral oil refinery process that is well known and proven. At least two plants exist in Europe. One is a 40 kt/yr plant in Belgium and another a 20 kt/yr facility operating in Spain. The latter one mixes all the light and heavy fractions obtained to feed a thermal engine producing electricity. More than seven plants are in operation in the US, with a total capacity of more than 160 kt/yr. The plant size for this technology ranges from 7 - 40 kt/yr.

2.5.2.4.5 Hydrotreatment

Hydrotreatment is a dedicated name for catalytic hydrogenation in the mineral oil industry. For waste oils, the main purpose is essentially to remove PAHs. It also reduces the sulphur content in the oil (this is a potentially useful characteristic if diesel and diesel extender is the intended output).

2.5.2.5 Production of biodiesel from vegetable waste oils

Purpose
To produce biodiesel from vegetable waste oil.

Principle of operation
Involves cleaning of the waste oils.

Feed and output streams
The types of waste oils treated are collected in waste transfer facilities and from the restaurant sector. The outputs are mainly biodiesel, which are used for transport and glycerine.

Process description
First the waste oils are filtrated and water is removed. The waste oil is then separated by distillation to obtain the outputs.

Users
At least two plants exist in the EU (in Spain and Austria) and one is planned to be constructed in Portugal.

2.5.3 Preparation of gaseous fuel from waste

Purpose
To prepare a gaseous fuel from a liquid or solid waste.

Principle of operation
Two ways of producing fuels from waste exists and these are:

- gasification of the waste at high temperatures by partial oxidation and then conversion of materials containing carbon into synthesis gas (mainly H_2 and CO)
- production of biogas (mainly methane) by the anaerobic digestion of waste (covered under biological treatments in Section 2.2.1).

Feed and output streams
Used oil can be fed, alone or in combination with other feedstocks, to gasification plants for the conversion of materials containing carbon to synthesis gas (H_2 and CO). This process can also use mixed wastes that cannot be economically separated; for example, oil and plastic which may be found together when used oil is returned in its original container.

Process description
See the Refinery and the WI BREFs.

Users
Gasification technology has been used worldwide for a long time in more than 100 plants and it provides a well used option for the re-use of waste oil as well as other types of wastes. This option is typically used when gas fuel has a use on site. In Greve (close to Florence in Italy), a gasifier operates using the RDF pellets from Florence. Here, they use the gas fuel for two purposes. The first purpose is to produce electricity in a gas boiler plant for the national grid. The second purpose is to deliver gas to a cement kiln located close to the gasifier. The synthetic gas can also be used for the production of methanol.

2.6 Techniques for the abatement of emissions

[126, Pretz, et al., 2003], [150, TWG, 2004]

There are many non-production techniques in use in the WT sector. In particular, techniques used to control and abate emissions to air, water and soil are also relevant for this document. Descriptions of many of these techniques can be found in the BREF on Waste Gas and Waste Water in the Chemical Industry and in Chapter 4 of this document (Sections 4.6 to 4.8) as well as in other BREFs (e.g. Waste Incineration). These techniques are not described in this section because they are typically techniques that might be considered in the determination of BAT, and consequently will be described and analysed in Chapter 4.

3 CURRENT CONSUMPTION AND EMISSION LEVELS

This chapter provides data and information about current consumption and emission levels in existing installations at the time of writing. Because it covers many types and sizes of waste treatment installations, data is very wide-ranging. The aim of this chapter is to bring together, as far as possible, consumption and emission levels for different waste treatment installations as a whole and as far as possible from each specific process/activity. The data quoted should, in most cases, enable estimates to be made of the concentration and loads of emissions from WT sites. This will in turn help a competent authority issuing a permit to verify the information provided by the applicant in the permit application.

The structure of this chapter is similar to that of Chapter 2, with the sections being divided into:

- Section 3.1: an overview of the emissions and consumptions from common waste treatment processes/activities
- Sections 3.2 to 3.5: the emissions and consumptions from the different processes/activities covered by this document. Again, such structure/classification should not be interpreted as any attempt to interpret IPPC Directive or any EC waste legislation
- Section 3.6: the emissions and consumptions generated by the techniques used to abate emissions
- Section 3.7: the monitoring systems typically applied in waste treatment installations.

Sections 3.1 to 3.6 follow the order laid out in Chapter 2 so as to make it easier to cross reference between chapters. In addition, each of these sections have been structured in the same way following the material flow logical steps, i.e. waste IN (input), consumptions (input), emissions (output) and finally waste OUT (output). Table 3.1 explains this layout further.

Section	Title of the section	Information included
3.X.1	Waste IN	Description of the type of wastes that may be treated as well as their physico-chemical properties. This section is important because the type of waste input is relevant for the determination of eventual emissions, residual wastes and the composition of the waste outputs
3.X.2	Consumptions	Consumption of energy (i.e. fuel, heat, electricity) and chemicals (i.e. water, air, additives, catalysts)
3.X.3	Emissions	This includes emissions to air and water of any component as a result of the process operation or related to the waste input. Residues (also waste in many cases) related to the type of process are also covered in this section
3.X.4	Waste OUT	When the outcome of a certain process is to be used as input into another process, it is also important to know the physico-chemical properties of the output. In some cases, this detail is not important and is then omitted
X being from 1 to 6: 1 Common techniques, 2 Biological treatments, 3 Physico-chemical treatments, 4 Regeneration treatments, 5 Preparation of waste fuel and 6 Abatement techniques.		

Table 3.1: Structure of each section of Chapter 3

Figure 3.1 shows a diagram of the mass/energy balance of a typical operation/process/activity. A waste input (called in this document waste IN) is treated in an installation, producing a processed/treated output (called in this document waste OUT). To change the physico-chemical properties of the waste IN, it is necessary to provide to the system, energy and chemicals (e.g. water, air, acids, etc.) as required to support the particular treatment. Application/operation of the waste treatment then generates emissions to air and water, as well as a unusable waste and possibly a usable waste OUT. The unusable waste (e.g. waste lime, bottoms of storage tanks, sludges) is generated by the process/operations and is different from the target waste OUT. The reason for differentiating between the wastes is that the waste OUT may be used for different purposes, but process generated waste/residues is typically not re-used.

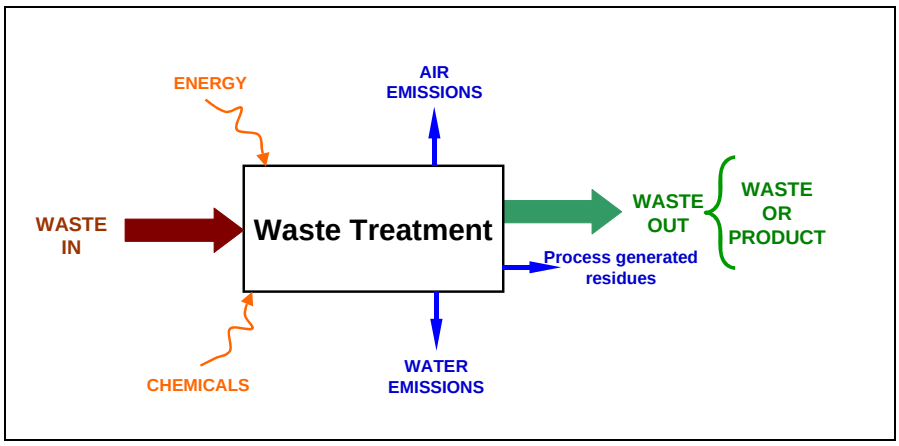


Figure 3.1: Inputs and outputs in a waste treatment operation
Note: Sections 3.X.1: Analysis of the waste to be treated, brown arrow; Sections 3.X.2: Analysis of the consumptions, orange arrows; Sections 3.X.3: Analysis of the emissions, blue arrows; Sections 3.X.4: Analysis of the waste treated, green arrow

Table 3.2 shows a summary of the main releases to the environment generated by WT activities.

Source	Substances released										
	Particulates	NO_x, SO_x, HCl	NH_3,Amines	H_2S	HCN	VOCs	Odours	Other organics	Metals	Suspended solids	COD
Common activities											
Acceptance (sampling/vehicle waiting)	A,W,L	A	A			A	A				
Transfer (pipework/pumps/valves)		A	A	A	A	A	A	W,L	W,L	W	W
Storage of solids (e.g. lime)	A,W,L										
Drum storage, bulk liquid storage and treatment vessels		A	A			A	A	A	W	W	W
Transfer and storage of wastes	A,W,L					A	A	A	A,W,L	W	W
Charging and mixing of treatment vessels	A,W,L					A	A	A	A,W,L	W	W
Removal of solid residues from vessel	A,W,L					A	A	A	A,W,L	W	W
Biological			A	A		A	A		W	W	W
Physico-chemical											
Precipitation/settlement and dewatering	W						A	W	W	W	W
Acid neutralisation		A	A(1)	A		A(2)	A(2)	A(2) W	W		W
Alkali neutralisation			A				A	W	W		W
Chromic acid neutralisation									W		
Cyanide treatment					A		A				
Stabilisation	A,W,L		A			A	A			W	W
Waste oil treatment						A	A	A			W

Notes: (1) There is a specific problem with the treatment of sulphuric acid that has been used to scrub an amine release
(2) Conventional treatment of acidic wastes contaminated with solvents
KEY: To air (A) To water (W) To land (L)

Table 3.2: Summary of typical releases to the environment generated by waste treatment activities
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

In order to complement the information directly provided by the TWG on emissions and consumptions of WT installations, a questionnaire was prepared and sent to TWG members (see Annex II). This was then forwarded by TWG members to WT facilities all over Europe. As a result more than 70 'filled-in' questionnaires were returned to the EIPPCB. A compilation of the data arising from this survey has been incorporated in this chapter and it has been referred as [66, TWG, 2003]. The consolidated analysis of the survey does not identify names, companies or specific figures or even identify individual comments from any specific company/site provider. Thus, data have been used in such a way so as to maintain confidentiality of the providers and preventing identification to any particular source.

3.1 Emissions and consumptions from common waste treatment processes/activities

[29, UK Environment Agency, 1996], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

This section contains emissions and consumptions data for the pretreatments/activities and post-treatments/activities commonly used in the WT sector. It contains those emissions and consumptions related to the waste treatment processes described in Section 2.1. This covers those sites that transfer, bulk and store wastes.

3.1.1 Waste IN in common treatments

The type of wastes that may be involved in these processes is very wide especially for hazardous waste. Table 3.3 gives the percentages of sites that process a certain type of waste at hazardous waste transfer stations in the UK. Non-hazardous waste transfer stations cover municipal solid waste, etc.

Waste streams	% of sites processing each waste stream
Non-chlorinated solvent	67
Scrap metal	53
Scrap metal (drums)	47
Chlorinated solvent	40
General inorganic liquid/sludge	40
General organic	40
Waste for incineration	40
Contaminated waste for landfill	40
Drums/IBCs	33
Non-hazardous waste for landfill	33
Oil	33
Batteries	27
Asbestos	13
Fluorescent tubes	7
Oil filters	7
Oil/water mixtures	
Acids and alkalis	

Table 3.3: Common waste streams processed at hazardous waste transfer stations in the UK [56, Babtie Group Ltd, 2002]

Some examples of waste IN for some common techniques are reported below:

Computer-controlled high rack storage areas for hazardous wastes
More than 600 different types (fluid, paste-like and solid hazardous wastes) of waste are treated.

Treatment of small quantities
This typically includes treatment, sorting and packing of hazardous wastes from private households, universities, laboratories, business enterprises and other customers. Additionally, the system can offer the possibility to condition inorganic material for underground disposal.

Shredding
The treatment is used for hazardous and non-hazardous waste. The wastes treated are solid and paste-like wastes, non-pumpable wastes like print and lacquer sludge, oil and other machining sludge.

3.1.2 Consumptions of common treatments

Although a number of sites run entirely on electricity, some have mobile or stationary plants that use diesel or fuel oils, or they have their own power plants that use gas (natural or biogas) or gasoil. Some common equipment that use fossil fuels are fork-lift trucks, small boilers, shredders and grinders. These take a mixture of standard vehicle diesel, and a range of fuel oils. Some waste plants in the UK have quantified their fuel use as ~200 tonnes per year. The proportion of raw materials (i.e. purchased reagents) used is relatively low as, in the first instance, wastes are used to treat other wastes. However, some new raw materials are used, as summarised in Table 3.4.

Raw material	Application	Principal environmental characteristics
Calcium hydroxide (lime)	Usually purchased in powder form for acid treatment	• hazardous substance • powder difficult to handle • produces large sludge volumes • for example, the treatment of sulphuric acid results in a large net production of calcium sulphate sludge
Sodium hydroxide (caustic soda) solution	Abatement reagent, typically used in wet scrubbing systems to control acid gases or as a scrubbing liquor in oil reprocessing	• hazardous substance • very low levels of mercury may be found in some grades of caustic soda, and these may be transferred to the installation effluent (see Section 4.1.3.5)
Ferric chloride solution	Additive to aid precipitation of metals and as a conditioning agent for sludge formation (as it helps with floc formation)	• strongly coloured in the event of a spillage or incident
Sodium hypochlorite	Used in the treatment and abatement for cyanide wastes scrubbing and odour control	• strong oxidising agent • stored away from potentially incompatible substances
De-emulsifiers	Used to 'crack' emulsified oil water mixtures in oil recovery processes	• high oxygen demand risk, if released to water in the event of an accident

Table 3.4: Examples of commonly used raw materials in waste treatments
[55, UK EA, 2001], [150, TWG, 2004]

3.1.3 Emissions from common treatments

Following the same structure as followed in Section 2.1, some individual sections on common treatments are discussed. At the end, the other common treatments not described before are covered in a tabulated form.

Energy systems

The use of fuels is a source of air emissions during combustion, and possibly of emissions to land as well due to spillage and leaks. The air emissions are predominantly CO_2 (carbon dioxide) and water from the combustion process, but can also include NO_x, SO_x, PM_{10}, PAHs, VOCs and CO (carbon monoxide). The emissions are related to the fuel specification and the age and use of the equipment (e.g. vehicles, biogas engines). Other pollutants that may appear are halogens (e.g. HCl and HF when waste is used as fuel within the installation) and metals.

The following table suggests a set of data that could be used to estimate the emissions. Data have been collected for three types of sources:

- line sources, including roads and railways (g/km)
- area sources, including emissions from agricultural and other land, and low intensity emissions from sources such as building heating systems
- point sources, including emissions from industrial plants.

The type of fuel used to fire in the energy system (e.g. furnaces, boilers, afterburner) will determine the nature of pollutants present.

	Type of fuel		
	Distillate	**Residual fuel**	**Diesel**
Air emissions			
CO_2[1]	3142	3112	3036 – 3142
PM			2.564
PM_{10}[1]	0.2	2.85	2.83
NO_x[1]	3.46	7.54	33.9 – 48.8
N_2O			0.041 – 1.3
CH_4			0.17 – 0.336
NM-VOC[1]	0.09	0.12	7.08 – 10.898
CO[1]	0.06	0.5	15.8 – 26.548
SO_2[1]	3.6	47.4	0.8 – 10.106
SO_x	19.56 x S^2	20.42 x S^2	
PAH[@](g)	0.15	0.151	4.07
Ni (g)	Tiny	1.1	
Cu (g)			1.7
Zn (g)			1
HCl			0.038
HF			0.038
Water emissions			
BOD			0.038
COD			0.038
Suspended solids			0.038
TOC			0.415
Phenol			0.038
Total metals			0.038
Cl			0.038
F			0.038

Units: kg (unless specified) per tonne of fuel

[1] Data sourced from the UK Emission Factors Database; gasoil (other sources) and Fuel Oil (other sources), from Australian National Pollution Inventory (converted from kg emissions per m^3 fuel) and European Environment Agency

[2] S is the % of sulphur in the fuel

[@] as benzo (a) pyrene

Table 3.5: Summary of data for small boilers using a distillate (gas), a residual oil (fuel oils 5,6) or diesel engines
[56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [65, EEA, 2003], [150, TWG, 2004]

Storage and handling

The main air emissions from the storage and transfer of waste are VOC emissions. According to the type of waste, dust may also be important. These comprise the major issues arising from handling wastes at transfer and treatment sites. The principal emissions arise from transfer and bulking activities since, in the majority of cases, any remaining residues in containers that may contain solvents will be vented to the air. General releases of VOCs from tanks due to thermal effects and releases from pipes and pumping systems can also occur but depend on the system installed in the plant structure.

Most of the fugitive emissions to air are from the transport, storage and bulking of organic wastes, primarily solvent wastes. Similar emissions are also expected from the transfer of ammonia wastes and from strong acid wastes.

The main emissions from decanting and bulking processes are to the air and may be related to the following although some of the practices mentioned below may be considered bad practices. If a practice is mentioned here, it does not mean that it occurs at the majority of sites):

- caps on the receiving containers, these may be open during the working day and give a continuous emission, albeit through a small aperture, of volatile components. This emission is particularly related to the displacement of saturated vapour from within the container with each new addition of liquid
- emissions directly from the liquids being transferred as the transfer takes place
- empty containers (drums, or bottles) which contain a measurable amount of waste materials, which, through rinsing out, is discharged to the on-site treatment process or to the sumps for disposal later. In some cases, these containers are placed in a skip for disposal to landfill or, when the contents are volatile, left to evaporate to air either with or without shredding. Such practice is actually not in accordance with the Landfill directive. Where the sites handle a large amount of solvents, drum-crushing systems can be used to squeeze and collect additional waste solvent from the drums
- the potential problem of leaks occurs during transfer, during displacement of the product in the headspace above the liquid layer, and when venting the residues from the original container. Where the material is held in storage tanks, there is an issue of outbreathing in response to atmospheric temperature and pressure. The problem is most acute with solvent transfers, but is also relevant to strong acids and wastes containing ammonia. Such practice is not considered to be a good environmental practice
- the transfer of materials from tankers to storage tanks, which are therefore controlled on a number of sites, particularly when this involves low boiling point solvent waste. The weakest link and subsequently the main source of spillage during transfer from the vehicle to storage arises from the transfer hoses
- although the volume lost during routine operations due to ill fitting or damaged hoses may be relatively small, persistent spillages may have a cumulative effect on the surface of the area, which in the long term may damage the surface and lead to a fugitive emission
- spillages may also be a source of odour
- the manual transfer of materials from small containers to 205 litre drums and IBCs. Typically this transfer has no control on emissions and it is common practice for the empty containers (containing perhaps 1 %, or up to 0.5 litres, of the original content) to be vented to the air prior to landfill. Such practice is actually not in accordance with the Landfill Directive

- with regard to monitoring and other activities on site, it is worth noting that:
  - most sites have little or no monitoring data for calculating emissions to the air and some kind of rough estimation method is needed to relate potential air emissions to the number of tankers or containers emptied or filled at the site
  - discharges to sewer or surface waters tend to have limited monitoring data as well, but the actual discharges are minimised by operational practices at the sites, such as bunding
  - transfer stations also undertake a range of other practices that can create emissions. These include the evaporation of solvents to the air from tank cleaning, from industrial wipes and from solvent sludges.

The range of emissions is very large and dependent on the type of activity (e.g. differences are particularly notable between physico-chemical treatment plants and oil re-processing plants). Each transfer of waste, and processing of the original container can generate liquid and vapour emissions. Some emissions generated by this activity are:

- tank bottoms from storage tanks
- air emissions generated by bulking in tanks loading and in unloading tankers due to displacement to the air (note: some transfer stations have very well equipped systems for balancing tanker emissions and controlling the discharges from tanks)
- evaporation emissions during decanting (e.g. VOCs) and bulking, also evaporation from wastes left in containers
- general spillages during decanting and handling. Spillages are typically retained in the bunded area or discharged to the interceptor
- air emissions generated by wiping cloths impregnated with solvents. In some installations, these are collected in sealed bin liners and then laid out to dry by evaporation to dryness prior to landfill. This is considered a bad environmental practice
- VOCs from the venting of empty drums being washed out (washings to underground storage tanks prior to landfill) and, from the evaporation of blanket wash solvents washed to the underground tanks
- emissions caused by bulking laboratory smalls. Emissions only typically occur in the event of spillages and are recorded in site diaries. General discussions at sites suggest that the number of substandard containers and badly labelled containers in this category are now minimal and that spillage and emissions due to poor containers is in fact rare
- accidental breakage of waste containers
- from storage tanks in the open, on hard-standing and bunded areas, and for which although the connections are over the bunded area, there is no system to deal with leaks from the collection/delivery systems and so the whole bunded area can become very contaminated. Rainwater in the bunded area will also become contaminated. On some sites, there is no provision to control displacement of air in the tanks during loading and unloading; others have very good control systems for both tanks and tankers. Air emissions are less well controlled. Tanks tend to have valve systems to regulate tank pressure and to allow inbreathing/outbreathing of headspace vapours. Emissions to the air can occur during tank charging or due to changes in atmospheric conditions. Small emissions will also occur during sampling and inspections. There is a potential for one-off larger emissions during tank cleaning
- non-evaporated liquids and solids, which may end up being landfilled or drained to sewer. This is considered a bad environmental practice
- fugitive air emissions from transfer operations between processes, especially with non-pumped systems. Also leaks from containers and from pressure/vacuum relief valves
- solid/liquid and gaseous emissions due to a possible container break in handling (accidental damage), depending on the waste material. Because the accident is reported in the site diary, the emissions can be estimated when the material is known
- in the case of the storage of waste oils, releases to the air come from condenser vents on hot oil storage tanks. On the storage tank, vents measurements for hydrocarbons are taken using Draeger tubes and typical values may be 10 to 20 mg/Nm^3 and peaking at 100 mg/Nm^3

- investigations into the microbiological pollution of waste sorting plants revealed mould fungi concentrations in the air at the workplace of up to more than 106 cfu/m^3 (colony-forming units).

Complementary to the information above, next Table 3.6 shows potential emissions from transfer stations, bulking processes and storage.

Activity	Description of release [1]	Release type	Release to
Filling of bulk storage tanks or IBCs by road tankers	Displaced air	VOCs	Air
	Losses from transfers	VOCs	Air
		Liquids	Soil
		Liquids	Water
Storage in bulk tanks	Vented material	VOCs	Air
	Tank bottoms	Waste	
Releases from pipes and pumping systems	All losses	VOCs	Air
		Liquids	Water
		Liquids	Soil
Gravity and vacuum emptying of drums, IBCs and other containers to bulk tanks	Displaced air	VOCs	Air
	Losses from transfers	VOCs	Air
		Liquids	Soil
		Liquids	Water
Storage and handling of empty IBCs	Washing	Liquids	Water
	Storage	VOCs	Air
	Disposal	Liquids/solids	Landfill
Storage and handling of empty drums and other similar containers	Crushing	VOCs	Air
		Liquids/solids	Water
		Liquids/solids	Soil
	Washing	Liquids/solids	Water
	Disposal	Liquids/solids	Landfill
	Storage	VOCs	Air
Maintenance of equipment	Tank cleaning/washing	Liquid/solid	Soil
		Liquid/solid	Water
		VOCs	Air
Planned evaporation of volatile liquids	Evaporation	VOCs	Air

[1] The wide range of possible emissions to air and sewer/controlled waters has to be estimated in relation to the range of activities and wastes handled at a particular site.

Table 3.6: Potential emissions from transfer stations, bulking processes and storage [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Emissions from some other common waste treatments

Table 3.7 summarises the most frequent activities/equipment found in common waste treatment processes and the emissions that may be generated.

Process/activity	Compounds found in WT processes that may lead to emissions
Air stripping columns	May cause a discharge of ammonia into the air which can be calculated by mass balance
Cleaning wastes or aqueous organic wastes from the chemical industry	These can contain a range of volatile compounds, chlorinated compounds and phenolic compounds. The solid and muddy residues produced during cleaning are disposed of as waste. If necessary, the waste is conditioned according to the acceptance criteria of the waste disposal facility
Crushing of oil filters	Waste contained in oil filters are particulate matter containing combustion products, including high PAHs/metal fragments, etc. 'stuck' together with oil. The solids from these operations tend to go into the oil water separation system for treatment plants, and leave with the bottom sludge. PAHs escape into the air with the oil mist produced during crushing or may be retained in the oil, or remain on the solids components of the filter. The PAH emissions to the air are potentially carcinogenic
Cutting	During drum cutting operations, the former contents of the drum and any residues that may be still present can be a cause of emissions
Washing of containers and vehicles	Fugitive emissions occur to air and water. Typically, a contaminated effluent is generated as well
Crushing and shredding	Regardless of the technique employed, there is typically no provision for environmental control and the emissions depend on the composition of the waste held within the drum. In the shredding process, the temperature of the shredded items may reach several hundred degrees. Shredding will cause emissions to the air, depending on the efficiency of the scrubber or other kind of air cleaning equipment. Fluids still present in the waste (e.g. solvents, mercury) may be released to the interior of the plant and may either evaporate or leak to the ground or may be collected as sludge. Dust from the plant will be spread to the surroundings. Other outlets from a shredding plant include a magnetic metal fraction, non-magnetic metal fractions, sludge from the washing process, and a fluff fraction which is a mixture of plastics, insulation materials, paper, soil, etc. The fluff fraction may be disposed of for incineration but sometimes is landfilled (not considered a good practice). A quite significant amount of heavy metals follows the fluff fraction. In the middle of the nineties Danish shredder plants shredded about 300000 tonnes waste. The fluff from the operation was estimated to contain about 0.15 tonne mercury, 200 – 1000 tonnes lead, and 0.5 - 2.5 tonnes of cadmium. The emission of mercury to air from the operations was estimated at <0.05 tonne
Drum and road tanker cleaning	Cleaning operations which specialise in cleaning drums that previously contained solvent and oil wastes may release large percentages of waste to the air since the solvent wastes are flushed to the air occasionally and in certain locations, during the cleaning process. This appears to be a similar issue to the evaporation of solvents to the air during decanting at certain transfer stations. The presence of any former content or any residue in drums may cause emissions during cleaning/washing operations. At some sites, unwashed drums might go directly to landfill along with the associated residues. A site processing drums contaminated with oil and organic materials estimated a 40 t/yr solvent discharge to the air. Part of this emission is due to the standard transfer station practice of venting 'empty' drums to the air. A site recycling drums from the inorganic sector had a high metals level in the discharge to sewer, but was able to calculate the discharge from regular analyses. Most treatment plants incorporate a washing out facility to enable the removal of residues from vehicle tanker barrels. In some cases, vapours may become trapped within the sludges and appropriate actions need to be taken to avoid any uncontrolled releases

Table 3.7: Activities/equipment that may lead to emissions from some common waste treatments [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [113, COWI A/S, 2002], [116, Irish EPA, 2003], [121, Schmidt and Institute for environmental and waste management, 2002]

Shredding

Parameter	Concentration	Unit
Dust	0.1	mg/Nm^3
SO_2	<0.06	mg/Nm^3
NO_x	8	mg/Nm^3
TOC	5	mg/Nm^3
CO	4	mg/Nm^3
HCl	13.8	mg/Nm^3
PCDD/PCDF	0.001	$ngTEQ/Nm^3$
Odour	85	GE/m^3
Cl	<0.1	mg/Nm^3
The flows of the exhaust air are 8028000 and 5628000 m^3/yr for the can shredder and the bin shredder respectively.		

Table 3.8: Exhaust air from shredding treatment of solid hazardous waste [157, UBA, 2004]

Emissions occurring due to accidents

The most significant environmental risks associated with waste treatment operations are the storage of hazardous wastes. This can involve emissions resulting from wastes reacting together, either from leaks and spillages or from treatment processes going out of control.

Procedure	Hazard	Hazardous event	Cause/possible initiating event
Sampling/ analysis	Toxic vapours	Chemical spray Blow-out Chemical spillage	Container under pressure Transfer from sampling vessel and withdrawal of sample (barrel-sampler) Waste not as expected
	Fire	Flammable materials ignite	Flammable vapour at point of sampling
General handling/ treatment	Toxic gases	Incompatible wastes mixed	Inadequate/incorrect information on wastes
		Waste spillage	Operator not working according to safe practices No safe operating procedures established Inadequate facility engineering Inadequate supervision Accidental discharge
Drum handling/ storage	Direct chemical contact	Blow-out	Contents under pressure
	Toxic gases Dusts	Spillages	Contents spilt during emptying/decanting Corroding/leaking drum Manual removal of contents
	Reaction Toxic gases	Mixing of incompatible wastes	Spillages/corroded drums Bulking up drums Wastes not conforming to labelling Wastes not adequately analysed
	Fire/ explosion	Flammable materials ignited	Unexpected flammable materials present Spark in taking lid off/flammable headspace Use of cutting tools to open drum Fire produces toxic degradation products

Procedure	Hazard	Hazardous event	Cause/possible initiating event
Unloading tankers	Toxic gases	Release as liquid/gas spray	Incompatible/reactive wastes mixed together Container under pressure/blow-out Unloading into wrong storage vessel Waste materials received 'hot' due to viscosity – solidification/thickening difficulties Gross failure of tanker Vehicle impact Spillage on coupling/uncoupling, failure of coupling
	Fire/ explosion	Flammable/ explosive mixture ignited	Flammable atmosphere in 'empty tanker'
Waste storage tank farm	Fire/ explosion	Flammable liquid or vapours ignite	Flammable vapour vented-off Vapour release from spills Pipeline failure Flammable vapour in tank headspace
	Reaction	Incompatible wastes mixed	Wastes react in storage vessels pipeline or conveyor failure
	Toxic gases	Non-compatible or reactive waste mixed in store or reagent spillage	Inadequate information on waste Waste does not conform to process specification
		Significant levels of toxic gases/fumes evolved	Inadequate venting of tanks, etc. Poor materials handling practices
Physico-chemical treatment	Toxic gases	Uncontrolled release during reaction	Failure of protective systems Incompatible waste mixed Wrong reagent added Too much/too little of reagents added Failure of pH control
Effluent dewatering from physico-chemical treatment	Toxic gases	Mixing incompatible effluents	Reaction not complete Residual contamination in effluents
Biological treatment		Fire	Biological degradation processes may cause self heating and auto-ignition. This does not only affects the biological treatment system. Auto-ignition may also occur in the bunker. In some cases fires can appear in the product storage area. A second reason for fires in solid waste fuel processing plants are particles that are still glowing.

Table 3.9: Example of most frequent accidents that may occur in WT installations [80, Petts and Eduljee, 1994], [126, Pretz, et al., 2003], [150, TWG, 2004]

Generic air emissions from common waste treatments

VOC

There are no real data available at present on VOC emissions. The vast majority of sites that undertake air monitoring, undertake it on an irregular basis and are unlikely to take a sample at the times of maximum discharge. Air emissions are particularly difficult to monitor from these sites as operations are generally in the open air and gases are not always controlled. VOC emissions at a site may be due to:

- a deliberate process activity at some sites carried out in order to reduce the flammability of wastes going to landfill. The quantities may be very small per unit of waste, but the operation takes place across a large number of sites and the accumulated effect may be very large. This practice is not common in the sector and is considered a bad practice so is now obsolete
- the agitation or heating of mixed materials left to settle in contact with the atmosphere. Oil treatment tanks are one obvious example, but chemical treatment tanks or sludge mixing tanks are also sources
- emissions of semi-volatile PAHs from crushing and sieving operations, particularly from the handling of oil filters at transfer stations
- the transfer of liquids to bulking containers, with a subsequent displacement of the product headspace above the liquid layer
- the venting of residues from original storage containers; and also from storage tanks outbreathing in response to atmospheric temperature changes.

There are example plants in the WT sector with no controls on discharges of volatile compounds into the air, indeed few processes have ever been designed to discharge pollutants to the air.

Acid emissions

The most serious air emissions are likely to arise from solvent transfer and storage activities, but they can also arise from chemicals such as strong acids and ammonia.

Ammonia emissions

Ammonia is detected in some WT sites. There is a general problem with ammonia emissions. However, this is usually easy to spot on site visits and by operators due to the low threshold concentration for odour detection, although it is harder to quantify. Locations where ammonia emissions have been detected are:

- in solvent transfer and storage
- in the pressing and storage of effluent sludge at several chemical treatment plants. This is an area that is rarely within the exhaust systems for the site and therefore emissions do not pass through the plant scrubbers. Furthermore, the scrubbing systems are usually caustic scrubbers
- from strong ammoniacal solutions directly to the air after an air stripping at one site, although the site monitoring (only annual monitoring carried out) says that background atmospheric levels are minimal
- effluent treatment plants
- acid treatment of waste oils
- wastes from the photographic industry are an example of a waste stream with a high concentration of ammonium salts and, although discharges to the air are not identified, this is a potential problem during transfer processes, giving rise to air emissions and potential contamination of water discharges.

Fugitive and diffuse emissions

In many installations, fugitive and diffuse emissions may be more significant than point source or channelled emissions. Common examples of the sources are:

- open vessels (for example, the effluent treatment plant)
- sampling activities
- storage areas (for example, bays, stockpiles, lagoons, etc.)
- the loading and unloading of containers
- transferring/bulking up of material from one vessel to another
- conveyor systems
- pipework and ductwork systems (for example, pumps, valves, flanges, catchpots, drains, inspection hatches, etc.)
- poor building containment and extraction
- potential bypass of abatement equipment (to air or water)
- spillages
- accidental loss of containment from failed plant and equipment
- tankers and vessels, manhole openings and other access points
- displaced vapours in receiving tanks
- cleaning or replacing of filters
- drum cutting
- waste water storage
- drum storage
- tank cleaning
- tanker washing/cleaning.

Particulate emissions

Sites handling powders and wastes giving rise to dusts (e.g. fly ashes) often have particulates to emit to the air.

Noise and vibration

'Noise' refers to 'noise and/or vibration' typically detectable beyond the site boundary.

Odour emissions

Emissions to air tend only to be checked subjectively by using the sense of smell. Odour emissions are associated with point sources as well as fugitive sources. In addition to ammonia previously discussed, the handling of any substance that is or may contain a VOC (or other odorous substances, for example, mercaptans or other compounds containing sulphur) will potentially lead to odour noticeable in and beyond the installation boundary. Odours may arise from:

- storage
- the transfer or bulking up of wastes containing VOCs or other odorous substances
- a failure to adequately inspect and maintain plant and equipment, which may lead to fugitive emissions, e.g. leaks from pumps.

Generic water emissions from common waste treatments

A distinction can be made between installations conducting 'dry' or solid phase operations, e.g. transfer or stabilisation, which do not produce a distinct liquid effluent; and those conducting liquid phase treatment, e.g. acid neutralisation and oil water separation.

'Dry' processes typically only produce effluents from activities such as from rainwater collection and incidents such as spills and leakages. In general terms, the strength of this effluent in terms of metals and COD levels will be relatively low. 'Wet' processes, in addition to the general effluent arising from yard drainage, etc., produce an effluent from the reaction, precipitation, settlement and dewatering processes.

Waste water may be generated in the installations due to:

- unplanned discharges to drain (e.g. emergency control, fire)
- spillage from storage
- discharge to storm drain
- discharge of bund and secondary containment contents
- process waste water (each case is covered from Section 3.2 to 3.5).

Many transfer stations are associated with adjacent treatment plants and all run-off goes into that treatment system where is treated. Others collect the run-off and tanker this to landfill. Again there is no discharge to receiving waters or sewer. The remainder of the installations discharge either to surface water (unusual option) or to sewer. In the vast majority of EU countries, it is not permitted to make direct discharges to sewer or to controlled waters. A security storage is then needed in order to control or treat the water before discharge. Some typical emissions are summarised in Table 3.10:

Emission to	Unit process or activity
Sewer	Physico-chemical treatment. Final effluent from acid/alkali neutralisation and the precipitation of metals
	Oil reprocessing. Effluent treatment to remove oil from condensate and yard drainage
	Cleaning
Watercourse	Rainwater collection
	Yard drainage

Table 3.10: Point source emissions to water
[55, UK EA, 2001]

In principle, there will always be small quantities of every material decanted at the site discharged to sewer, due to drips and splashes even if there are no spills recorded. The most common materials to be bulked at transfer stations are dilute acids (often from metal treatment), caustic solutions, oils, non-halogenated solvents and aqueous organic wastes. The discharge is almost certain to contain organic carbons, nitrogen compounds (total nitrogen), chloride, some metals and, when bulking non-halogenated solvents, xylene. Discharges to sewer may reach COD levels of several thousand milligrams per litre. The nature of the discharge depends on the wastes being handled at the installation, which invariably involves a wide variety of substances, thereby resulting in a complex effluent.

Emissions to water also occur from washing containers and tanks if this occurs in the WT plant. Liquid discharges may arise from the washing and processing of containers prior to their reprocessing, or from the washing of road tankers. One approach of estimating these emissions is to assume that the residual material in each type of container after emptying is 0.5 % of the volume, and that all of this material is washed to sewer. In general, volatile residues from containers of solvent waste are evaporated directly to the air rather than being washed to sewer.

General leaks and spills can occur in waste transfer stations. Most sites are on hard standing and liquid and solid spills are eventually washed away to the main interceptors and then to sewer or to an adjacent treatment plant.

Generic releases to soil and process generated waste from common techniques
Most sites will have a continuous, but small, discharge of waste to the site base-ground due to drips, splashes, crushing residues, pipe connections, oil leaks, etc. and these may be washed to the surface water collection points by rainwater and site cleaning. Tank bottoms are another typical waste when storing waste.

Example of inventory of emissions from a waste transfer station

Operation	Emissions to air (kg/yr)	Emissions to sewer (kg/yr)
Repacking and labelling of laboratory chemicals	0	0
Breakage/leaks during loading and storage	VOC as TRI 20.3	Small amounts of oil, but these will be picked up in weekly monitoring data and not doubly counted here
Decanting into IBCs	Dichloromethane 360 Ethanal 48 Trichloroethylene 60 VOC as TRI 60 VOC 1320 Xylene 360	All solvent species Total nitrogen Total phosphorus Chloride TOC Metals
Transfer from IBCs to solvent storage tanks	ethanal 76 VOCs 1330 xylene 570	Xylene TOC
Fuel use for fork lifts (Use of 5 tonnes of diesel per year)	CO 79 CO_2 15710 NM-VOC 35.4 NO_2 244 PM_{10} 14.15 SO_2 4	TOC
Sewer discharges	0	TOC 5980 NH_3-N 14 Cu 0.5 Ni 0.5 Zn 0.5 Oil 150 Xylene, toluene, TRI, trichloroethylene, Cl, P trace discharges
Totals	CO 79 CO_2 15710 Dichloromethane 360 Ethanal 124 NO_2 244 PM_{10} 14.15 SO_2 4 TRI 80.3 Trichloroethylene 60 VOC 2706 Xylene 930	TOC 5980 NH_3-N 14 (assumed cannot reach limit for nitrogen) Cu 0.5 Ni 0.5 Zn 0.5 Oil 150 Xylene, toluene, TRI, trichloroethylene, Cl, P

Overview of the installation

The above data correspond to a hazardous waste transfer station fitted with an impermeable base. It has bulking areas with blind sumps and a roof. The solvent storage tanks are in a separately bunded area with activated carbon filters on vents. Thermal out-breathings and head space displacement losses due to charging the storage tanks, are scrubbed prior to be discharged into the air. Loading, unloading and drum storage areas of the site are in the open and drain to the interceptor, hence to the sewer. There is a continual monitoring of pH and flowrate, and a weekly monitoring of COD, metals, oil, ammoniacal nitrogen and suspended solids on the sewer discharge. Packaging materials and old contaminated containers are sent to landfill.

The site handles a very wide range of materials, but mainly the following streams:

- halogenated solvents comprising on average 80 % solvent; 20 % solids. Of the solvent fraction, 10 % is trichloroethylene; 10 % 1,1,1 trichloroethane; and 60 % dichloromethane
- non-halogenated solvents, on average 70 % solvent, 30 % solids and water, with the solvents comprising 10 % toluene; 30 % xylenes; 10 % acetone, 20 % others, mainly MEK, ethanol, ethanal, methanol and aliphatic C_{10}-C_{12} hydrocarbons
- the other major waste streams are dilute hydrochloric acid and zinc, sulphuric acid and phosphoric acid from metal processing, soluble oils, dilute caustic soda, dilute ammonia solutions from photographic processes, aqueous paint residues, aqueous adhesive residues and ethylene glycol. All of these are bulked prior to onward transfer or storage.

Waste OUT produced is 120 tonnes of waste fuel and 60 tonnes of halogenated materials per year. The installation handles 120 tonnes of waste from IBCs filled at the site and a further 260 tonnes of waste that arrives in IBCs.

Table 3.11: Example of total estimated emissions from a waste transfer facility [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Emissions from specific waste treatments

Specific waste treatments	Air	Water	Waste
Aerosol destructor - crusher	In some cases, propellants are discharged to the air via the exhaust fan	A mass balance suggests that emissions to water could be as much as 250 t/yr, but there is insufficient detail on the tonnage of liquid waste produced at present to make an accurate calculation	Liquids from the crushing process are collected and sprayed onto the adjacent landfill
	The active ingredients and carrier solvents can include materials such as paint thinners, alcohols, and possibly some pesticides		
CFC recovery treatments	The oil waste will contain some CFCs that evaporate in the air. A small additional discharge will occur during routine sampling	Discharges can be estimated	CFC refrigerants are recovered for re-use and generate a small stream of oil, that is sent for further treatment. A tiny amount of used dessicant (contaminated with oil) goes to landfill each year
Delivery storage and transfer of materials	VOCs, acids or ammonia wastes		
Glass crushing	There are large problems with particles, despite the presence of extractor fans, with dust settling on equipment, the plant and on the finished product. Abatement equipment is not fitted		
PCB cleaning	A monitoring programme typically covers PCB discharges to the air, to surface waters and to the land in the vicinity of the installation. The trichloroethylene (TCE) is distilled on site for re-use, and the residual sludge is sent for incineration.		
Cleaning of transformers containing PCBs	Decontamination of PCB transformers is never completely applied to all components, and this means that a residue remains which must be incinerated. In the best case this will be just the porous parts (wood and paper), unless the solvent technique is applied for long process times, and a product will finally be obtained which can be sent for land-filling if the residual PCB levels are legally acceptable. There is potential for fugitive emissions of PCB via the formation of aerosols.		

Table 3.12: Emissions from specific waste treatment processes
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [150, TWG, 2004]

3.1.4 Waste OUT from common waste treatments

Depending on the type of operation of the treatment technique, the physical and/or chemical properties of wastes may change when common techniques are applied. However, it is found that some common techniques (e.g. storage, acceptance, reception) do not change the chemical or the physical properties of the waste IN. On the other hand, others such as, for example, blending, mixing, crushing, shredding, change the properties of the waste IN.

3.2 Emissions and consumptions from biological treatments

[33, ETSU, 1998], [51, Inertec, et al., 2002], [54, Vrancken, et al., 2001], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [66, TWG, 2003], [76, EEA, 2003], [81, VDI and Dechema, 2002], [86, TWG, 2003], [113, COWI A/S, 2002], [138, Lanfranchi, 2003], [150, TWG, 2004]

This section discusses the emissions and consumptions of the biological treatments mentioned in Section 2.2. Each section of this Section 3.2 is structured in the same way as Section 2.2, namely the treatments follow the order of: emissions and consumptions of anaerobic digestion, mechanical biological treatments and lastly biological treatments applied to contaminated soil. Emissions associated with an ancillary treatment, e.g. transfer station operation, are covered in Section 3.1.

3.2.1 Waste IN in biological treatments

Generally successful biotreatment only occurs when the waste is non-toxic (although micro-organisms can acclimatise to some extent and to certain wastes), within the relatively narrow pH range of pH 4 – 8, and with a C:N:P ratio of around 100:5:1. Biological treatment is, if well prepared, able to be adapted to a great variety of organic compounds which can be found in wastes or contaminated ground.

Anaerobic digestion
Anaerobic digestion may be used to treat liquid or solid wastes directly (e.g. MSW), or to treat the biological sludge generated by an earlier aerobic stage. There are a number of possible feedstocks which can be used in anaerobic digestion. These include the following: source separated food waste, sludge (e.g. sewage sludge from municipal waste water treatment), agro-industrial by-products, manure, slurries, some fractions of the MSW, and yard waste.

Anaerobic digestion (AD) is better suited to waste with a higher moisture content than aerobic digestion. The process of AD can occur between 60 and 99 % moisture content. Moisture content is also important. A low value increases both the ammonium inhibition of the AD process and the salt toxicity. Therefore, kitchen waste and other putrescible wastes, which by themselves may be too wet and lacking in structure for aerobic digestion, can provide an excellent feedstock for AD. Liquids are often added to the AD processes (either water or recycled effluent) to maintain a high moisture content.

The characteristics of the feedstock have very important effects on the AD process. A high quality feedstock will increase the quality of the digestate. High heavy metal concentrations in the feedstock can be toxic to methanogenic bacteria, in the following order (of increasing severity): iron<cadmium<zinc<chromium<lead<copper<nickel. The volatile solids content will affect the extent to which the process needs to be monitored to avoid the damaging effect of overloading.

The type of waste accepted in this type of treatment is, principally, source separated biodegradable waste, since matter and nutrients are to be recovered with minimal contamination, composting of residual waste or separated fractions thereof is becoming increasingly uncommon. Therefore, the types of waste typically used are the wet organic fractions from kitchen waste and from hotels and restaurants. Garden and park waste and paper and board are not usually processed. Some waste fractions excluded are metals, plastic, glass, animal waste, which is undesirable at plants without hygienisation due to the degradation of lignin which requires post-digestion composting.

There are two main alternatives for waste separation. The choice between them has an important bearing on the anaerobic digestion feedstock quality:

- source separation (not covered under the scope of this document) – this is actively encouraged in a number of Member States. It includes separation of the putrescible organic fraction (biowaste). It is generally accepted that source separation provides the best quality feedstock for both AD and composting, offering both a maximum organic content and a minimum contamination with heavy metals, glass and plastics. After digestion of this source separated waste in a reliable process, the end result will be the formation of a quality digestate and a high volume of biogas
- centralised separation – this is is the only route for obtaining a digestible fraction from residual waste. The techniques involved include mechanical processing, optical processing and hand-picking. The digestible fraction obtained tends to be more contaminated than source separated biowaste, with inevitable consequences for the digestate's ultimate utilisation (there is some evidence that where pulping is used as a pre-process sorting phase, liquid separation can lead to the removal of some more hazardous elements). There is also the risk of larger non-separated components of the waste being carried over and then causing physical damage to treatment plants further downstream (by abrasion, blockages or tangling).

Mechanical biological treatments

The types of waste that may be accepted by this treatment are non-source separated municipal waste, sludge (e.g. sewage sludge from municipal waste water treatment plants) and commercial solid waste. Technically speaking, there is no restriction in also treating a wet organic fraction (e.g. kitchen wastes), garden and park waste, organic waste from hotels and restaurants or paper and board. However typically these last types of waste are not usually treated by these treatments.

The moisture content of intake waste is extremely variable, but it would be expected that green wastes and household wastes have a moisture content of at least 40 – 50 %.

Biological treatments applied to contaminated soil

Characteristic	Desired range
Organic content	0.025 – 25 w/w-%
Solid content	10 – 40 w/w-%
Water content	60 – 90 w/w-%
Solids particle size	<0.635 cm. diameter
Feed temperature	15 – 35 °C
Feed pH	4.5 – 8.8

Table 3.13: Desired inlet feed characteristics for slurry biodegradation processes for soil decontamination
[30, Eklund, et al., 1997]

The effectiveness of slurry biodegradation for certain general contaminant groups is shown in Table 3.14.

Contaminant	Applicability
Organic contaminants:	
Halogenated semivolatiles	2
Non-halogenated semivolatiles	2
Pesticides	2
Halogenated volatiles	1
Non-halogenated volatiles	1
Organic cyanides	1
PCBs	1
Dioxins/furans	0
Organic corrosives	0
Inorganic contaminants:	
Inorganic cyanides	1
Asbestos	0
Inorganic corrosives	0
Non-volatile metals	0
Radioactive materials	0
Volatile metals	0
Reactive contaminants:	
Oxidisers	0
Reducers	0
KEY: 0 = No expected effectiveness - expert opinion is that the technology will not work 1 = Potential effectiveness - expert opinion is that the technology will work 2 = Demonstrated effectiveness - successful treatability test at some scale has been completed	

Table 3.14: Applicability of slurry biodegradation for treatment of contaminants in soil, sediments, and sludges
[30, Eklund, et al., 1997]

3.2.2 Consumptions of biological treatments

Anaerobic digestion
The consumptions of a mechanical-biological treatment (MBT) containing separation and anaerobic digestion are typically: water, auxiliary materials and energy:

Water
The total water consumption for treatment of 1 tonne of waste is 78 litres. This treatment uses either tap or groundwater. Water is consumed in the following process steps:

- steam production: 22 litres per tonne waste
- production of polymer solution: 56 litres per tonne waste.

Auxiliary materials
The following products (delivered by truck) are used as auxiliary materials:

- anionic polymeric flocculants (polyacrylamide powder): 60 grams per tonne waste
- iron chloride solution (40 w/w-%): 3 kilograms per tonne waste
- anti-foaming products (polyalkylene glycol solution in water): 50 grams per tonne waste.

Energy

The only energy source which is used during the normal operation of the installation, is electricity, which could be generated on-site, and heat, which may be needed for possible drying processes and for heating the buildings. The electricity use per tonne of waste is 55 kWh_e. This electricity could be generated at the installation itself by the combustion of biogas in a biogas engine (efficiency: 35 %). The biogas consumption for electricity production is 29.1 Nm^3 biogas containing 55 vol-% CH_4 (i.e. 37 kg). The electricity production and the energy use is given in the Table 3.15.

Energy type	kWh per tonne MSW	Source
Electricity input	50 – 55	Own production (biogas engine)

Table 3.15: Electricity consumption and production
[54, Vrancken, et al., 2001], [59, Hogg, et al., 2002], [66, TWG, 2003]

Up to one third of the biogas produced is needed to heat the digester itself, since the process requires warm conditions.

Estimates concerning the utilisation of electricity by the plant vary a great deal. In rural AD plants, approximately 20 % of the electricity produced in the process is required for the plant operation, while urban plants may utilise 2/3 of the electricity produced.

Mechanical biological treatments

MBT technique	Aeration rate (Nm^3 air/(m^3 of waste.h))
Tunnel:	40 – 60
Moving heap pre-degradation after degradation	 5 – 10 1 – 5
Heap	10

Table 3.16: Aeration rates
[132, UBA, 2003]

In quasi-dynamic biological systems the major part of organic waste contents is degraded within the first four weeks of biological degradation. During this period, the highest aeration rates are needed and up to 60 or 70 % of the total heap air supply is consumed. In the case of process interruptions in the pre-biological degradation, biological degradation is deferred towards the later biological degradation phases/aeration fields. The same holds for static processes without turnover. In the case of upstream fermentation, the intensive degradation of the easily degradable organic components occurs in the closed fermenter. Thus the exhaust gas quantities from the after-degradation are strongly reduced compared to fully aerobic degradation processes.

Energy

Aerobic process	Electricity (kWh/t)	Diesel oil (kJ/kg)
Enclosed aerobic digestion	27 – 65 [2]	5
Windrows	0	15
Range[1]	4 – 72 [2]	5 – 132 [3]

[1] Range contains different types of installations with more or less sophisticated gas treatments and without gas treatments
[2] Higher end of the range typically corresponds to process with advanced purification of exhaust gases
[3] Higher diesel consumptions are associated with a lower electricity consumptions

Table 3.17: Specific energy consumptions of aerobic digestion processes
[59, Hogg, et al., 2002], [66, TWG, 2003], [150, TWG, 2004]

Water
MBT plants sometimes add water to the windrows, as moisture is lost during the aerobic digestion, which could otherwise lead to a shortage of water and halt the aerobic digestion process. This typically occurs during summer and winter months.

In some cases, there is no net water consumption in the process. In the drying process, water is produced (350 litres -in vapour form- per tonne waste). During the aerobic digestion, temperatures of 50 – 60 °C are reached. Thus, water lost from the feedstock becomes water vapour (about 90 %) and is typically released to the air. However, in some cases, some of this water is condensed. The treatment of this condensation water is quite complex.The purified waste water (permeate) is used as process water in the cooling circuit. It is evaporated in the cooling tower. Tap water is only used in the cooling tower as make-up water (10 litres per tonne of waste). However, other sources reported that the water consumption range from 260 - 470 litres per tonne of waste treated.

Auxiliary products
As reported, no auxiliary materials are used in the process, except for the plastic foil used to bale the waste solid fuel.

Biological treatment of contaminated soils
Most often, organic pollutants are used as a source of carbon and energy by micro-organisms. Also, the concentration of nutrients like nitrogen and phosphorus must be adjusted to support microbial growth. Usually, an ammonium salt like NH_4Cl is used for nitrogen addition and phosphorus as phosphate salt. However, micro-organism growth needs lots of elements like vitamins and some metals (Fe, Mg, Cu, etc.). These elements can be naturally present in soil but improvement can be sometimes necessary. C/N/P ratios are sometimes used to determine the total quantity of nutrient necessary. In fact, a regular control of nutrient concentration in soil must be achieved. Polluted soil is sometimes mixed with compost to optimise biological treatment. Compost addition is most often included between 10 and 30 % and never exceeds 40 %. Water is sometimes also used in order to increase the moisture content in the soil.

Oxygen and nutrients (N and P) are added to the contaminated soil to biostimulate the biodegradation. Increasing the micro-organisms flora with specific organisms (e.g. bacteria, fungus), increases the biodegradability of the contaminants.

3.2.3 Emissions from biological treatments

The specific emissions from biological treatments depend on:

1. volatile components already being a content of the feedstock,
2. the amount and type of waste being treated and
3. on the type of treatment.

For example, wastes derived from biological sources (such as rendering or food industry effluents) are less likely to produce high emission loads. Thus, e.g. the emissions (loads of TOC, methane, N_2O, ammonia, etc.) from the biological treatment of separately collected biowaste (not covered in this document) are comparable to the emissions from the biological treatment of MSW and sludge except for some volatile VOC ingredients from MSW (e.g. fluorinated chlorinated hydrocarbons).

heavy metals in the original material will be well mixed with the rest of the material, by dissolution, extraction or simply by being torn into small pieces during the operation.

A common characteristic of the biological treatment is that heavy metals and other non-biodegradable components are subjected to dilution by mixing, dissolution in the aqueous phase, become part of the body of the micro-organisms, concentration by loss of moisture and weight and so on. In general, heavy metal compounds are not selectively separated from the waste and not selectively concentrated to a target output material.
Volatile chemical constituents are the most likely to result in fugitive air emissions, together with ammonia. Municipal wastes tend to produce metals in the effluent or sludge.

Anaerobic digestion
Figure 3.2 shows the relevant emissions from anaerobic digestion processes.

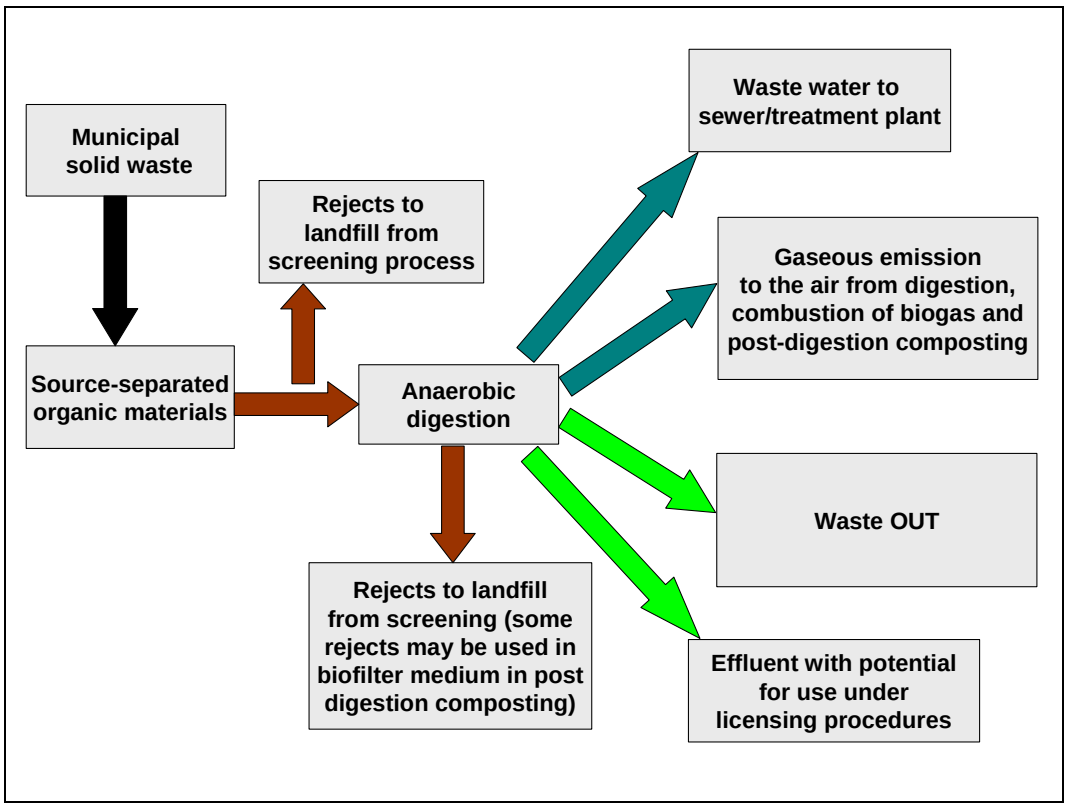


Figure 3.2: Schematic representation of anaerobic digestion inputs and outputs
Note: Brown arrows represent solid materials
Blue Arrows represent emissions
Green Arrows represent waste OUT with some use
[59, Hogg, et al., 2002], [150, TWG, 2004]

Air emissions
This process is enclosed and air emissions are unlikely to occur except during transfer to and from the digester. Anaerobic systems generate less emissions than aerobic systems per kilogram of waste, since the principal gaseous emission (methane) is a desired product. However emissions related to the delivery of waste and mechanical treatment may cause emissions of odours and dust and the aerobic digestion of the digestate may cause a significant odour problem if not properly treated. The emissions generated by the combustion of the biogas are typically higher than the emissions generated during the biogas production process.

A simple mass balance would suggest that, if the input material has a moisture content of 70 %, and if the volatiles solids content of the remainder is 80 %, then the input waste must contain 240 kg of volatile solids. Unscreened stabilised biomass might account for 40 % of the initial weight, of which 40 % might be moisture with the remainder having a volatile solid content of 40 %. This implies a loss of 144 kg, volatile solids, if the incoming material has a moisture content of 70 %.

As already stated, since the digestion process is enclosed, air emissions are unlikely, except during transfer to and from the digester. However, fugitive emissions of biogas are possible from emergency vent valves and from poorly sealed water traps. This can result in a range of hazards, including the risk of fire or explosion, as well as toxicity from contaminant gases such as H_2S and mercaptans (generating odour). Nitrogen gases also are possible.
Particulate emissions are also less likely than from aerobic digestion because the process is enclosed, but there will probably be some waste preparation units which may have larger particulate emissions.

Component	Emissions concentration	Unit	Specific emission (g/tonne of waste)	Specific emissions (g/MJ of methane)
Flue-gas				11000 Nm^3/t
Methane	Fugitive	vol-%	0 – 411	0.1
CO_2	31 – 35.2	vol-%	181000 – 520000	85
CO			72.3	0.25
NO_x			10 – 72.3	
NH_3	Fugitive			
N_2O			0	0.2
SO_x			2.5 – 30	0.15
H_2S	284 – 289	mg/Nm^3	0.033	
TOC (VOC)			0.0023	
PM (e.g. bioaerosol)				
Odour	626	GE/Nm^3		
Chloroform	2	$\mu g/Nm^3$		
Benzene	50 – 70	$\mu g/Nm^3$		
Toluene	220 – 250	$\mu g/Nm^3$		
Ethylbenzene	610 – 630	$\mu g/Nm^3$		
m+p+o xylene	290 – 360	$\mu g/Nm^3$		
Halogenated HC and PCBs			0.00073	
Dioxins/furans (TEQ)			$(0.4 – 4) \cdot 10^{-8}$	
Total chlorine	1.5	$\mu g/Nm^3$		
HCl			0.011	
HF			0.0021	
Cd			$9.4.10^{-7}$	
Cr			$1.1.10^{-7}$	
Hg			$6.9.10^{-7}$	
Pb			$8.5.10^{-7}$	
Zn			$1.3.10^{-7}$	
Fugitive means that fugitive emissions of these components occur but no data have been provided to quantify it				

Table 3.18: Examples of gaseous emissions from anaerobic plants
[33, ETSU, 1998], [54, Vrancken, et al., 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [150, TWG, 2004]

Water emissions

Although anaerobic systems can be operated in stages to reduce the overall COD in the effluent, they are generally operated for efficient methane production, and the liquid effluent thus tends to be more concentrated than the effluent from aerobic systems.

The emission species will be similar to those from aerobic systems, but the volume of liquid is much higher and measurements will be needed to calculate emissions (e.g. TOC). The aqueous fraction may be discharged to sewer, or it may go through an aerobic waste water treatment prior to discharge. TOC, total nitrogen, total phosphorus and chloride levels will need to be monitored at the plant inlet and outlet to optimise plant performance, and are probably the most relevant indicators for such optimum performance.

Those units processing biological wastes from the food industries or agriculture are unlikely to produce metals in the liquid emissions. Moreover, the metal content in a discharge may be lower than for an equivalent aerobic system because metal compounds are precipitated and leave with the solid fraction. However, a small amount can appear in the liquid effluent as suspended solids.

The quantity of waste, or excess water generated depends upon a number of factors (extent of biodegradation, moisture content of input wastes and the extent to which the process water is recirculated, the way in which digestate is used -in some cases it is directly applied to land as slurry- and the degree to which steam is used to heat the biomass). Most processes seek to extract excess water from the digestate prior to aerobic digestion of the remaining biomass. In some countries, however, little or no attempt is made to do this and the digestate is used on land as a soil conditioner. Some site studies state 100 – 500 kg per tonne of waste (wet weight). The excess waters are likely to be more polluted from dry systems, since more water is recirculated in the wet systems. Figures for wet and dry systems are given in Table 3.19. The figures on dry and wet systems in Table 3.19 relate to the waste water before removal of the suspended solids. In the post-treatment phase, the liquor from the digestate may be subjected to a process of denitrification, or filtered and/or fed to a decanter, with solids potentially being added to the digestate and the excess water being delivered to sewer.

Components	Units	Dry systems	Wet systems	Amount (g) [1]
Waste water flow	m^3/t			0.47
COD	mg O_2/l	20000 – 40000	6000 – 24000	20 - 530
BOD	mg O_2/l	5000 – 10000	2500 – 5000	
Ammonia				1 – 160
Nitrate				1 – 10
Total N	mg N/l	2000 – 4000	800 – 1200	
Total P				
Cl				
Sulphate				1 – 5
As				
Cd				
Cr				
Cu				
Hg				
Ni				
Pb				
Zn				

[1] Based on 261 litres of waste water/tonne waste (possibly to be reduced to 211 litres by means of a partial re-use of the water used for the production of polymer solution). The range depends on the type of waste water treatment applied

Table 3.19: Typical waste water characteristics from anaerobic digestion
[59, Hogg, et al., 2002], [33, ETSU, 1998], [56, Babtie Group Ltd, 2002], [66, TWG, 2003]

Digested matter and waste

Concerning anaerobic digestion, the sludge or digestate is usually dewatered. The content of heavy metals may be leached out to soil or washed off into watercourses if the digestate is used as a compost, a soil cover or landfilled. In the event the content of heavy metals is too high to allow a land application, the compost/sludge may be used for daily covering at landfills. In this aspect, the groundwater Directive may be applied.

As the resulting anaerobic sludges are generated in a reducing environment, such sludges may concentrate some compounds such as metal sulphides and some organics (e.g. non-soluble intractable organics). The sludges processed from MSW or sewage sludge with an industrial feed will have a metal content in the waste intake, which will be deposited in the sludge.

The sludge cake, generated in the waste water treatment plant can go for a further chemical purification. If no purification is carried out, the sludge cake needs to be disposed of by landfill or can be (co-)incinerated. The residue of the sand washing is probably not suitable for thermal treatment, due to its low calorific value, and thus is disposed of by landfill.

Mechanical biological treatments

The loss of weight during the aerobic process is about 10 – 20 % of dry substance matter of input waste, equivalent to 30 – 40 % loss referred to the total weight. However, these data do not differentiate between moisture loss and carbon dioxide production. Aerobic systems operated in the open are more likely to create a wide range of emissions because the temperature and moisture content of the process is harder to control. There is much more chance that the material will saturate and produce a liquid emission, and a higher chance of the process turning anaerobic with subsequent emissions of methane.

Various companies co-digested hazardous organic waste streams with municipal or green wastes and low concentration of halogenated organics with aqueous organic wastes. In both cases, it is reasonable to expect the biomass to adapt to a new food source, but it is also reasonable to expect that the temperature rise in composting, or agitation of the tanks in activated sludge systems, will create a discharge to the air of new species.

By contrast to composting plants treating green waste and separately collected biowaste, the material treated in MBT plants may exhibit a broad range of emissions (municipal waste). MBT exhaust gas may contain fluorinated chlorinated hydrocarbons, ammonia, mercury, methane, N_2O and other compounds.

The MBT exhaust gas is partially produced during the mechanical treatment, but mostly is related to the biological process in which heat is released. Depending on the process, management temperatures from 30 up to 90 °C may be reached. Thus a great part of the moisture contained in the waste is driven out. Furthermore, the remains of solvents and of mineral oil carbohydrates can be driven out. Under these boundary conditions, the MBT exhaust gas contains at least the following material groups:

- water in the form of water vapour saturated process exhaust air which is not likely to be below saturation unless unsaturated hall air is added
- degradation products of organic decomposition which are also known from alcoholic fermentation, such as acetone, acetaldehyde, ethanol, methanol, butanol and other short-chained compounds
- solvents, especially benzene, toluole, xylene
- odorous terpenes, mainly limonene and alpha- and beta-pinene
- traces of mineral oil carbohydrates.

Air emissions

There is a limited amount of information available on emissions from aerobic operations. The emissions of air pollutants and odorous substances of MBT plants are:

- waste specific (type, composition, age)
- treatment specific (aerobic degradation, fermentation)
- process specific (type of aeration)
- dependent on operational management
- influenced meteorlogically (weather conditions) in the case of open reactors.

In addition to the release of odorous substances at delivery and during mechanical treatment, the emissions of the plant are mainly determined by the following sources:

- aerobic degradation
- fermentation
- exhaust air/exhaust gas treatment.

Microbiological degradation releases are from 30 to 50 MJ of heat per kg of organic substance in the waste. This heat leads to the desired self-warming of the material. The surplus heat that exceeds the quantity necessary for maintaining the process temperature is dissipated through evaporation of the water. The water thus fulfils the important function of the heat carrier.

Capacity MBT	**Part of the facility**	**Air renewal, temperature[1], process conditions**	**TOC (FID)**	**Concentration of odour**		**Odour**
kt/yr			**mg/m³ and g/t respect**	**spectrum GE/m³**	**average GE/m³**	**10^6 GE/h**
30	Mechanical treatment and low bunker	Forced ventilation, approx. 2-fold air renewal, 5 – 10 °C during the measurement	40 mg/m³ 20 – 25 g/t	-	-	-
200	Mechanical treatment and low bunker	Forced ventilation, approx. 1.5-fold air renewal, 10 – 13 °C during the measurement	15 – 25 mg/m³ 25 – 55 g/t	150 - 630	390	38
30	Total exhaust air of MBT (2 weeks biological degradation)	Mixture of exhaust air from halls and heaps, approx. 3-fold air renewal, 25 – 30 °C during the measurement	60 – 130 mg/m³ 500 – 720 g/t without methane 10 - 30 mg/m³ approx. 700 g/t methane			
50	Total exhaust air of MBT (16 weeks biological degradation)	Mixture of exhaust air from halls and heaps, approx. 1-fold air renewal, 20 – 30 °C during the measurement	700 – 880 g/t 200 – 700 mg/m³ up to 12000 g/t methane			
70	Exhaust air from biological degradation (fermentation with 8 weeks of biological degradation)	Mixture of exhaust air from halls and heaps, approx. single air renewal, 25 – 30 °C during the measurement	50 – 180 mg/m³ 590 – 720 g/t without methane approx. 80 mg/m³ approx. 1100 g/t methane	8000 – 20000	15000	1200 to biofilter

[1] There are some systems (air suction systems) where temperatures can reach up to 40 °C

Table 3.20: Examples of air parameters from some MBT
[132, UBA, 2003], [150, TWG, 2004]

Some data on air emissions from aerobic operations is shown in Table 3.21 below.

Parameters/ pollutants	**Emission to air (values in g/tonne of waste digested)** [6]
Flow	Exhaust air: 2500 – 30000 Nm^3/t
Ammonia[3]	5 – 3700 Other data: 0.12 times intake tonnage[1] 20 – 40 mg/Nm^3 [4]
Carbon dioxide	98 – 563 kg/tonne of MSW 482 – 566 kg/tonne of MSW if machinery, energy system and construction are included Other data: 10 – 20 % intake tonnage of waste x 1000 20 % of the intake dry solids
N_2O	11 – 110
NO_x	100
Methane	411 – 2000
Particulate matter[2]	163 – 186
PM_{10}s	e.g. bioaerosols
Odour	50 – 500 GE/m^3
TOC (VOC)[5]	0.7 – 600
AOX	
CFC	
Dioxins/furans	0.1 ng/m^3
Microbes	
Mercury	

[1] Reduce emission factor by 50 % if the system uses forced air or another method to ensure aerobic conditions throughout; increased emission factor if high nitrogen wastes received.
[2] Filter systems on the exit air will reduce general particulate emissions, but not PM_{10}.
[3] If treatment process conditions move away from the range of pH 4 – 8 and with a C:N:P ratio of out of 100:5:1, then larger quantities of other gases may evolve; larger quantities of ammonia may become particularly prevalent if there is too much nitrogen in the feedstock.
[4] Equals 545 – 1090 grams per tonne before any abatement of ammonia (e.g. biofilter).
[5] Methane may represent 1/6 of the TOC amount.
[6] In some cases several ways of calculation or different types of emission data are presented.

Table 3.21: Relevant emissions for MBT operations
[54, Vrancken, et al., 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [66, TWG, 2003], [75, UNECE,], [81, VDI and Dechema, 2002], [132, UBA, 2003], [150, TWG, 2004]

Ammonia emissions

Nitrogen in the waste can easily be converted to ammonia, and this is more likely to happen if the C:N ratios are unbalanced (too much nitrogen), or the mass becomes anoxic. For green wastes, this is more likely in the summer months with high levels of grass mowings in the waste and insufficient woody material as a bulking agent. Enclosed aerobic digestion or biodegradation systems with a high forced air injection providing an excess of oxygen produce less ammonia than standard windrows. The ammonia load of the crude gas of MBT plants amounts to between 10 to 560 mg/Nm^3 depending on the process variant, specific exhaust air quantity, etc. With upstream fermentation, up to 1000 mg/Nm^3 may be found in the pre-biological degradation. In addition to its effect of polluting the air, a high ammonia concentration in the crude gas damages the biofilters often used in MBT plants. Therefore, the aim has to be to keep the ammonia load of the crude gas prior to entry into the biofilter as low as possible. Upstream pH controlled acid scrubbers can reliably keep NH_3 concentrations below 10 mg/Nm^3.

Sites undertake a range of riddling, sieving, grinding and turning operations. *Particulate* emissions occur, but there are no data to quantify them. It is known that most aerobic digestion operations generate a range of fungi, particularly aspergillus. Filters on the exit air will minimise particulate emissions. PM_{10} emissions are a possibility.

Bioaerosols
These are micro-organisms and other tiny biological particles that are suspended in air. They are respirable and generally invisible. Bioaerosols can be produced by the aerobic process. Surveys have drawn particular attention to a fungus called Aspergillus fumigatus. It is found all over the world, especially in soils and in forest litter. It is particularly associated with the aerobic digestion process as it is capable of degrading cellulose (a carbohydrate found in plant material) and is capable of surviving at high temperatures (up to 65 °C). As part of its lifecycle, Aspergillus fumigatus produces tiny spores.

Odour emissions
They may come from anaerobic conditions. Odours are emitted from the surface of open piles, windrows, maturation piles, storage piles and stockpiles. Exhaust gases from controlled aeration systems also contain odourous compounds. Typically the most problematic odorous compounds at aerobic digestion facilities include ammonia, hydrogen sulphide, mercaptans, alkyl sulphides such as dimethyl sulphide, dimethyl disulphide and terpenes. These compounds are present in many feedstocks or are formed during the process through aerobic or anaerobic actions.

Some pesticide
They may be broken down by photolysis, plant metabolisms or microbial action. Others are persistent.

Methane
Methane will also be an issue, although the plant will usually be run in such a way so as to minimise this production. Methane emissions may range from 10 to 2000 mg/Nm^3.

VOCs
Any volatiles in the feedstock will tend to be emitted to the air due to the temperature rises. The crude gas from MBT plants contains a large number of single organic compounds in relatively high but fluctuating concentrations. The TOC concentration (total organic carbon) that records all organic contents is a parameter suitable for monitoring. The MBT crude gas contains TOC concentrations of between 10 to 2000 mg/Nm^3, but up to 7500 mg/Nm^3 have been measured. Open-air heaps have TOC-concentrations above 1000 mg/m^3 due to inevitable anaerobic conditions within the core of the heap. Carbon concentrations of more than 10000 mg/Nm^3 have been recorded at the surface of non-aerated open-air heaps especially with anaerobic conditions within the heap. The main outflow of the TOC occurs during the first hot biological degradation phase, i.e. in the first one or two weeks of biological degradation. Next Table 3.22 shows the list of organic compounds identified in MBTs.

Alkanes		
1,1-dimethylcyclopentane	4-methylnonane	n-dodecane
1,3-dimethylcyclohexane	5 ratified alkane	n-heptane
1,4-dimethylcyclohexane	5-methylundecane	n-hexane
10 ratified alkane	6 alkylcyclohexane	n-nonane
11 ratified alkane	butylcyclohexane	n-pentadecane
2 ratified ektane	2 C_3-cyclohexane	n-pentane
2 ratified undecane	C_4 –cyclohexane	n-tetradecane
2,3-dimethylpentane	cyclohexane	n-tridecane
2,4-diphenyl-4-methyl-2-pentene	decane	n-undecane
2-methyldekane	dimethylcyclohexane	nonadecane
2-methylheptane	dodecane	propylcyclohexane
2-methylhexane	ethylcyclohexane	tridecane
2-methylnonane	ethylcyclopentane	trimethylbenzol
2-methylundecane	hexadecane	trimethylcyclohexane
3-methyldecane	methylcyclopentane	undecane
3-methylheptane	methylbutane	3 ratified heptane
3-methylhexane	methylcyclohexane	7 ratified nonane
3-methylnonane	methyloctane	2 ratified octane
4-methylheptane	n-decane	ratified dodecane
PAHs		
1,2,3,4-tetrahydromethyl-naphthaline	naphthaline	acenaphthene
1,2,3,4-tetrahydronaphthaline (tetraline)	dimethylnaphthaline	methyldecaline
ethylnaphthaline (vinylnaphthaline)	1-methylnaphthaline	2 -methylnaphthaline
decahydromethyl- naphthaline	methyltetraline	
Acids and esters		
2-butene acidethylester	butyric acidmethylester	hexanal
2-methylbutyric acidethylester	2 carbonacidester	hexanacidethylester
3-methylbutyric acidethylester	6 carbonacid	fattyacidethylester
alkanacidethylester	acetic acid	myristinacidisopropylester
alkanacidethylester (acid >C_7)	2 alkanacid	pentanacidmethylester
aceticacid -1-methylethylester	aceticacidalkylester	propanacidethylester
benzoacid	aceticacidbutylester	propanacidmethylester
benzoacidbenzylester	aceticacidethylester	hetradecane acid
butyricacid	aceticacidmethylester	hexadecane acid
butyricacidethylester		
Terpene		
α-pinene	β-pinene	β-myrcene
pinene	D-limonene	3-carene
myrcene	camphor	
Aldehydes/ketones		
1,2-diphenylethanone	3-buten-2-one	hexanal
2,3-butandione	3-hydroxy-2-butanone	methyl-2-butanone
5 2-alkanone	3-pentanone	methylisobutylketone
2-butanone	Acetaldehyde	nonanal
2-heptanone	Acetone	octanol
2-hexanone	acetophenone	pentanal
2-methylpropanal	decanal	ramified 2-heptanone
2-pentanone	diphenylethandione	dodecanal
2-undecanone		
Alcohols		
1-butanol	2-methyl-1-propanol	isopropanol
1-pentanol	2-methylbutanol	ramified alcanol
2-butanol	3-Methyl-1-butanol	ramified pentanol
2-ethyl-1-hexanol	butanol	ethanol
2-methyl-1-butanol		

benzene	2 C_6-benzene	methylpropylbenzene
5 C_3-benzene	3-dimethylethylbenzene	propylbenzene
C_4-benzene	ethylbenzene	styrol
1-methylpropylbenzene	ethylmethylbenzene	toluene
15 C_4-benzene	o/m/p-xylene	3-trimethylbenzoene
7 C_5-benzene	methylisopropylbenzole	
Halogenic compounds		
1,1,1-trichlorethane	dichlormethane	tetrachlorethylene
dichlorbenzene	fluorethylene	trichlorethylene
Sulphur compounds		
2-butanthiol	dimethylsulphide	sulphur dioxide
dimethyldisulphide	methanthiol	carbon disulphide
Siloxanes		
cyclohexasiloxane	cyclotetrasiloxane	cyclosiloxane
cyclopentasiloxane	hexamethyldisiloxane	siloxane
octamethylcyclotetra-disiloxane		
Phthalates		
diethylphthalate	dimethylphthalate	
Ethers		
tetrahydrofurane		

Table 3.22: Organic compounds which were verified within the scope of four screening inquiries of exhaust air (three aerobic tests with intensive and after-biological degradation, one anaerobic plant)
[132, UBA, 2003]

Chlorofluorocarbons (CFC)
The few available data shows that in MBT plants CFC loads of more than 10 grams per tonne input material may be released depending on the processed waste type (Table 3.23). Leading substances are CFC R11 (trichlorofluoromethane) and R12 (dichlorofluoromethane) which were used frequently in the past.

Parameter (g/tonne)	**Facility A (exhaust air from tunnel)**	**Facility B (exhaust air from biological degradation trommel)**	**Facility B (exhaust air from biological degradation trommel)**	**Facility B (exhaust air from halls)**	**Facility C (exhaust air from biological degradation module)**
Probe spring	Winter	Summer	Winter	Summer	(estimated)
R11	n.d.	8.5	4.1	0.4	2.2 – 2.3
R12	n.d.	11.3	0.2	0.4	1.3 – 1.4
R21	n.d.	n.d.	-	n.d.	n.d.
R113	n.d.	n.d.	<0.05	n.d.	1.9
R114	n.d.	n.d.	0.2	0.4	1.2 – 1.4
n.d. = not detectable					

Table 3.23: CFC emissions from MBT (raw gas)
[132, UBA, 2003]

Waste water
Sites are unlikely to produce a surplus of liquid because the aerobic digestion process emits large volumes of water to the air and generally requires additional liquids as 'top-ups'. If they do, then these will be occasional intermittent flows. Although it is known that some sites have had problems with waste water, the quantities of liquid emissions are likely to be small since aerobic digestion is an exothermic process.

Water parameter	Specific emissions (kg/tonne of MSW)	Concentration of the waste water (mg/l)
Waste water flow	260 – 470	
TOC		40
COD	0.457	120 – 200
BOD_5		20 – 25
HC		10 – 20
BTEX		0.1
AOX		0.5
Chloride	0.152	
Total N		70
Total P		1 – 3
CN	$7.28 \cdot 10^{-5}$	0.2
Sulphide		0.1 – 1
Cd	0	
Cr	0	0.5
Cr (VI)		0.1
Cu	0	
Hg	0	
Mg	0	
Ni	$7.94 \cdot 10^{-4}$	
Pb	$5.96 \cdot 10^{-4}$	
Zn	$2.38 \cdot 10^{-4}$	
Copper and zinc would be expected in any aerobic digestion leachate as they are plant micronutrients. There is a possibility of toxic metals in the effluent although most metals will remain in the aerobic digestion product.		

Table 3.24: Leachate from aerobic digestion
[54, Vrancken, et al., 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [66, TWG, 2003], [75, UNECE,], [81, VDI and Dechema, 2002], [132, UBA, 2003], [150, TWG, 2004]

Emissions to land

Aerobic digestion sites should make certain whether or not there are liquid emissions to land, even if they have a concrete base underneath the windrows, as the concrete basement may not be non-continuous, and part of the operation may be on a permeable surface. If the base is impermeable, then there will be a discharge to surface waters or sewer or a collection in sumps. If the aerobic digestion sites are on the landfill, liquid discharges will go to the landfill treatment plant.

There is also a possible problem if excess rainwater falling on the windrows is not evaporated by the heat of the aerobic digestion process. Surplus water would pick up fatty acids and humic acids and solids from the aerobic digestion process and then transfer the discharge to land, surface water or sewer.

Sludge and/or digestate for onward disposal to landfill typically have organic compounds, nitrogen and phosphorous compounds, chloride and chromium.

Biological treatments applied to contaminated soil

Air emission due to *ex situ* biodegradation

Little information exists on volatile losses from *ex situ* bioremediation processes. Table 3.25 summarises the data available for both slurry-phase and biopile systems. Although these data are limited, volatilisation appears to be a small component of the overall removal of hydrocarbons in these processes.

Contaminants	Emission rate	Total emissions	Biodegradation/ Volatilisation	Notes
Slurry-phase bioremediation				
Creosote	0.07 – 6.3 g HC/h	n.a.	n.a.	Off-gas concentrations peaked during day 1 and decreased to near baseline by day 5
Petroleum sludge	n.a.	910 kg HC	n.a.	425000 kg of soils were treated. Emissions reduced to background by day 6
Petroleum sludge	n.a.	10 - 20 kg/yr; 1.5 kg dredging 30 kg storage tank; 4 kg pond	n.a.	A full-scale system is estimated to have 500 to 2000 kg of VOC emissions
Biopile				
Gasoline	n.a.	n.a.	99 %/1 %	Air emissions measured for the stockpiling/handling, mixing, and curing operations. Mixing component accounted for 96 % of contaminants lost. 73 % of VOCs lost were trapped in carbon units
Petroleum	0.01 kg/hr HC once through; 0.03 kg/hr HC after treatment (carbon)	n.a.	n.a.	Off-gas was also recycled back to the biopiles to further reduce emissions
Petroleum	16 ppb BTEX start-up; 5 ppb BTEX (day 8); <1 ppb BTEX (day 35)	n.a.	>99 %/<1 %	
HC: Total hydrocarbons				

Table 3.25: Summary of emission data for ex-situ bioremediation systems [30, Eklund, et al., 1997]

In open lagoons and in aerobic digestion and land treatment processes, the primary environmental factors which influence air emissions, in addition to the biodegradability and volatility of the waste, are process temperature and wind speed. Emissions tend to increase with an increase in surface turbulence due to wind or mechanical agitation. The temperature affects emissions through its influence on microbial growth. At temperatures outside the band for optimal microbial activity, volatilisation will increase. Emissions from self-contained reactors are also determined by reactor design parameters such as the amount of air or oxygen used to aerate the slurry. Higher gas flows will strip more volatiles out of solution and increase air emissions.

3.2.4 Waste OUT from biological treatments

The structure given to this section corresponds to the same one that has been given to Section 2.2, and describes the waste (or products) generated by the biological treatments of waste (the Waste OUT, according to the definition in Table 3.1).

Anaerobic digestion

An overview of the expected waste OUT (based on the source separated MSW input) is given in Table 3.26.

Fractions suitable for energy recovery	Specific amounts (kg per tonne MSW)	Heating value (MJ/kg)	
		Lower	Higher
Biogas [1]	117.5 (75 – 364 Nm^3)	15.4	16.8
Light residue	37.3	12.4	21.5
RDF	257.2	17	25.8
Wood-like fraction	14	4.9	10.0
[1] This lower yield is mainly explained by the higher content of non-degradable material (sand). Yields may vary from season to season (higher yields during autumn/winter).			

Table 3.26: Expected waste OUT (based on the standard composition of waste) from the installation
[54, Vrancken, et al., 2001], [59, Hogg, et al., 2002]

Biogas

In the biogas, there are also other constituents in smaller concentrations including carbon monoxide, hydrogen, nitrogen and oxygen. A larger proportion of inorganics and polluting substances in the process will lead to smaller amounts of a 'dirtier' biogas. The constituents of biogas (other than carbon dioxide and methane) can be quite important in its end-use. Table 3.27 shows such the typical composition of a biogas generated by anaerobic digestion.

Component	Biogas concentration (vol-%)	Specific production (g/tonne of waste)	Specific emissions (g/MJ of methane)
CO_2	25 – 50	181000 – 520000	85
Methane	50 – 75	0 – 411	0.1
Water (biogas)	6 – 6.5		
O_2	0.9 – 1.1		
N_2	3.9 – 4.1		
H_2			
H_2S	<0.1 – 0.8		
Ammonia	<0.1 – 1		
Mercaptane	In spores		
Low molecular fatty acids			
Higher molecular substances	traces		

Table 3.27: Composition of biogas generated by anaerobic digestion
[33, ETSU, 1998], [54, Vrancken, et al., 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [132, UBA, 2003]

The biogas may be partly used for the production of power and/or heat (e.g. electricity, building heating, vehicles powered with biogas) by combusting it in a biogas engine. When biogas is used to generate energy, it is possible to generate from 20 to near to 300 kWh of net energy per tonne of waste. Several references have been enclosed in Table 3.28.

Study/process	Net energy production (kWh/tonne of waste)		
	Minimum*	Average*	Maximum*
AN-Anaerob	38	49	60
DBA	45	53	60
Kompo	85	88	90
NOVEM	21	88	154
Plaunener-Verfahren	85	98	110
Waterman BBT		100	
DHV study		102	
White et al		110	
Prethane-Biopaq	80	110	140
IEA Bioenergy	75	113	150
BTA	100	115	130
Dranco	105	131	157
Vrancken		140	
WAASA	120	145	170
IWM	100	150	200
Schwarting-UHDE		154	
D.U.T	254	273	292
* If only one figure is quoted, the reference in question did not provide a range			

Table 3.28: Net energy production figures from different sources
[59, Hogg, et al., 2002], [54, Vrancken, et al., 2001], [150, TWG, 2004]

Solid waste fuel to be used as fuel

More information on this matter can be found in Section 3.5.4.1. The solid fuel prepared is a presorted mixture of paper and plastics. Washing of the digestion product yields two additional streams a residue and a wood-like fraction, with a residual calorific value that allows thermal treatment. The three streams added together give 308.5 kg solid fuel mix for thermal valorisation. The solid fuel mix has a lower heating value of 16.5 MJ/kg and a dry solids content of 66 %.

Type of waste	%
Organic waste	45
Others	31
Paper/cardboard	13
Plastics	9
Textile	2

Table 3.29: Composition of the solid waste prepared
[54, Vrancken, et al., 2001], [150, TWG, 2004]

Digestate

The amount of digestate generated ranges from 100 – 500 kilograms per tonne of waste IN. This range is due to an extention of biodegradation, the moisture content of waste IN, the extent of process water recirculation, the way in which the digestate is used and the degree to which steam is used to heat biomass. The composition varies as shown in Table 3.30:

Feedstock	Units	N	P	K	Mg	Ca
Biowaste/RDF	% of TS	1.2	0.68	0.74		0
Source sep. MSW	% of DM	1.90	0.66	0.63	-	-
Source sep. MSW	ppm	20.0	11.9	14.7	11.6	49.7
Source sep. MSW	ppm	11	8	10	-	-
Organic fraction MSW	ppm	1 – 1.3	6 – 12	8 – 12	17 – 26	60 – 110
Fruit/veg from market	ppm	21.9	9.5	10.5	4.7	-
Unsorted MSW	ppm	11	8	10	-	-
Unsorted MSW	ppm	19	13	15	3.67	-

Table 3.30: Chemical characteristics of anaerobic digestate
[59, Hogg, et al., 2002], [150, TWG, 2004]

Other products/waste

Recovered product	Specific production (tonnes per tonne of waste treated)
Nutrient recovery	4.0 – 4.5 kg N/tonne 0.5 – 1 kg P/tonne 2.5 – 3 kg K/tonne
Energy recovery	0.4 – 0.9 MJ electricity per tonne of waste. In addition, CHP plants may generate a similar quantity of heat
Total solid residuals depending on waste	0.3 – 0.6
Quality products for recycling (recovery)	Fibres (0.07 – 0.3) (for composting)
Other residuals possible for re-use with restrictions	Fluids (0.6) Inerts (0.05) Sand (0.08)
Residuals for landfilling or other waste treatment	Overflow sieving (0.02 – 0.1)
Metals (containing ferrous)	0.043
Ferrous metals	0.032
The separation and washing of the digested material yields fractions of inert materials, sand and a fibrous fraction. The inert materials and the sand fraction can be used as a building material. Another output corresponds to the fibrous fraction.	

Table 3.31: Overview of anaerobic technology for the treatment of biodegradable municipal waste [59, Hogg, et al., 2002], [54, Vrancken, et al., 2001]

Mechanical biological treatments

The aerobic treatments reduce the tonnage of input materials by the conversion of part of the biomass to carbon dioxide and water through microbial actions.

Fractions suitable for energy recovery	Specific amount (kg per tonne MSW)	Heating value (MJ/kg)	
		lower	higher
RDF	300 – 460	16.6	19.9
Fractions not suitable for energy recovery		**Destination and properties**	
Ferrous	32 – 40: 24 ferrous 1 8 ferrous 2	Scrap trade (2 fractions) Pre-separation Post-separation	
Inerts	48.6 <40 glass	Re-use	
Non-ferrous	8 – 10	Recovery	
Organic rich material (to biological treatment)	550 - process losses 200 - treated waste for landfilling 350	TOC 18 w/w-% Upper heating value of 6 MJ/kg Density >1.5 t/m^3 (wet) Hydraulic conductivity k_f<10^{-8} m/s	

Table 3.32: Waste OUT from MBT
[54, Vrancken, et al., 2001], [59, Hogg, et al., 2002], [81, VDI and Dechema, 2002]

Grey compost

Copper and zinc can be expected to be found in any compost as they are plant micronutrients. Other heavy metals will be associated with whole aerobic digestion only, or by the addition of, hazardous waste streams. In general, metals will be retained in the solid fraction. Metals will bioaccumulate in the compost fraction. Some products recovered by this treatment are shown in the Table 3.33.

Recovered product	Value (tonnes/tonne of waste treated)
Nutrient recovery	2.5 – 10 kg N/tonne of biowaste recovered 0.5 – 1 kg P/tonne of biowaste recovered 1 – 2 kg K/tonne biowaste recovered
Energy recovery	Likely (e.g. through dry stabilisation/separation processes to manufacture RDF). Depending on the configuration, RDF may be (typically) 0.2 – 0.5 tonnes, with a calorific value of around 15 – 20 MJ/kg (sometimes higher). In addition, in some configurations, digestion processes can recover energy from degradation of the biodegradable fraction (can be >100 kWh depending on composition)
Total solid residuals depending on waste (tonnes/tonnes waste)	0.7 – 0.9
Quality products for recycling (recovery)	Metals (0.05)
Other residuals possible for re-use with restrictions	RDF (0.3 – 0.4) Stabilised organic fraction (0.07 – 0.2) ▪ respiration activity (AT_4): <5 – 7 mg O_2/g TS ▪ gas formation: GB21 <20 mg/g TS
Residuals for landfilling or other waste treatment	Heavy and light rejects (0.2 – 0.4)

Table 3.33: Overview of MBT outputs for the treatment of biodegradable municipal waste [59, Hogg, et al., 2002], [150, TWG, 2004]

The characteristics of the aerobic digested product has the following characteristics: one kilogram of treated waste potentially releases a total load of 1 – 3 g of COD, 0.5 – 1.5 g TOC and 0.1 – 0.2 g NH_4-N into the leachates. The real numbers clearly depend on the intensity respective and the duration of the treatment. Table 3.34 shows the potential emissions from grey compost by gas and leachate.

Emission potential		Unit	Untreated MSW	Mechanical-biological treated MSW
by gas: carbon		litre/kg of dry matter g C_{org}/kg dry matter	134 – 233 71.7 – 124.7	12 – 50 6.4 – 26.8
by leachate:	TOC	g/kg of dry matter	8 – 16	0.3 – 3.3
	N	g/kg of dry matter	4 – 6	0.6 – 2.4
	Cl	g/kg of dry matter	4 – 5	4 – 6
Note: Minimum values represent the stabilisation degree reached by more modern MBTs				

Table 3.34: Range of organic carbon, nitrogen and chlorine transfer by gas and leachate [81, VDI and Dechema, 2002]

Biological treatments applied to contaminated soil

	Initial concentration		Final concentration		Removal[(a)]	
Compound	**Solids (mg/kg)**	**Slurry (mg/kg)**	**Solids (mg/kg)**	**Slurry (mg/kg)**	**Solids (%)**	**Slurry (%)**
Phenol	14.6	1.4	0.7	<0.1	95.2	92.8
Pentachlorophenol	687	64	12.3	0.8	98.2	92.8
Naphthalene	3670	343	23	1.6	99.3	99.5
Phenanthrene and anthracene	30700	2870	200	13.7	99.3	99.5
Fluoranthene	5470	511	67	4.6	98.8	99.1
Carbazole	1490	139	4.9	0.3	99.7	99.8
Note: Treatment carried out using a 190 m^3 reactor (a) Includes the combined effect of volatilisation and biodegradation						

Table 3.35: Performance of a slurry biodegradation process treating wood preserving wastes [30, Eklund, et al., 1997]

3.3 Emissions and consumptions from physico-chemical treatments

[30, Eklund, et al., 1997], [51, Inertec, et al., 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [89, Germany, 2003], [94, USA DoE, 2002], [99, Fons-Esteve, et al., 2002], [100, UNEP, 2000], [101, Greenpeace, 1998], [121, Schmidt and Institute for environmental and waste management, 2002], [123, Perseo, 2003], [134, UBA, 2003], [147, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [154, UNEP, 2004], [156, VROM, 2004], [157, UBA, 2004]

This section contains the emissions and consumptions of physico-chemical (Ph-c) treatments discussed in Section 2.3. Chemical treatment processes cover a wide range of unit operations and a wide range of wastes. This section also applies to chemical treatment plants operating neutralisation processes. The following sections highlight information available to site operators from their current record systems and the areas where emissions are likely to occur. Most sites are on a totally enclosed base with all liquids entering or generated on-site (including rainfall) returned to the process. This sector is very diverse, but also one of the best monitored sectors, as was observed in site visits.

The structure of each of the following sections in this section is the same as the one followed in Section 2.3. Emissions associated with an ancillary treatment, e.g. transfer station operation are covered in Section 3.1.

3.3.1 Waste IN in physico-chemical treatments

Waste waters
The waste waters treated by physico-chemical treatments are:

- the core waste streams – these are inorganic acids and alkalis and their rinse-waters, together with cleaning, washing and interceptor wastes from a range of processes
- chemical industry wastes – these may include aqueous alcohol/glycol streams and process wash-waters
- (possibly) cleaning wastes with low levels of chlorinated compounds such as dichloromethane or phenolic compounds. Cleaning waters from the food industry may contain these substances as well
- aqueous wastes containing solvents
- high nitrogen wastes (potential for ammonia emissions)
- wastes containing phosphorus
- occasional inorganic wastes: for example wastes containing arsenic
- cyanide wastes - typically this waste will consist of solid or liquid cyanide salts, for example, sodium cyanide from surface metal treatments. They may also be present in printing wastes, usually as silver cyanide. Examples of cyanide based plating solutions include copper, zinc and cadmium cyanides
- developer waste (photographic wastes) typically includes a solution with a high percentage of ammonia salts, predominantly thiosulphate
- waste waters from shaping; oil wastes; organic chemical processes; and water and steam degreasing processes.

Without going into detail and/or individual and special cases, the essential sources of Ph-c plant treatable wastes are indicated in Table 3.36.

EWL chapter	Title	EWL list
06	Wastes from inorganic chemical processes	0601 waste acidic solutions 0602 waste alkaline solutions 0603 waste salts and their solutions 0604 waste containing metals 0605 sludges from on-site effluent treatment
07	Wastes from organic chemical processes	0701 wastes from the manufacture, formulation, supply and use (MFSU) of basic organic chemicals 0702 wastes from the MFSU of plastics, synthetic rubber and man-made fibres 0706 wastes from the MFSU of fats, grease, soaps, detergents, disinfectants and cosmetics
11	Inorganic wastes containing metal from metal treatment and the coating of metal; non-ferrous hydro-metallurgy	1101 liquid wastes and sludges from metal treatment and coating of metals (eg. galvanic processes, zinc coating processes, pickling processes, etching, phosphating, alkaline degreasing)
12	Wastes from shaping and surface treatment of metals and plastics	1201 wastes from shaping (including forging, welding, pressing, drawing, turning, cutting and filing) 1202 wastes from mechanical surface treatment processes (blasting, grinding, honing, lapping, polishing) 1203 wastes from water and steam degreasing processes
13	Oil wastes	1304 bilge oils 1305 oil/water separator contents
19	Wastes from waste treatment facilities, off-site waste water treatment plants and the water industry	1908 wastes from waste water treatment plants not otherwide specified

Table 3.36: Types of waste that may be treated in a physico-chemical treatment plant [121, Schmidt and Institute for environmental and waste management, 2002]

The essential mass flow from Ph-c plants is the waste water, corresponding to about 85 to 95 % mass of the waste accepted for treatment.

Aqueous marine waste

Most of the waste water from aqueous marine waste is contaminated with oil, organic substances and solid material (e.g. sediment). The contents of heavy metals, salts and other inorganic substances in the water and oil fractions are relatively low. Table 3.37 shows the acceptance and processing criteria for flocculation/flotation and biological treatment.

Component	Limit value acceptance (mg/l)	Limit value processing (mg/l)	List mixing policy*
PCBs	Detection limit	Detection limit	X
Dioxins	Detection limit	Detection limit	X
Pesticides	Detection limit	Detection limit	X
Organotin compounds	Detection limit	Detection limit	X
Brominated diphenyl ethers	Detection limit	Detection limit	X
Inhibition respiration	10 %	10 %	
N-total (Kjeldahl)	to discuss	500	
CN	to discuss	5	
Phenol	to discuss	1500	
VOX	100	20	
EOX	10	5	X
Cd	0.1	0.1	X
Hg	0.01	0.01	X
Total heavy metals	25	25	X
*the limit value of acceptance is in accordance with the policy on mixing.			

Table 3.37: Acceptance and processing criteria for flocculation/flotation and biological treatment for aqueous marine waste
[156, VROM, 2004]

Waste solids and sludges
Some waste solids and sludges treated by physico-chemical treatments are:

- asbestos
- slag or bottom ash from combustion processes
- FGT waste (e.g. incineration ashes from MSW, hospital waste or industrial waste incinerators)
- sludge to be stabilised. Sludges from chemical industry may contain sulphates and organic salts
- stable waste
- sludge from waste water processing (municipal or industrial)
- residues from the metallurgical industry (dusts, sludge, slags). These may have high contents of Cr(VI)
- spent catalysts
- paint residues
- mineral residues from chemical processing
- wastes containing acid and soluble compounds
- high arsenic content residues from the chemical, metallurgical or ore industries
- contaminated soil. According to meeting devoted to assessing indicators for soil contamination [99, Fons-Esteve, et al., 2002], there are three main indicators used to establish whether soil is contaminated or not. These are typically acidification, eutrophication (the typical indicator is nitrogen content) and the content of heavy metals (e.g mercury). Contaminated soil can contain rocks, bricks, and reinforcing rods that could damage the equipment used for material handling if not removed.

The following text gives some information about some of these types of waste.

Bottom ash and FGT wastes from combustion processes
Some wastes from combustion processes are bottom ashes, FGT waste and filter cakes. Table 3.38 shows the physico-chemical characteristics of such waste from MSW incinerators:

Properties	Compounds	Values
pH		11 – 12.5 – 13
Soluble salts content	Cl, sulphates	Up to 70 % (Conductivity 15000 – 27000 – 37000 µS/cm)
Heavy metals	Pb, Zn, Cd, Cr	Up to several %
Inert compounds	Silica, alumina, lime	
Fine particulates		<100 µm
Density		Low (0.4 – 0.6)
Hygroscopic material	Salts, excess lime content	
Leaching test before treatment	Solubles Cr Cd Pb Zn As	10 – 80 % 1.5 – 8 ppm 1 – 500 ppm 1 – 1400 ppm 1 – 10000 ppm 1 – 50000 ppm
Middle number in ranges corresponds to averages.		

Table 3.38: Characterisation of residues from MSW incinerators
[51, Inertec, et al., 2002]

The general components of slag/bottom ash from household incineration are silicates, alkaline earth, chloride, sulphates, non-ferrous metals (e.g. As, Cd, Cu, Pb), ferrous metals and heavy metals. The main components are the mineral fraction, the non-incinerated fraction and the scrap metal.

Categories	Percentage by weight (%)
Mineral fraction	85 – 90
Non-incinerated fraction	1 – 5
Metal scrap	7 – 10

Table 3.39: Main components of slag/bottom ash
[89, Germany, 2003]

Values in %-wt	Slag/bottom ash (fresh)			Slag/bottom ash after storage (ageing time of 3 months)		
Parameter	**Min.**	**Average**	**Max.**	**Min.**	**Average**	**Max.**
SiO_2	42.91	49.2	64.84	39.66	49.2	60.39
Fe_2O_3	9.74	12	13.71	8.41	12.7	17.81
CaO	10.45	15.3	21.77	10.42	15.1	23.27
K_2O	0.83	1.05	1.36	0.84	0.91	1.42
TiO_2	0.65	1.03	1.33	0.65	0.88	1.12
MnO	0.06	0.14	0.22	0.1	0.17	0.26
Al_2O_3	6.58	8.5	10.79	7.43	8.83	10.45
P_2O_5	0.55	0.91	1.49	0.5	1.04	2.61
MgO	1.79	2.69	3.4	1.84	2.59	3.51
Na_2O	1.86	4.3	5.81	2.05	4.15	7.49
Carbonates	2.56	5.91	10.96	5.59	5.83	7.62
Sulphates	2.5	15.3	28.3	5.8	12.5	22.5
Cl	1.3	3.01	7	1.5	2.71	4.6
Cr (ppm)	174	648	1035	295	655	1.617
Ni (ppm)	55	215	316	90	165	260.2
Cu (ppm)	935	2151	6240	1245	2510	5823
Zn (ppm)	1200	2383	4001	1795	3132	5255
Pb (ppm)	497	1655	3245	1108	2245	3900

Table 3.40: Chemical composition of bottom ash after the household incineration plant
[150, TWG, 2004]

The following Table 3.41 and Table 3.42 describe some general values of bottom ash parameters after the incineration process, with data from two different treatment plants.

Values	Pb	Cr	Cu	Cd	As	Zn	Hg	Ni
Minimum	0.6	0.1	0.2	0.0001	0.003	0.5	0.07	
Average	1.6	0.5	2.2	0.021	0.012	4.8	0.7	
Maximum	5.2 – 6	2 – 9.6	7	0.02 – 0.08	0.022	10 – 21	2	0.5
Values in g/kg of bottom ash								

Table 3.41: General bottom ash values after the household waste incineration process [89, Germany, 2003]

Metal	Bottom ashes (slag) (ppm)	Bottom ashes[1] (slag) (ppm)	Fly ash and residues from dry and semi-dry processes (ppm) [1]	Mixture of fly ash and sludge from wet scrubbing process (ppm) [1]
Cd	0.3 – 70.5	0.01 – 0.1	1 – 10	<0.001
Cr	23 – 3170	0.001 – 0.01	1 – 10	0.01 – 0.1
Hg	0.02 – 7.75	0.001 – 0.01	<0.001	<0.001
Pb	98 – 13700	1 – 10	10000 – 100000	0.001 – 0.01
[1] Values correspond to concentration ranges in initial leachates Some more information on incinerators can be found in the waste incineration BREF				

Table 3.42: Metals in bottom and fly ashes of municipal solid waste incinerators [113, COWI A/S, 2002], [150, TWG, 2004]

During the combustion of coal, two types of coal ashes are generated. Classic fly ashes are mainly composed of non-combustible elements and non-burned particulates, and contain, on average, 50 % silica, 25 – 30 % alumina, 8 % iron oxides (containing Ca, K, Mg, Na, Ti and traces of As, Cd, Cr, Cu, Ni, Pb, Se, Zn). The other type of fly ash is composed of silico-calcareous ashes that are generated from the particulate abatement techniques and sulphur oxide abatement techniques. These ashes are rich in calcium sulphate. More information can be found in the Large Combustion Plant BREF.

The ashes from heavy fuel oil typically contain sulphur, vanadium and nickel. They are also characterised by high percentages of non-burned carbon, typically 60 % but can reach up to 80 %. More information can be found in the Large Combustion Plant BREF.

Asbestos

Table 3.43 below shows ranges found in the composition of different asbestos types.

Value in %	Friable asbestos	Transite asbestos
Al_2O_3	0.16 – 1.57	1.08 – 2.60
CaO	2.86 – 3.89	7.53 – 36.20
Fe_2O_3	5.43 – 8.17	0.55 – 11.85
FeO	0.00	0.00
K_2O	0.02 – 0.26	0.39 – 0.43
MgO	69.00 - 78.49	1.22 – 56.13
MnO	0.04 – 0.18	0.01 – 0.2
Na_2O	0.41 – 0.73	0.01 – 0.14
P_2O_5	0.16 – 0.22	0.02 – 0.20
SiO_2	12.04 – 16.10	20.87 - 60.01
TiO_2	0.02 – 0.06	0.09 – 0.23
Loss on ignition [1]	48.47 – 51.53	17.96 – 44.35
[1] Indicator of the organic content of the sample.		

Table 3.43: Asbestos composition [94, USA DoE, 2002]

High temperature drying
The drying facility performs the pretreatment of aqueous paste-like wastes such as metal hydroxide sludges or coagulated lacquer and paint sludges.

Thermal distillative drying
Solid/paste like hazardous wastes which contain considerable amounts of free or bound fluids are treated. They are processed in order to recover solvents, to produce defined solid products or for drying in the facility.

In addition, heat cost allocator tubes or aerosol cans may also be treated. Heat cost allocator tubes are used for measuring heat energy consumption. They consist mainly of a glass tube and methyl benzoate as the evaporative medium. The drying residue (cullet) of the heat cost allocator tubes can be smelted in the corresponding steel mills or used in road construction. The condensate from the drying process can be recycled, i.e. it is re-used for the production of heat cost allocator tubes.

Waste IN in the treatment of specific wastes

Hydrogenation of POPs
According to the US DOE, this system can handle most types of waste, including landfill leachates, lagoon bottoms, soils, sludges, liquids, and gases. However, US DOE has cautioned that reaction by-products and intermediate reduction products need to be monitored in the off-gas from both the reduction process and the boiler. US DOE also noted the need to determine the fate of mercury and other volatile inorganics.

The process is non-discriminatory; that is organic molecules such as PCBs, PAHs, chlorophenols, dioxins, chlorobenzenes, pesticides, herbicides and insecticides are quantitatively converted to methane.

Supercritical water oxidation
Environment Australia reports that technology is limited to the treatment of waste that is either liquid or that has a particle size of less than 200 µm, and it is most applicable to wastes with an organic content of less than 20 %.

Supercritical water oxidation has been applied to a broad range of materials, e.g. aqueous waste streams, sludges, contaminated soils, industrial organic chemicals, plastics, synthetics, paints and allied products, industrial organics, agricultural chemicals, explosives, petroleum and coal products, and rubber and plastic products. It is applicable to the treatment of a range of contaminants including acrylonitrile waste water, cyanide waste water, pesticide waste water, PCBs, halogenated aliphatics and aromatics, aromatic hydrocarbons, MEK and organic nitrogen compounds.

The solvated electron technique
Table 3.44 below shows the waste IN and waste OUT for the treatment of chlorinated waste by the solvated electron technique.

Material treated	Products	Disposal options
Concentrated PCBs	Biphenyl, $Ca(OH)_2$, $CaCl_2$	Landfill as salts
PCBs in soils	Biphenyl, $Ca(OH)_2$, $CaCl_2$, clean soil	Return soil to ground
PCBs on surfaces	Biphenyl, $Ca(OH)_2$, $CaCl_2$	Collect salts and landfill
PCB/oil mixtures	Biphenyl, $Ca(OH)_2$, $CaCl_2$, oil	Re-use oil. Landfill salts
Concentrated HCB	Benzene, NaCl, NaOH.	Separate benzene and landfill salts
HCB in soils	Benzene, NaCl, NaOH, clean soil	Separate benzene and return soil with salt to ground

Table 3.44: Products and disposal options for the use of solvated electron technique [100, UNEP, 2000]

3.3.2 Consumptions of physico-chemical treatments

Waste waters

In some physico-chemical treatments, bases are necessary. In some cases, waste bases are re-used in waste applications for neutralisation purposes. The neutralising agent used could be a solid or liquid waste stream or a bought-in alkali, as most plants need to buy in some supplementary alkalis. Aqueous acid containing metals, alkali and neutral wastes are common additions and the Ph-c plants are typically designed to produce a sludge containing slightly alkaline metal. Table 3.45 shows the consumptions of some physico-chemical treatments of contaminated water.

Parameter	Yearly consumption (t/yr) *	Specific consumption (kg/tonne of waste treated) *	Yearly consumption in inorganic pathway (t/yr)	Yearly consumption in organic pathway (t/yr)	Yearly consumption of WWT (t/yr)	Yearly consumption of lacquer treatment facility (t/yr)	Yearly consumption of laboratory chemical treatment (t/yr)
Average throughput	45000		20000	66000	30000	Lacquer: 15000 Solvent: 15000 Lacquer powder: 1000	1000
Average consumption of acids	230[1]	5.1	HCl: 69 Sulphuric: 48	HCl: 8 Phosphoric: 8	HCl: 39.4		0.5
Lime	590[1]	13.1	1023		50		10
Flocculation agents	290	6.4		8	16		
Other chemicals[2]		0.4 – 3.0					
Sodium sulphite			10.2		2		
Water consumption			759	9900	1788	2700	
Energy consumption				275 kW	369 MWh	Fuel oil: 1139 m^3 Electricity: 189 MWh	
Waste water			11573	48348	12687		250
Hydrogen peroxide			6.2				0.1
Sodium hypochlorite			4.9				
Iron chloride solution				118			
Iron oxide					65.8		
Sodium hydroxide				110			1
Activated carbon				6			
Potasium permanganate					0.4		
Splitting additives					25		
Amidosulphone acid					n.a.		

* Notes: Data based on the data from Ph-c plant operators with a capacity of 850 kt/yr combined. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for treatment of accepted waste observed here, can be attributed to EWL groups 11,12,13,16 and 19

[1] Values do not include waste acids or waste alkalis accepted and used

[2] Detoxification chemicals, organic breaking up of emulsions, sorption, sulphuric precipitation

Table 3.45: Consumptions of physico-chemical treatment of waste waters
[121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003]

A total amount of approximately 0.4 m^3 prepared chemicals are used per m^3 waste water. Table 3.46 shows the chemicals consumed and some of their consumption levels for detoxification, neutralisation and dewatering for the removal of metals.

Chemical	Consumption
Lime or sodium hydroxide for neutralisation/precipitation	(NaOH 50 %) 120 l/m^3 waste water
Sulphuric or hydrochloric acid for acidification	(HCl 30 %) 10 l/m^3 waste water
Hypochlorite (oxidation cyanide)	
Iron (II) sulphate or sodium bisulphite (reduction Cr^{6+} to Cr^{3+})	
Aluminium sulphate or chloride (flocculation)	
Iron (III)chloride (flocculation)	
Sodium sulphide (precipitation)	0.3 kg/m^3 waste water
Materials for the improvement of precipitation, flocculation, coagulation and complex destruction	

Table 3.46: Chemicals consumed and some of its consumption levels for detoxification, neutralisation and dewatering for the removal of metals from waste waters
[156, VROM, 2004]

Precipitation/flocculation
The following inorganic materials are predominantly used in precipitation/flocculation:

- caustic soda
- soda ash (sodium carbonate)
- lime
- iron (III) chloride
- iron (II) chloride
- aluminium sulphate
- sulphides.

Synthetic flocculation materials are also used for the improvement of floc formation and sedimentation characteristics. They consist principally of non-ionic polymers, anionic polymers, cationic polymers and co-polymers of ionic and non-ionic compounds.

Table 3.47 shows the chemicals used for the precipitation of solute heavy metals; this information refers to chemically pure chemicals. In practice, it may be seen that the quantities actually required may be 10 to 20 % larger. Precipitation values for different metals are shown in Table 3.48.

Used alkali (g)	Metal to be precipitated					
	Fe (II)	Fe (III)	Cu	Ni	Cr	Zn
CaO	100	150	88	96	162	86
$Ca(OH)_2$	134	201	116	126	213	114
NaOH	144	216	126	136	231	122
Na_2CO_3	190	285	168	181	307	162
MgO	73	110	63	69	117	62
$Mg(OH)_2$	105	158	92	100	169	90

Table 3.47: Theoretical consumption of alkalis in precipitation per 100g metal
[121, Schmidt and Institute for environmental and waste management, 2002]

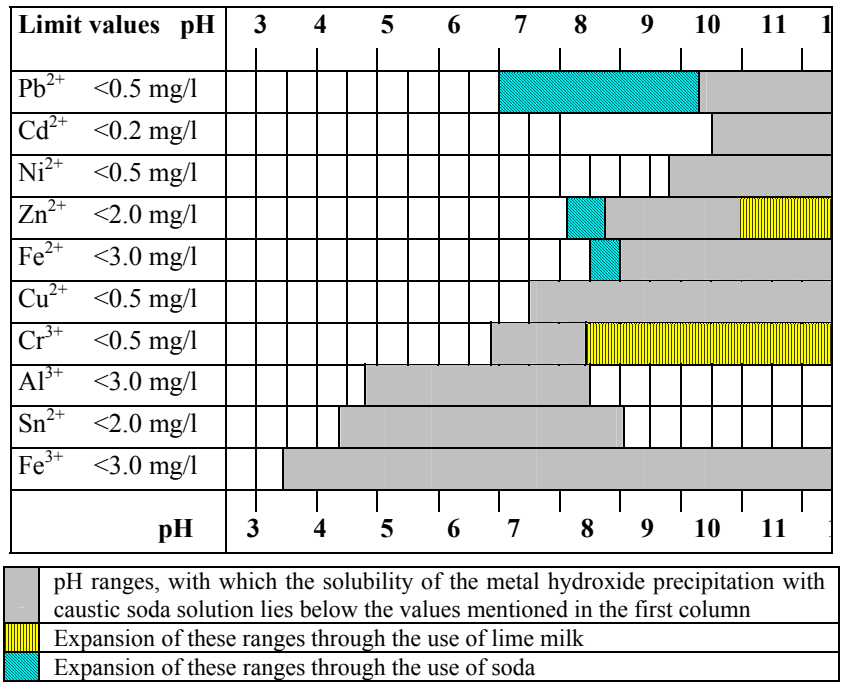


Table 3.48: Range of precipitation values for various metals
[121, Schmidt and Institute for environmental and waste management, 2002]

Precipitation sludge must be disposed of if recycling is not possible. Dewatering is generally necessary. Precipitation/flocculation materials must be selected to suit the dewatering procedure used. Sludge formed from materials containing aluminium generally display poor dewatering characteristics.

Precipitation/flocculation is a reaction and/or a reaction combination which is essentially dependent on the pH value. To this extent, the most significant reference parameter is the pH value. Since the waste water produced through precipitation/flocculation is discharged into sewerage systems, certain criteria must be met. In order to maintain these values, additional treatment steps and procedures for the treatment of waste water follow flocculation and precipitation.

Oxidation/reduction

Redox reaction	Oxidant or reductor	pH	Observations
Oxidation of cyanide and nitrite	Sodium hypochlorite (NaOCl) or chlor gas (Cl_2)	for CN: ~ 10 for NO_2: ~ 3	• reaction relatively quick • relatively high degree of salting up of the resultant waste water • formation of organic materials, which are shown as AOX (Note: the limit value is AOX = 1 mg/l in the waste water to be introduced into the sewerage system)
Oxidation of cyanide and nitrite	Hydrogen peroxide (H_2O_2)	for CN: ~ 10, catalyst: Fe (II)-salts for NO_2: ~ 4	• reaction relatively slow • negligible salting up of the waste water, • no new formation of materials as AOX • formation of mud, due to catalyst (Fe II-salts) • formation of foam (in particular in the presence of organic materials)
Oxidation of nitrite	Aminosulphonic acid (NH_2SO_3H)	~ 4	• reaction slowed • formation of sulphates • formation of elementary nitrogen
Reduction of chromate	Sodium hydrogen sulphite ($NaHSO_3$)	~ 2	• fast reaction • causes salting up of the waste water • formation of mud
Reduction of chromate	sulphur dioxide (SO_2)	~ 2	• fast reaction • slight salting of the waste water • slight mud formation
Reduction of chromate	Sodium dithionite ($Na_2S_2O_4$)	pH independent	• fast reaction • leads to salting of the waste water • formation of mud
Reduction of chromate	Iron (II) sulphate or chloride ($FeSO_4$/$FeCl_2$)	~ 3	• slow reaction • leads to the salting up of the waste water • formation of mud

Table 3.49: Consumption of chemicals for redox reactions
[121, Schmidt and Institute for environmental and waste management, 2002]

Sorption (adsorption/absorption)

Table 3.50 contains information on various adsorbencies. The large area of activated carbon, which according to this is particularly well suited for the adsorption of materials is notable. However it must then be ensured that the material to be adsorbed (i.e. to be separated) also reaches the inner surface of the activated carbon. It is therefore the essential task of the reactor and plant technology to achieve an intensive contact between the material and the adsorbent to be separated. In the treatment of material mixtures, the effect and/or efficiency of adsorbents is determined in general by experiment.

TYPE	Characteristics			
	Specific surface (m^2/g)	Micropore volumes (ml/g)	Macropore volume (ml/g)	Apparent weight (g/l)
Grain carbon for water purification	500 – 800	0.3 – 0.6	0.3 – 0.4	300 – 500
Powder carbon for decolourisation	700 – 1400	0.45 – 1.2	0.5 – 1.9	250 – 500
Fine-pore silica gel	600 – 850	0.35 – 0.45	<0.1	700 – 800
Large-pore silica gel	250 – 350	0.3 – 0.45	0.05 – 0.1	400 – 800
Activated alumina	300 – 350	0.4	approx. 0.1	700 – 800
Adsorbent resin	400 – 500			650 – 700

Table 3.50: Physical data of adsorbents
[121, Schmidt and Institute for environmental and waste management, 2002]

Ion exchangers

Ion exchangers	Stability		Regeneration substance
	pH	°C	g/l resin
Weak-acid, cation exchanger ionic form: H^+, PF^+	1 - 14	75 - 120	HCl: 70 – 140 or H_2SO_4
Strong acid, cation exchanger ionic form: H^+	1 - 14	~120	HCl: ~80
Weak base, anion exchangers ionic form: OH^-, Cl^-	1 - 14	70 - 100	NaOH: ~60
Strong base, anion exchangers ionic form: OH^-, Cl^-	1 - 12	35 - 70	NaOH: ~80

Table 3.51: Overview of types of exchangers and their properties
[121, Schmidt and Institute for environmental and waste management, 2002]

Aqueous marine waste

Heat is required for the heating of tanks and pipelines in order to keep them frost-free, for the preparation of chemicals, for the improvement of separation processes and for other processes. The amount of energy consumed depends on climatic conditions. Electricity is required for pumps, compressors and other facilities. Further differences in energy consumption may be caused by a difference in storage capacity or the application of evaporation.

The overall consumption of energy for heat production varies from 140 to 490 MJ/m^3 waste water. The overall consumption of electricity varies from 65 to 170 MJ/m^3 waste water. The energy data include other activities such as the cleaning of vessels, which means that they are an overestimate of the energy consumption needed for physico-chemical and biological treatment.

For several steps in the treatment, chemicals are used, e.g. alkalis, acids, flocculating and coagulating agents, activated carbon and oxygen. The use of waste acids and alkalis reduces the consumption of primary chemicals. In Table 3.52, some data on the consumption of chemicals are presented.

Chemical	Consumption (kg/m^3 waste water)	Comments
Alkalis	2 – 3	
Acids	0 – 1	Depends on the use of waste acids
Flocculating/coagulating agents	1 – 7	
Oxygen	5	Depends on the use of air or oxygen
Activated carbon	0.04	

Table 3.52: Data on consumption of chemicals in the treatment of aqueous marine waste and similar waste
[156, VROM, 2004]

Water is required in centrifuges and for the preparation of chemicals. The use of the effluent from the biological treatment reduces the consumption of water.

Waste solids and sludges

Table 3.53 and Table 3.54 show consumption values from soil washing treatment plants.

Consumption	Used for	Value
Electrical	Pumps and attrition units	15 – 25 kWh per processed tonne of soil
Chemical	Function of the treated pollution. Some chemicals (such as the floculating agents) are usually used in all plants	3 to 5 kg per tonne of dry sludge
Water	Mainly due to loss of water with the residual filter cake	0.1 to 0.3 tonnes per tonne of processed soil

Table 3.53: Consumptions of soil washing processes plants
[123, Perseo, 2003]

Capacity	t/yr	68000
Fuel consumption	MJ/yr	0
Electricity consumption	MWh/yr	900
Electricity/plant capacity	kWh/t	13.235
Heat consumption	MWh/yr	0
Cooling	MJ/yr	0
Chemicals	sodium hydroxide anti-foaming products polyelectrolyte	

Table 3.54: Consumptions of a installation treating contaminated soil by washing
[66, TWG, 2003]

3.3.3 Emissions from physico-chemical treatments

3.3.3.1 Emissions from the physico-chemical treatments of waste waters

The physico-chemical treatment of waste waters generates a flow of decontaminated water which corresponds to the so-called waste OUT stream of the treatment. An analysis of this stream is given in Section 3.3.4. The following two figures (Figure 3.3 and Figure 3.4) extrapolate flow diagrams leading to the emissions from the physico-chemical treatment of waste waters.

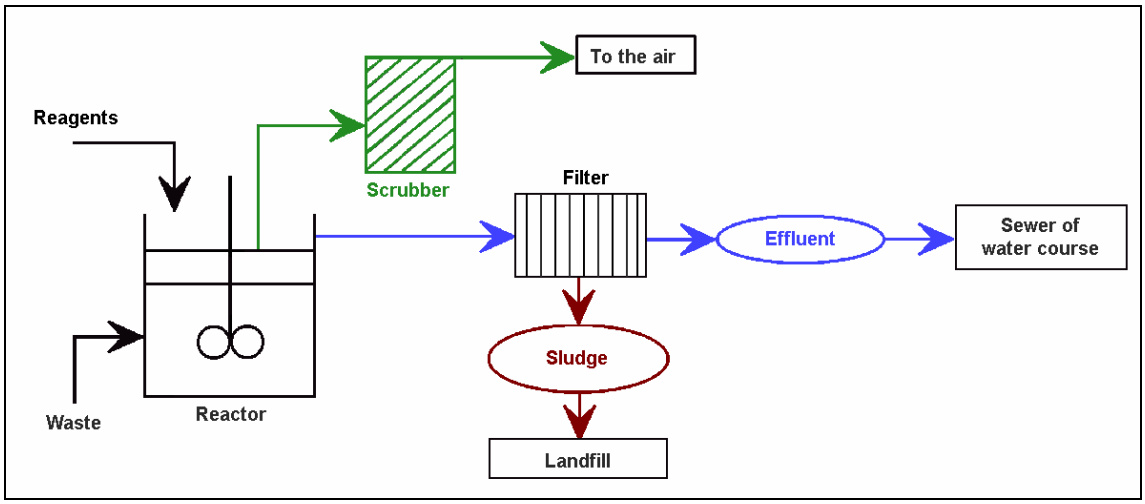


Figure 3.3: Main emission flows from the physico-chemical treatments of waste water
[80, Petts and Eduljee, 1994]

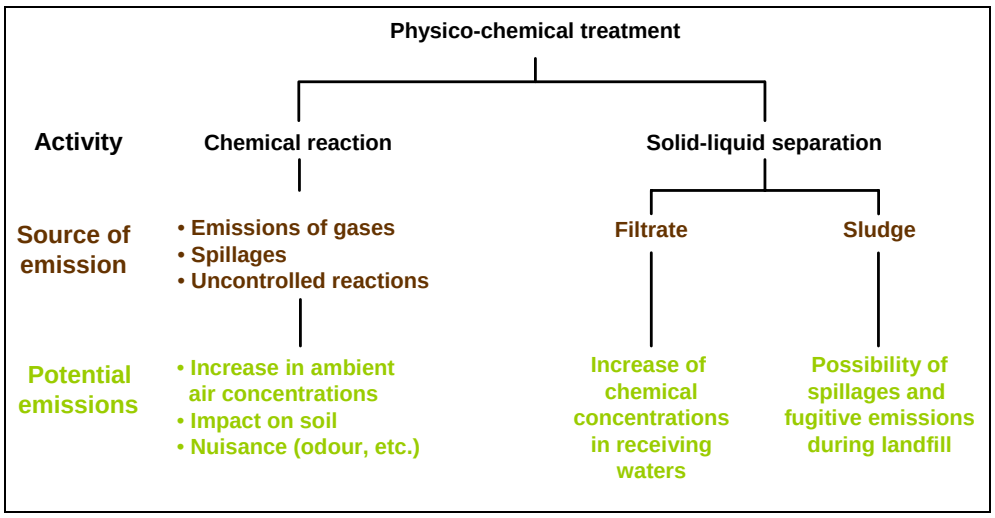


Figure 3.4: Potential emission streams from physico-chemical treatments
Note: Some of these emissions only appear in badly operated physico-chemical treatments
[80, Petts and Eduljee, 1994], [150, TWG, 2004]

Air emissions

Some organic compounds can travel through the plant without being removed and then end up in the final sludge or effluent, whereas others may be evaporated during the exothermic reactions of neutralisation or during sludge pressing. Certain organic wastes contain 'hidden' species. For example, lubricating oils contain naphthalene, BTEX, phenols, copper and nitrogen and can lead to ammonia and xylene emissions to the air during the oil separation from water, or to increased levels in the final site effluent. Aqueous wastes containing solvents may be emitted due to the heat of the process. High nitrogen wastes have a potential for ammonia emissions to the air.

Some materials passing through the plant (typically not captured by physico-chemical processes) are TOC/COD, dichloromethane, phenol, BTEX and naphthalene associated with the waste water from oil pretreatment and TOC, dichloromethane, phenol, BTEX and naphthalene associated with the waste from oil pretreatment.

The air emissions from individual plants depends on the abatement system used. Very few plants have monitoring programmes in place that can quantify their air emissions. Air emissions from these treatments are typically VOCs, acid gases and ammonia. Although difficult to quantify given the lack of monitoring programmes, it can be seen that if closed treatment vessels and air collection/treatment systems are in use, these emissions are reduced. Issues such as the presence of low concentrations of organic solvents in the waste might not always be picked up by WT operators, but these may be important environmentally as they could lead to relevant emissions to the air during the process.

Air emissions may be associated with rapid pH changes, rapid temperature rises and with vigorous agitation. Gaseous reaction products also still occur. Most installations will liberate VOCs from the waste through a mixture of heating, agitation or sludge pressing or drying. There is also always a possibility that reaction intermediates may be released as well. Emissions of metals to the air can be assessed on analytical results. Evaporation also occurs in an uncontrolled manner, such as the evaporation of solvents when mixing solids and liquids or from the stirring of sludges in open tanks.

Emissions of organic compounds may appear when treating mixed waste streams (for example, from the neutralisation of acid, solvents are displaced into the vapour phase which cannot be abated by a wet scrubber used to abate acidic emissions) or are present because its recovery is neither technically nor economically viable (that is, as contaminants associated with wastes that are difficult to handle are treated by other methods).

Air emission parameters	Measured annual average emission values (mg/Nm^3)	Mass flow (g/h)
Flow of exhaust air	325 Nm^3/t	
TOC[1]	2.84 – 36	500 (534 kg/yr)
Dust	0.21	40.3 kg/yr
BTX	4.9	
Benzene		2.5
HCN	<0.05 – 0.12	0.043 - 15
H_2S	0.31	15
Cl_2	<0.03	15
SO_2	1.17	0.5
HCl	0.3	0.2
Hg	0.01	0.0034
Notes: Data based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for the treatment of accepted waste covered here can be attributed to EWL groups 11,12,13,16 and 19. Exhaust air emissions are in general measured intermittently. The measurements are essentially made to monitor the processes, where contamination of the exhaust air can be expected in the intended operation, such as evaporation or cyanide oxidation. [1] Values correspond to mg of carbon		

Table 3.55: Air emissions from physico-chemical treatment of waste water [121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003], [157, UBA, 2004]

The emissions of VOC from aqueous marine waste treatments range from 0.4 to 0.6 kg/m^3 waste water if no exhaust gas treatment is applied. Biological treatment generates emissions of odour. One of the example plants reports an average emission level of 540 million ouE/h.

Water emissions (for more information see Section 3.3.4)
Aqueous residues (if any) are generally sent to sewer. Wastes from the chemical industry, high nitrogen wastes (maybe landfill leachates) and oil recovery/re-processing may introduce additional species and thus need to be considered more carefully. High nitrogen wastes increase the likelihood of a discharge of nitrous oxide. Metals, ammonia and organic chemicals are typically present in water streams.

In all cases, the effluent consents will require protection of the sewerage treatment works from the plant discharge, this protection is focused on COD, pH, oil content, ammoniacal nitrogen, metal content, sulphates and sulphides, as well as dichloromethane (the most common halogenated cleaning compound and liable to be a contaminant of wash-waters and interceptors). The total discharge volume will usually be known.

Although precipitation techniques for metals are reasonably effective, a typical physico-chemical process (under a trade effluent consent) may discharge between 1 – 3 tonnes of metals to sewer annually (the actual value depends on the size of the plant and the amount and type of waste. For example, considering the emission values that appear in Table 3.69, and without considering Fe as a metal, a volume of waste water of 500000 m^3 is necessary to reach some of the upper levels of the range). This is associated with particulates carried over in the effluent from the process and arising from inefficiencies in either the precipitation stage or during settling out of the precipitated metals.

Most sites do not have data for the chloride, total nitrogen and total phosphorus in the sewer discharge. Rough calculations show that for sites where data are available, the emissions are low, unless the site specialises in phosphoric acid treatment or handles high nitrogen flows. Most sites are required to analyse for ammoniacal nitrogen so they can provide a minimum emission value.

The process of waste waters mixed with organic material (e.g. mix of mineral oil, synthetic oil, kerosene, interceptor waste, aliphatic hydrocarbon, aromatic hydrocarbon, alcohol, chlorinated solvents, esters, ethers, aldehydes, ketones, fats, waxes, greases) generates around 836 kg of waste water per tonne of waste IN and 5.5 kg of sludge per tonne of waste IN.

Emissions to water of salts, e.g. sulphates and chlorides, occur. These salts are added as reagents and are not removed in the process of precipitation, neutralisation and filtration. This causes the effluent to have high concentrations of these compounds.

Solid wastes and emissions to land

The sludge generated from physico-chemical treatment plants can be pressed and sent to further treatment, pressed and mixed with other sludges (generally organic) on site or mixed with residues from flue-gas cleaning to give a solid product (with exothermic reaction). Almost all of the sites produce a sludge/cake, which is then commonly incinerated or co-incinerated, or in a few cases directly landfilled.

Metal levels in the waste are well characterised, but organic contamination is not. N and P are not typically quantified in waste and will be present in the aqueous solution.

Process generated waste	**Specific amount (kg/tonne of total waste processed in the Ph-c treatment plant)**
Oil	30 – 90
Concentrates[1]	14 – 40
Hydroxide sludge[2]	60 – 90
Mud from purification and emptying processes	10 – 50
Notes: Data based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for the treatment of accepted waste observed here, can be attributed to EWL groups 11,12,13,16 and 19. The oil is generally recycled and the remaining substances recycled or disposed of, depending on their characteristics and the market conditions. [1] Concentrates from evaporation/stripping and membrane filtration as well as from ultrafiltration and ion exchangers. [2] The weight relates to damp mud, drained TS: ~35 – 45 %.	

Table 3.56: Process generated waste from physico-chemical treatment plants [121, Schmidt and Institute for environmental and waste management, 2002]

Waste from the Ph-c treatments arise principally from precipitation/flocculation, concentrates from membrane filtration, evaporation or ion exchange; waste is also produced in cleaning and draining processes, constructions and containers. The extent to which waste can be used depends on the individual case. For example, separated oil is generally recyclable, concentrates from membrane filtration, evaporation or ion exchange can be recycled in some cases, sludge from precipitation/flocculation are generally disposed of, waste from cleaning and draining are generally disposed of and disposal is usually by immobilisation or incineration.

Table 3.57 below shows the composition of sludge generated in the physico-chemical treatment of waste waters.

Compound	Value	Unit
pH	7 – 9	
TOC	54.7	wt-%
Loss of ignition	54.7	wt-%
Hydrocarbons	30000	mg/kg
PCDD/F	<0.1	ng-TE/kg
PCB (∑ 6)	<0.12	mg/kg
EOX	10	mg/kg
CN total	<0.1	mg/kg
As	0.2	mg/kg
Cd	2.7	mg/kg
Cr total	887	mg/kg
Cu	349	mg/kg
Hg	0.2	mg/kg
Ni	210	mg/kg
Pb	211	mg/kg
Tl	14	mg/kg
Zn	1970	mg/kg

Table 3.57: Sludge generated in the physico-chemical treatment of waste waters [157, UBA, 2004]

The amount of sludge containing metal (filter cake) that is produced depends on the specific contaminants in the waste water, their concentrations and on the reagents and other chemicals that are used. The sludge quantity varies from 2.5 to 10 % of the waste water input. By replacing lime by sodium hydroxide the amount of filter cake is reduced. However, lime is necessary for the precipitation of fluorides.

The filter cake with high concentrations of metals, e.g. nickel and copper, can be used as a raw material in the metallurgical industry. In other cases, the filter cake is disposed of as solid waste.

Solid residues from aqueous marine waste
The generated solid residues are:

- solid residues from the decanter/centrifuge and filters (50 kg/t waste water)
- separated oil and chemical fractions (possibly suitable for re-use as fuel).

Emissions from particular physico-chemical activities
The emissions listed in Table 3.58 below can be expected to occur from most treatment plants. The scale of the emission depends on the plant throughput and on the abatement systems applied.

Physico-chemical activity	Air	Water	Residues/Soil
Addition of solid sodium carbonate or addition of sulphuric acid to form nickel or chromium sulphate	Emissions of CO_2, plus other acid gases (e.g. SO_x) depending upon the initial solutions	Liquid fraction is returned into the treatment and blending part of the plant. This is a tiny fraction of the main waste IN	The product precipitates out and is left to cool and crystallise before being bagged and sent off for recycling
Cyanide oxidation		HOCl	
Fluorescent tubes/lamp processing	Hg and SO_x	The discharge is a weak sodium hydroxide solution	
Precipitation of metals		Zn, Cu, Cd	
Silver recovery systems	There is an unquantified issue of ammonia, and possibly SO_x, from photographic chemicals due to the high nitrogen and sulphur levels in the solutions. Additionally there may be There are additional VOC emissions due to bulking and transfer processes		Possibly high nitrogen levels in the waste
Treatment of printing and photographic waste	Ammonia, VOC and potentially SO_x	Suspended solids, nitrogen (mainly nitrate) and COD	Waste typically has a high nitrogen content
Use of raw caustic		Hg	
Unit operations			
Air stripping	Ammonia and VOCs, including organic solvents (e.g. DCM)		
Dissolved air flotation (DAF)			Sludges that are taken from the bottom of settlement tanks will generally be up to 4 % dry solids
Evaporation	Normally takes place in fully enclosed systems but various vent valves can result in fugitive emissions		
Filtration/pressing This is a common area for emissions from chemical plants	Ammonia and, if there is a high organic content in the wastestreams, VOCs		
Ion exchanger		The eluate of an ion exchanger must be further treated in the plant according to its composition/concentration	

Physico-chemical activity	Air	Water	Residues/Soil
Mixing tanks	May produce a range of emissions, partly as the result of chemical reactions, and partly from heat effects reducing the solubility of gases in water. Ammonia is the most common gas mentioned as a problem at this stage of the process.		
Neutralisation	This can be a violent exothermic reaction with a rapid change in pH. Acidic acids such as CO_2, HCl, Cl_2, NO_x, and SO_x, as well as ammonia are emitted from the reactor tank, together with any contaminant volatile materials, such as cleaning solvents in wash-waters. The gases can carry liquors and particulate matter with them	Typical components are chloride, phosphorus, nitrogen and metals	Typical components are chloride, phosphorus, nitrogen and metals
Organic splitting of emulsions			Generally smaller quantities of mud (filter cakes) develop in organic splitting than with acid splitting
Oxidation/reduction		The salination of the waste water is process-dependent	
Settlement	Emissions to the air are possible but unlikely		Sludges that are taken from the bottom of settlement tanks will generally be around 0.5 – 1.0 % dry solids content
Sludge management (e.g. pressing or sludge storage)	VOCs as fugitive emissions. Gases from solution		
Solvent extraction	Solvents as fugitive emissions. Significant potential for emissions on transfer and emergency releases	Solvents	
Stripping	Emissions are trapped in the areas provided in the Ph-c plant		

Table 3.58: Emissions from physico-chemical treatment processes applied to waste water [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [121, Schmidt and Institute for environmental and waste management, 2002]

3.3.3.2 Emissions from the physico-chemical treatment of waste solids and sludges

The emissions listed in Table 3.59 below can be expected to occur from most treatment plants. The scale of the emission depends on the plant throughput and on the abatement systems applied.

Physico-chemical activity	Air	Water	Residues/Soil
Filtration/pressing	Ammonia and, if there is a high organic content in the wastestreams, VOCs		
Buildings for immobilisation mixing	Emissions via roof vents. Emissions occur during transfer from the mixing pit to removal off-site; and via access doors from spillages/leaks during charging of the reaction vessels		
Sludge blending	Particulate matter and VOCs, particularly if an exothermic reaction occurs		
Sludge management (e.g. pressing or sludge storage)	VOCs as fugitive emissions. Gases from solutions		
Solidification	There is a potential for particulate emissions from this operation		
Automated charging of waste	VOC, dust odour during the transfer of wastes and reagent		
Reaction vessel	Emission occur due to the reaction of incompatible substances. Uncontrollable reactions due to incorrect dosing of reactants or the formation of hot spots through poor mixing	Leakage through badly maintained or damaged equipment	Leakage through badly maintained or damaged equipment
Reagent silo	Dust arises from the overfilling of reagent silos. Also fugitive dust emissions from silo connections and dust from reagent stockpiles stored loose		

Table 3.59: Emissions from physico-chemical treatment processes applied to solids and sludges [55, UK EA, 2001], [56, Babtie Group Ltd, 2002]

The fugitive emissions from material handling operations for *ex situ* processes are often overlooked or ignored, but they may represent a significant fraction of the total emissions from the soil treatment.

Emissions from soil excavation and removal activities

VOC emissions from handling operations in soil excavation and removal result from the exchange of contaminant-laden soil-pore gas with the atmosphere when soil is disturbed, and from some diffusion of the contaminants through the soil. There are several potential emission points involved in excavation; all are considered to be fugitive area sources. For excavation, the main emission points of concern are emissions from:

- exposed waste in the excavation pit
- material as it is dumped from the excavation bucket, and
- waste/soil in short-term storage piles.

In addition, the earth-moving equipment will involve additional sources of emissions of VOC, particulate matter, nitrogen oxides, etc. It is known that large amounts of VOCs may be released from soil during handling, so VOCs are typically the emissions of most concern. Emissions of particulate matter and associated metals and semi-volatile compounds may be of concern at particular sites.

Given the frequency with which the excavation of contaminated soils is carried out, surprisingly little air emission or emission rate data for excavation have been published.

However, some measured emission rates for two sites for combined excavation and dumping operations are available and quote figures as high as 4 g/min for specific compounds. Here, most of the VOCs present in the soil was stripped from the soil during excavation, based on a comparison of measured total emissions versus the mass of these same contaminants in the soil (calculated from soil concentration data). This was true for both sites, despite differences in soil concentrations and soil type.

Activity	Sludge volume (m^3)	Exposed surface area (m^2)	C_{8+} hydrocarbon emission rate (g/s)	C_{8+} emission flux ($g/m^2/s$)
Sludge disturbance	25 – 27	45 – 125	1.33	0.01 – 0.03
Sludge excavation	26 – 48	125 – 261	7.76	0.03 – 0.06
Sludge dewatering	1.7	3.3	1.24	0.38
Post-disturbance	26	91	1.11	0.01

Table 3.60: Results of emission measurements
Based on [30, Eklund, et al., 1997]

The magnitude of volatile organic compound (VOC) emissions depends on a number of factors, including the type of compounds present in the waste, the concentration and distribution of the compounds, and the porosity and moisture content of the soil. The key operational parameters are the duration and liveliness of the handling, and the size of equipment used. The longer or more energetic the moving and handling, the greater likelihood that organic compounds will be volatilised. The larger the volumes of material being handled per unit operation, the lower the percentage of VOCs that are stripped from the soil, because the surface area to volume ratio is minimised.

Soil containing benzene or other volatile carcinogens would likely pose a large risk to on-site workers and the surrounding populace if it were to be excavated.

The magnitude of emissions from soil handling operations will vary with the operating conditions. The rate of excavation and dumping, the drop height, the amount of exposed surface area, the length of time that the soil is exposed, the shape of the storage piles, and the dryness of the surface soil layers will all influence the levels of VOC emissions. Add-on control technologies are available for minimising emissions, but these are relatively ineffective and costly to implement compared with the controls for point sources.

Emissions from thermal desorption

Air emissions from thermal desorption systems are influenced by the waste characteristics, the desorption process applied, and the emissions control equipment used. The air emissions associated with thermal desorption come from several sources. The point sources of air emissions vary widely with each process. The stack of an afterburner vents combustion products, as does a fuel-fired heating system if the combustion gases are not fed into the desorber. A fuel-fired heating system typically operates with propane, natural gas, or fuel oil. If the VOC emission controls consist of a baghouse, scrubber, and vapour phase carbon adsorber, the off-gas will contain small concentrations of the original contaminants, as well as the products of any chemical reactions that might occur. The volume of off-gas from a thermal desorption unit depends on the type of processor. Table 3.61 below gives some values for emissions from thermal desorption.

	Flow of gases (Nm^3/h)	Pollutants that may be contained
Direct heating	17000 – 85000	VOC
Indirect heating	1700 – 8500	VOC

Table 3.61: Emissions from direct and indirect heating thermal desoption [30, Eklund, et al., 1997]

Various types of thermal desorption systems can produce up to nine residual process streams: treated soil, oversized media rejects, condensed contaminants, water, particulate control dust, clean off-gas, phase separator sludge, aqueous-phase spent carbon, and vapour- phase spent carbon. Off-gases from indirectly heated units, i.e. thermal screws, can be treated with smaller chemical/physical systems, such as a baghouse or a condenser, followed by an afterburner.

Pollutant	From
Fugitive emissions	• excavation of contaminated soil • classifier, feed conveyor, and the feed hopper • components of the thermal desorption system and controls • exhaust gases from the heating system, treated soil, particulate control dust, untreated oil from the oil/water separator, spent carbon from liquid or vapour phase carbon adsorber, treated water, and scrubber sludge
Particulate matter, nitrogen oxides (NO_x), carbon monoxide (CO) and acid gases	Combustion and pyrolysis
Dioxins, furans and phenol	

Table 3.62: Generic emissions from thermal desorption [30, Eklund, et al., 1997]

Parameter	Initial concentration [1] (ppm)	Final concentration [1] (ppm)	Removal efficiency (%)	Typical off-gas characteristics[2] stack concentration
PM		700 – 1000 mg/Nm^3		
Benzene	0.11 - 39.5	<0.01 – 0.06	84.5 – 99.9	4.3 – 8.6 ppm
Toluene	0.27 – 2	<0.01 – 0.1	n/a	0.6 – 0.8 ppm
m,p-Xylenes	<0.8 – 3	0.2 – 1.2	<75	0.42 – 3.5 ppm
o-Xylenes	3.1 – 15.6	<0.01	99.7 – 99.9	
Total Xylenes	13.1	0.1	99.2	
Ethylbenzene	0.11	<0.01	>90	
THC	39 – 393	5.7 – 9.5	85 – 97.5	129 – 2800 ppm
VOC		0.045 – 2.27 kg/h		
Diesel	1875	<1	>99.9	
Naphthalene				5136 – 6757 µg/Nm^3
Acenaphtylene				634 – 901 µg/Nm^3
Acenaphthene				317 – 638 µg/Nm^3
Fluoranthene				405 – 763 µg/Nm^3
Phenanthrene				385 – 645 µg/Nm^3
Anthracene				<1.4 – 427 µg/Nm^3
Fluoranthene				24 – 135 µg/Nm^3
Pyrene				32 – 111 µg/Nm^3

[1] Based on two or three installations depending on the parameter.
[2] Based on two installations. Emission control equipment consists of a wet scrubber and cyclonic demister. ppm values refered to dry conditions

The VOC emissions from asphalt aggregate dryers will vary by several orders of magnitude depending on whether afterburners are used as a control device. These treatment systems typically do not employ VOC controls, unless they have been modified for soil remediation.

A company has estimated the typical emissions for soil treatment in a modified asphalt aggregate dryer. This system consists of a direct-fired rotary drum operating at 290 – 540 °C. A primary cyclonic tube collector and pulse-jet baghouse are used to control particulate emissions. A thermal oxidiser (i.e. an afterburner) destroys organic compounds in the off-gas stream (99 – 99.99 % efficiency). Based on a processing rate of 32 – 54 t/h.

Table 3.63: Characteristics of inputs and outputs of asphalt aggregate dryers [30, Eklund, et al., 1997]

Contaminant	Units	Residence time (minutes)	Temperature (°C)	Initial concentration	Final concentration	Rate of uncontrolled emissions (g/h)	Estimated emissions rate (g/h)
PCBs	ppm	19	550	37.5	2	1.14	5.68e-02
2,3,7,8-TCDD	ppb	40	560	260	0.018	0.00832	4.16e-04
	ppb	19	560	236	0.018	0.00755	3.78e-04
	ppb	10.5	560	266	0.018	0.00851	4.26e-04
	ppb	24	460	233	0.5	0.00744	3.72e-04
	ppb	5.6	550	48	0.084	0.00153	7.67e-05
	ppb	20	555	56	0.23	0.00178	8.92e-05
Overall estimated efficiency is 95 %							

Table 3.64: Estimated emissions of selected compounds for the clean-up of PCB contaminated soil using a thermal desorption process [30, Eklund, et al., 1997]

Emissions from vapour extraction of solid waste

The air emissions associated with vapour extraction systems come primarily from the stack. Additional releases of volatile organics may occur from the treatment of any contaminated water that is extracted. Fugitive emissions are considered negligible due to the negative pressure throughout most of the system.

Emissions include untreated volatile organics from the extraction process. A removal and subsequent emission of semi-volatile organic compounds will also occur, though less efficiently than for VOCs. There may also be smaller amounts of air emissions associated with the control system. Due to the variety of technologies used for vapour treatment, stack emissions may also include some products of incomplete combustion, NO_x, particulate matter, CO, and acid gases. Of primary concern, however, are the volatile organics emitted from the point sources. Air emission data for several vapour extraction systems are summarised in Table 3.65.

No. of systems surveyed	Parameter	Units	Range or value	Approximate average
13	Flowrate per well	m^3/min	0.2 – 8	2
	Removal	kg/day	0.9 – 113	27
	Exhaust gas concentration	ppmv	20 – 350	100
17	Total flowrate	m^3/min	0.1 – 161	23
	Treatment:	n^o systems		
	• none		9	
	• carbon		6	
	• catalytic incineration		1	
	• combustion		1	
	Removal rate	kg/day	2 – 195	45
17	Total flowrate	m^3/min	0.7 – 318	62
	Pollutant concentration	ppmv	150 – 3000	400
	Control efficiency	%	90 – 99	95

Table 3.65: Emissions from vapour extraction systems
[30, Eklund, et al., 1997]

The emission rate of VOC compounds over time from continuously operated vapour extraction systems tends to show an exponential-type decay curve.

Pollutant	Peak uncontrolled stack emissions [1] (g/h)	Peak controlled stack emissions [2] (g/h)
Trichloroethylene (TCE)	1712	17.1
trans-1,2-Dichloroethylene (DCE)	99.4	0.99
1,1,1-Trichloroethane (TCA)	13.6	0.14
Tetrachloroethylene (PCE)	3.18	0.03
TOTALS	**1830**	**18.3**

[1] Uncontrolled emissions based on the removal rate of each contaminant
[2] Based on estimated 99 % overall control efficiency for two carbon adsorption canisters in series

Table 3.66: Estimated emissions for an in-situ vacuum extraction system
[30, Eklund, et al., 1997]

Emissions from soil washing

In the soil washing process, the greatest potential for emissions of volatile contaminants occurs in the excavation, materials handling, feed preparation, and extraction processes. The waste streams also have the potential to be sources of VOC emissions. The solvent recovery process involves vaporisation of the solvent, so fugitive emissions are possible from this as well as from other stages of the solvent process. Waste streams also have the potential to be sources of VOC emissions if any VOCs are already present in the waste stream. For solvent extraction processes, emissions of the solvent itself also may be a cause for concern.

Storage areas need to be kept under specific control to avoid pollution dispersion, especially of dust. For liquid effluents, the plants are always equipped with a water-slurry treatment unit, where the water is sent before being discharged.

Soil washing generates four waste streams: contaminated solids separated from the wash-water; waste water; waste water treatment sludge and residual solids; and air emissions.

Water parameter	Concentration (mg/l)
Suspended solids	60
BOD_5	25
COD	350
Nitrit N (NO_2-N)	10
P, total	2
Cr, total	0.3
Cu	0.5
Hg	0.005
Ni	0.3
Pb	0.3
Zn	2
Residues generated by the process[1]	
Sludges	Mineral sludges
Other residual fractions	Particle PAHs and metal oxides
[1] The subsequent fate of these residues are reported to be landfill	

Table 3.67: Emissions from an installation treating contaminated soil by washing [66, TWG, 2003]
Note: Capacity of the installation is 68 kt/yr

Emissions from solvent extraction
Up to five waste streams may result from the solvent extraction process: concentrated contaminants; solids; waste water; oversized rejects; and treated air emissions.

Solvent extraction units will be of a closed-loop design in which the solvent is recycled and reused. Typically, solvent extraction units are designed to produce negligible air emissions, but some solvents have been detected in the off-gas vent system. In addition, significant levels of emissions (both vapour-phase and particulate matter) may occur during waste preparation activities such as excavation and materials handling.

Emission from treatments of FGT waste
The main environmental concern related to handling, utilisation and disposal of combustion wastes is the potential emission of heavy metals, organic pollutants and salts. The main pathways for this are by leaching and by airborne dust emission. As airborne emissions can be controlled relatively easy, leaching is an environmentally more important issue. It should also be noted that hydrogen gas generation from FGT waste by contact with water has been documented and can potentially cause considerable problems. Its generation is dependent on intermediate FGT waste storage and the type, design and operation of the landfill that it may be developed.

Emissions from stabilisation methods
Several of the stabilisation methods have an initial washing step, where a major part of soluble salts and, to some extent, metals are extracted before chemical binding of the remaining metals. These methods are finalised by dewatering the stabilised product, which will then be ready for landfilling. Then, washing solid waste generates a waste water that needs some sort of treatment because of the content of some components. However, depending on the local authorities, such generated waste water may be discharged into the environment or treated in the chemical industry to recover some salts (e.g. sodium salts).

Emission from asbestos treatments
The fibrous nature and the size of the fibres are the main parameters that makes asbestos dangerous. During treatment some emissions may be generated.

3.3.3.3 Emissions from the treatment of specific wastes

Hydrogenation of POPs
At a Canadian facility, product gas was found to contain no detectable PCBs, while concentrations of total chlorobenzenes and dioxins were similar to those of the blanks. This suggests that the product gas did not contain quantifiable levels of these substances. When the product gas was burned in the steam reformer, dioxins were emitted from the reformer stack at a concentration of 15 pg TEQ/Nm^3. This dioxin formation was attributed to the use of PCB contaminated air from the site of the reformer's combustion air.

All outputs from the destruction of PCB contaminated waste using this process can be contained and tested. There are no uncontrolled emissions from the process which could result in releases of PCB contaminated air, solids, or liquids to the surrounding environment. Releases of PCBs to the environment could only occur during waste handling prior to treatment, where the possibility of spillage exists.

Because the reaction takes place in a reducing atmosphere in the absence of oxygen, the possibility of dioxin and furan formation is said to be eliminated. If the hydrogen (dry basis) content is maintained at percentages greater than 50 %, the formation of PAHs is prevented.

Type of waste	Destruction efficiency (%)	DRE (%)
PCB oils	99.999808 – 99.9999996	99.9999985 – 99.9999997
chlorobenzenes	99.9999836 – 99.9999972	99.9999842 – 99.9999985
Dioxins present in PCB oils	99.999 – 99.9999	

Table 3.68: Reported destruction efficiency of hydrogenation processes [100, UNEP, 2000]

If either the product gas or the ambient air used as combustion air for the boiler or similar units contains hydrogen chloride or other chlorinated species, dioxins may be generated during their combustion. In order to meet the fundamental technical criteria for POPs destruction, both the product gas and combustion air must be treated to remove such chlorine donors and so prevent dioxin formation.

Care is required to avoid high rates of gas generation, which could over-pressurise systems. The process has a limited surge capacity: over-pressurisation could therefore result in the release of waste material.

During typical operations, 30 to 50 % of the product gas is burned as fuel for the boiler or other auxiliary units.

Residues generated by the process include product gas from the reactor, scrubber water and sludge from product gas treatment, and small quantities of grit from the reactor. The product gas is either catalytically reformed to recover hydrogen or burned as fuel in one or more of the auxiliary systems – the boiler, catalytic reformer and/or sequencing batch vaporiser.

Hydrogenation of PCBs and POPs
All emissions and residues are captured for assay and reprocessing, if needed. Destruction rates ranging from 99.9 to 99.99999 % have been reported at sites operating on a commercial scale in Australia.

Supercritical water oxidation
Process residues are usually contained and consist of water, gas (less than 10 ppm of CO and very low amounts of oxides of nitrogen, acid gases such as hydrogen chloride or sulphur oxides and particulates) and solids if the waste contains inorganic salts or organics with halogens, sulphur or phosphorus. Residues generated during the process such as ash and brine require disposal.

3.3.4 Waste OUT from physico-chemical treatments

Much of the waste OUT from these processes goes to landfilling.

Waste waters
The essential mass flow from Ph-c plants is the waste water, corresponding to about 85 to 95 % of the mass of the waste accepted for treatment. The waste water quality of Ph-c plants is regularly monitored by the supervisory authorities and within a framework of self-monitoring. Due to this monitoring activity, extensive data are available on the composition of waste water from Ph-c plants.

Water emission parameters	Ranges values of the annual average values (ppm)	Ranges of annual charge (kg/yr)
pH	6.9 – 10.4	
Electric conductivity	1150 – 13500 µS/cm	
Transparency (view depth)	10 – 47 cm	
Suspended solids	<0.5 – 32 <0.1 – 2.1 ml/l	<0.6
TOC	2200 – 3800	38061
BOD	5 – 2490	
COD [1]	200 – 17870	
Hydrocarbons	<0.1 – 19.8	89
Detergents (anionics)	0.6 – 14.8	
Mineral oil	5 – 10	
Phenol index	0.8 – 25	317
AOX	<0.01 – 0.7	9
EOX	<0.1 – 0.5	
BTX	<0.1 – 1.2	10
Cl	3975 – 35420	
Cl free	<0.1 – 0.3	
CN	<0.1 – 0.6	<1
CN free	<0.01 – 0.1	
F	0.5 – 8.6	
N - organic	109 – 440	
N - total	8.4 – 590	
NH_3-N	22 – 1330	
Nitrate-N	0.9 – 472	
Nitrite-N	0.90 – 10.2	38
P - total	<0.1 – 14.75	
Sulphate	65 – 3630	
Sulphide	1012	
Sulphide free	<0.1 – 0.77	<1
Al	<0.1 – 5	63
As	<0.01 – 0.1	<0.1
Cd	0.0004 – 0.1	
Co	≤ 0.1	
Cr total	0.05 – 0.3	3.8
Cr (VI)	<0.01 – 0.1	<1
Cu	<0.1 – 0.4	2.5
Fe	0.2 – 20	253
Hg	0.0001 – 0.02	<0.02
Mn	<0.1 – 2.7	
Ni	0.05 – 1.4	3.8
Pb	<0.02 – 0.7	<1
Se	<0.1 – 0.5	
Sn	<0.1 – 0.4	
Zn	<0.1 – 3.9	12
Notes: Ranges have been constructed from several sets of emission data provided. A data set is based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for the treatment of accepted waste covered here, can be attributed to EWL groups 11,12,13,16 and 19. Another set corresponds to 20/80 percentile of the annual average values for some Ph-c plants, and another to measured minimum/maximum values found in demulsification plant treatment (data from 1994 – 1999) [1] Some data relate to THE dissolved COD fraction and other correspond to the total COD		

Table 3.69: Waste OUT from the physico-chemical treatment of contaminated waters [121, Schmidt and Institute for environmental and waste management, 2002], [134, UBA, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

Outputs of lacquer treatment facility are shown in Table 3.70 below:

Material	Amount (t/yr)	Composition (mg/kg)	
Dried material	10000	PCB	<0.05
		BTEX	104.8
		As	<1
		Cd	6.7
		Cr total	77
		Cu	905
		Hg	0.25
		Ni	43
		Pb	339
		Tl	<0.5
		Cyanide total	6200
Organic process water	2000	Cd	<0.5
		Hg	<0.5
		Zn	1.7
Solvent reclaim	13000		

Table 3.70: Waste OUT of physico-chemical treatment of contaminated water treating mainly lacquer coagulum and solvents
[135, UBA, 2003]

Table 3.71 shows the emission levels achieved after a polishing step of the effluent, e.g. by sand filtration or ion exchange filters.

Compound	Concentration (mg/l waste water) (24 hour samples)
Free cyanide	1.0/0.2
Halogenated VOCs	0.1
Mineral oil	200 (random sample)
Ag	1.0/0.1
Cd	0.2
Cr (total)	1.0/0.5[1]
Cr(VI)	0.1
Cu	2.0/0.5
Ni	2.0/0.5
Pb	2.0/0.5
Sn	3.0/2.0
Zn	2.0/0.5
[1]standards for discharged load of metals (Cr, Cu, Ni, Pb and Zn) <200 g/day and >200 g/day	

Table 3.71: Emission levels achieved after a polishing step of the effluent, e.g. by sand filtration or ion exchange filters
[156, VROM, 2004]

Waste solids and sludges

The final material after stabilisation/solidification will have a similar composition of metals and organic content as the original waste. However, the final material has a reduced toxicity and solubility of metals and organic compounds compared to the original waste.

The annex of the Landfill Directive (EC 33/2003) contains the criteria and procedures for the acceptance of waste at landfills. The criteria contain some limit values for hazardous waste acceptable at different types of landfills. These are based on leaching limit values and restrict some metals, some anions and organic compound parameters.

Water permeability of stabilised waste depends on many parameters (e.g. nature of the waste, nature and amount of added reagent, aimed objectives) so permeability values may vary from 10^{-9} to 10^{-12} m/s.

Immobilised bottom ash/slag

In general, there are several possibilities employed for the re-use of bottom ash, after treatment. When the slag values do not meet defined parameters, a slag re-use with defined technical safety measures is possible. Some examples of re-use options are described below and are shown in Table 3.72:

- used in road and street construction. The bottom ash is used as a solid base for at the construction of, e.g. parking places, airports and harbour areas. However, there is a need for an impermeable layer which coaches over the bottom ash layer to avoid leaching, this can be asphalt or perhaps concrete
- used in soil constructions, e.g. road embankments or noise protection walls. It is important that the area where bottom ash will be used has to be a hydrogeologically favourable land. This means that there has to be a layer of 2 meters of clay or loam which protects the groundwater from adverse effects. Furthermore, there has to be a mineral surface which is impermeable (d >0.5 m and k_f <10^{-8} m/s)
- used in important water management zones and in hydrogeologically sensitive areas and is subject to exception for individual case inspections.

Recycling paths of treated bottom ash/slag	%
Anti-freeze course	27
Filling material	22
Ballast substructure	11
Improvement of land	9
Base frame/dam construction	5
Land consolidation	5
Noise protection wal	3
Landscaping	1
Unbound street and road construction	1
Others	16

Table 3.72: Recycling paths of the mineral fraction of treated bottom ash in Germany [150, TWG, 2004]

The following Table 3.73 and Table 3.74 below characterise the important bottom ash parameters after a physico-chemical treatment process.

Metals	Minimum	Average	Maximum
As	0	0.074 – 0.15	0.187
Cd	0.0008	0.0037 – 0.01	0.0167
Cr	0.067	0.172 – 0.6	0.726
Cu	0.150	0.6 – 6.826	29.781
Hg	0	0.01 – 0.07	0.37
Ni	0.023	0.165 – 0.6	0.661
Pb	0.19	1 – 1.222	4.063
Tl	0		
Zn	0.470	1.5 – 2.970	14.356
Units: in g/kg, except Hg that is in mg/kg Zero in this table means below analysis detection limit			

Table 3.73: Metal composition of treated bottom ash after treatment (solid analyses) [89, Germany, 2003], [150, TWG, 2004]

Chemicals	Minimum	Average	Maximum
Cl	29		
Sulphates	43		
CN total	0		
Phenol index	0		
As	1.3	5.3	16.1
Cd	0	0.8	5
Cr	0	15.2	200
Cu	0	60.7	300
Hg	0	<0.2	1
Ni	0	2.9	40
Pb	0	11.4	59.0
Tl	2		
Zn	0	19.4	300
Units in µg/l Zero in this table means below analysis detection limit			

Table 3.74: Eluate analysis of bottom ash quality after treatment
[89, Germany, 2003], [150, TWG, 2004]

Waste OUT from a classical soil washing unit

Generally, soil washing units produce recycled materials suitable for the construction industry (concrete producers, asphalt plants) or as refilling materials after internal quality control and external control have been carried out on the specific properties of the materials (to ensure compliance with local regulations)

Different fractions can be distinguished:

- coarse fraction: gravels which can be calibrated in several ways. These are basically formed by fine gravels measuring 2 – 20 mm and coarse gravels measuring 20 – 80 mm
- sand fraction: consist of sand generally sized from 60 µm to 2 mm
- residual organic fraction (>60 µm): these fractions are incinerated or sent to an appropriate landfill
- fine residual fraction (filter cake <60 µm): usually this is sent to a special landfill with or without additional treatment (e.g. inertisation, stabilisation) or may be sent for a further treatment if required (e.g. thermal desorption, classical incineration).

	Capacity (t/yr)
Waste IN	68000
Waste OUT	50500
• sand	36000
• gravel	13000
• fines	1500

Table 3.75: Waste OUT of a installation treating contaminated soil by washing
[66, TWG, 2003]

Waste OUT from excavation

Excavation has been found to decrease the soil moisture content and the dry bulk density of the soil. Data show that the water content fraction decreases by 35 % to 56 % and the dry bulk density of the soil decrease by 13 %.

Waste OUT from thermal distillative drying

The dry residue of the treatment of aerosol cans is separated into steel and waste aluminium before smelting. These metal fractions fulfil all acceptance criteria of the steel mill operations. The condensates from the drying process consist of complex solvent mixtures that may only be used thermally or have to be incinerated. When unused faulty aerosol cans are treated, it may be discussed in advance with the producer if recycling of the contained solvents is also possible.

Waste OUT from a CFC treatment plant

Table 3.76 below shows the specification of the products achieved by the cracking of the CFC solvents.

Parameters	Unit	Target	Actual value
Water content	ppm	<50	34
Oil content	ppm	<100	60
Amine content	ppm	<100	10
Acid	ppm	<1	0.03
Halogens	vol-%	<0.1	0.004
PCB and PCT	vol-%	0	0
Information from a CFC distillation plant of Figure 2.11 shown in Section 2.3.5 This interconnection treatment facility converts CFCs into hydrochloric acid and hydrofluoric acid.			

Table 3.76: Specification of CFC cracked products
[147, UBA, 2003], [150, TWG, 2004]

3.4 Emissions and consumptions from waste treatments applied mainly to recover the materials from waste

[6, Silver Springs Oil Recovery Inc., 2000], [13, Marshall, et al., 1999], [14, Ministry for the Environment, 2000], [29, UK Environment Agency, 1996], [41, UK, 1991], [42, UK, 1995], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [86, TWG, 2003], [96, Straetmans, 2003], [125, Ruiz, 2002], [129, Cruz-Gomez, 2002], [147, UBA, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

This section contains the emissions and consumptions of treatments mentioned in Section 2.4. The following sections (Sections 3.4.X) details information available to site WT operators from their current recording systems and highlights areas where emissions are likely to occur. The structure of each of the following sections in this section is the same as the one followed in Section 2.4. Emissions associated with ancillary treatments, e.g. transfer station operations, are covered in Section 3.1.

3.4.1 Waste IN treated to obtain a recycled material

When the aim is to obtain useable materials and not just material to be disposed of, the treatment given to each type of waste will typically be very specific, and will target the conversion of the waste into the useable end-product required.

Waste oils

Oils have many uses, e.g. they are used as a fuel, as lubricants, as a heat transfer medium, as cutting fluids, and as hydraulic fluids. Each has its own specification, usually based upon the hydrocarbons occurring within a specific boiling point range from the distillation of crude oil. Oils that need to be stable at high temperatures will not include large quantities of low boiling point hydrocarbons, whereas, oils used as fuel are more likely to include these lower boiling point hydrocarbon mixtures.

Before marketing, most base oils produced in mineral oil refineries are blended with a variety of additives to give them the required properties. Typical additive packages comprise between 5 and 25 % of the base oil. However, probably at least half of the additive package is base oil used as solvent. Lubricating oils contain large numbers of additives, but the actual formulae are in most cases trade secrets. Data on the components and additives in new oils are given in the Safety Data Sheet which accompanies fresh products as supplied, however precise details of the formulations are company proprietary. Hydraulic oils contain very few additives.

Some general classes of additives have been identified and are shown in Table 3.77 below. The information is not specific, but suggests that a number of metal additives, some chlorinated organic compounds, aromatic hydrocarbons, phenolic compounds and different kinds of polymers are used.

Additive	Compounds used
Anti-corrosion	Zinc dithiophosphates, metal phenolates, fatty acids and amines
Anti-foam	Silicone polymers, organic copolymers
Anti-oxidant	Zinc dithiophosphates, hindered phenols, aromatic amines, sulphurised phenols
Anti-wear	Zinc dithiophosphates, acid phosphates, organic sulphur and chlorine compounds, sulphurised fats, sulphides and disulphides
Detergent	Metallo-organic compounds of sodium, calcium and magnesium phenolates, phosphonates and sulphonates
Dispersant	Alkylsuccinimides, alkylsuccinic esters
Friction modifier	Organic fatty acids, lard oil, phosphorus
Metal deactivator	Organic complexes containing nitrogen and sulphur amines, sulphides and phosphites
Pour-point depressant	Alkylated naphthalene and phenolic polymers, polymethacrylates
Seal swell agent	Organic phosphates, aromatic hydrocarbons
Viscosity modifier	Polymers of olefins, methacrylates, di-enes or alkylated styrenes

Table 3.77: Types of additives used in lubricants
[67, DETR, 2001]

Additives need to be retained in the oil over its whole useful life. This means that even if the individual substance would be expected to be driven off at normal engine operating temperatures, there must be another additive incorporated that binds it within the oil formulation.

This requirement to keep additives in circulation, and to keep breakdown products in circulation to increase the longevity of the oil, creates one of the discussion points for emissions of waste oil. Although a number of components are solid at ambient temperatures and could be expected to settle out of the oil and into the sludge layer, dispersants in the oil will tend to keep them within the oil layer. Larger solids are taken out of the engines by the oil filters.

During use, the composition of the oil will charge markedly, due to the breakdown of the additives, the formation of additional products of combustion and unburned fuels, the addition of metals from wear and tear on the engine and from the breakdown of the base oil itself.

Large treatment sites recognise that there will be a range of species in waste oil and thus screen the incoming waste for flashpoint, metal and chlorine levels; whereas smaller sites will typically just accept the oil waste. There is a distinct shortage of analysis data for incoming wastes, although the screening activities of a few sites show that industry anticipates high metal levels and contamination by flammable solvents, giving a measurable flashpoint.

Used oils collected by high volume users can be more tightly controlled and may hence be more consistent in composition.

Type of waste containing waste oils	Comment
Oil filters	No specific analysis has been found but these are known to contain waste engine oils plus the residues of larger sized solids formed in the engine and that have been trapped in the filter. In addition, there is the plastic and metals of the filter. Metals tend to go for recycling
205 litre steel drums	Waste oil and steel
25 litre drums	Waste oil and plastics
Bulk used engine oil	Used engine oil is the main wastestream processed at waste management licensed sites. Most of the emissions will be due to this material

Table 3.78: Type of waste containing waste oils
[56, Babtie Group Ltd, 2002]

There are no comprehensive analyses available of the waste oils entering oil treatment plants. Instead the next couple of tables (Table 3.79 and Table 3.80) show the data gathered on the chemical components that typically exist in the different types of waste oils. It is not expected that in reality all waste oils will be covered by the lower or top ends of the ranges mentioned in these two tables.

Waste oil components	Concentration range (ppm)	Origin/comments
Al	4 – 1112	Bearing wear or engine
Alkyl benzenes	900	Petroleum base oils
Aromatic compounds	14 – 30 w/w-%	For used motor oil, these arise from the lubricant base oil
Aliphatic compounds	65.4 w/w-%	N-alkanes are about 0.4 % waste oil, but the distribution is slanted towards the longer molecules that are less likely to evaporate: • tetralin 0.0012 % • dodecane 0.014 % • tridecane 0.014 % • octadecane 0.07 % • nonadecane 0.2 %
Antifreeze		
As	<0.5 – 67	
Ash content	0.4 – 0.64 [1]	
Ba	50 – 690	Detergent additives, additive package
BTEX	300 – 700	A composite analysis shows a high level of short chain hydrocarbons (benzene (0.096 – 0.1 %), xylenes (0.3 - 0.34 %), toluene (0.22 – 0.25 %)), with boiling points below 150 °C.
Ca	900 – 3000	Detergent additives
Cd	0.4 – 22	
Cl	184 – 1500[2]	Chlorine in used oils arises from: • contamination (either accidental or deliberate) with chlorinated solvents and transformer oils, both of which are now more closely controlled • lubricating oil additives • the lead scavengers added to leaded gasoline • it is used as a cold-flow additive
Chlorinated hydrocarbons	37 6300 18 – 2800 18 – 2600 3 – 1300	dichlorodifluoromethane trichlorotrifluoroethane trichloroethanes trichloroethylene perchloroethylene used oils can have a significant, but variable, chlorine content, including organochlorines as PCB, dichlorodifluoromethane, trichlorotrifluoroethane, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene. They may be formed chemically during the use of contaminated oil
Cr	2 – 89	Engine wear
Cu	<11 – 250	Bearing wear
Engine blowback	8 – 10 w/w-%	Absorbed gas, gasoline and diesel fuel. A variety of 'thermal breakdown products' are also included in the composition of waste oil
Fe	100 – 500	Engine wear
Halides	Up to 500	
Heavy hydrocarbons		Arise from polymerisation and from the incomplete combustion of the fuel
Hg	0.05 – <11	
Light hydrocarbons	5 – 10 w/w-%	A certain amount of unburned fuel (gasoline or diesel) dissolves in the oil and also arise from breakdown of the oil
Lubricant base oil	Up to 95 w/w-%	Major components are aliphatic and napthenic hydrocarbons and/or olefin polymers (e.g. polybutenes and poly-alpha-olefins in some lube base oils). Smaller amounts of aromatic and polyaromatic hydrocarbons are also present. The heavy metal content is less than 500 ppm. Phenols may be present at a few ppm

Waste oil components	Concentration range (ppm)	Origin/comments
Metals such as Al, As, Ba, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, P, Pb, Sb, Si, Sr, Ti, V, Zn	Up to 10000 combined	These originate from the lube oil additives, engine wear and foreign sources. They appear in waste oils as additives within lubricating oil, from wear and tear on engines and with machining oils. Additives (particularly the metals) typically remain in the oil after use
Mg	100 – 500	Detergent additives
Ni	10	Engine wear
Naphthalenes	9.7 – 470 – 2300 [4]	From base oils
Nitrogen compounds		From the addition of nitrogen compounds
Non – lubricant related compounds		Used oil often becomes contaminated by all kinds of materials, usually because of bad collection/segregation. Materials that may appear are brake fluid and antifreeze, vegetable oils, cigarette packets, solvents, etc.
P	6 – 1000	Anti-oxidant/anti-wear additives
PAH	30.3 – 204 – <1000 [4] Sum of 26 individual PAHs represented 0.17 % of the oil or 1.2 % of the aromatic fraction	The aromatics also include a huge range of PAHs in concentrations of up to 700ppm for an individual species. They appear from base oils and from incomplete combustion. Examples are benz(a)anthracene (0.87 – 30 ppm), benzo(a)pyrene (0.36 – 62 ppm), pyrene (1.67 - 33 ppm), naphthalene (47 ppm), biphenyl (6.4 ppm) and also chlorinated polyaromatics
PCB	<0.5 – 11 – <50	Under the Waste Oil Directive, the maximum content of PCB allowed in used oils to be treated for disposal is 50 ppm. It occurs due to contamination with transformer oils
Pb	8 – 1200 Up to 14000 when leaded gasoline is used	Leaded gasoline/bearing wear
S	0.1 – 2.8 w/w-%	From base oil and combustion products.
Sediments	0.5 – 2 w/w-%	Soot and sediment from the combustion chamber, free metals and dirt. Sediment formation is aggravated by the mixing of used oils from several manufacturers' additive packages, and collection sources
Si	50 – 100	Additives/water
Sn	Trace amounts	Bearing wear
Tl	0.1	
V	300	From base oil
Water	5 – 10 w/w-%[3]	Combustion
Zn	6 – 4080	Anti-oxidant/anti-wear additives

Note: Additions of figures cannot be made to fit perfectly because they correspond to different sets of data.
[1] Both parameter limits are average values
[2] Up to 8452 ppm in collected used oil due to contamination with chlorinated solvents and sea salt from ship slops
[3] Up to 30 %
[4] When three numbers appear in a range, the middle number corresponds to the average

Table 3.79: Indicative list of components present in used oils
[4, Langenkamp, 1997], [5, Concawe, 1996], [6, Silver Springs Oil Recovery Inc., 2000], [14, Ministry for the Environment, 2000], [37, Woodward-Clyde, 2000], [56, Babtie Group Ltd, 2002], [42, UK, 1995], [150, TWG, 2004]

Used industrial oils

A variety of oils are used in industry including soluble oils and some halogenated oils, although these are becoming less common. Oil is used as hydraulic oil, as lubrication, as a heat transfer medium, as an electrical medium and as a cutting fluid.

Soluble oils/machining oils are very common, but there is no information so far about their composition. Many of these industrial oils undergo intensive in-house recycling to extend their useful life, and the majority of any metal contaminants associated with grinding operations are removed by in-house systems and recovered. In the absence of other data, the following assumptions have been made:

- these oils are used in open systems. Their formulations do not include very low boiling point/volatile hydrocarbons because of the fire risk and health risks during use and the need to retain the product characteristics during use. They are agitated during use, and take away excess heat from machining surfaces, thus in operation they are heated above the ambient temperature. Therefore, VOC emissions during waste treatment are typically very small
- the metal content will vary considerably from source to source. The main metals worked with will be copper, zinc, nickel and chromium.

	Concentration	**Reason**
Cadmium	50 % of concentration in lubricating oil or 0.000155 %	Cadmium is currently being phased out from the manufacture
Chromium	100 % of concentration in lubricating oil or 0.0028 %	Common: typically used at the same level as in engine oil
Copper	100 % of concentration in lubricating oil or 0.025 %	Common: typically used at the same level as in engine oil
Lead	0	No particular reason to machine this
Naphthalene	0.0042 %	No data at all, naphthalene is in all oils, but would expect the formulation to have the lowest amount possible (taken from fuel oil n°6 content) because it would be a solid at room temperature and does not seem to add anything chemically useful to the formulation
Nickel	0.0028 %	No data for lubricating oils
PCB		Found in transformer coolant oils
Xylenes	0.22 %	
Zinc	50 % of concentration in lubricating oil or 0.029 %	Common machining component, but zinc appears to be a major additive in lubricating oils

Table 3.80: Estimated metal concentrations in industrial waste oils
[56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Electrical oils are specialist oils which undergo a laundering process, so very little waste arises from them. The main concern with these oils is the risk of PCB contamination. Typically waste treatment facilities do analyse for PCBs.

Oily water from interceptors

Most waste from interceptors comes from car parks and vehicle service areas. It is, therefore, reasonable to assume that it is similar in content to used engine oil but will contain additional silt, possibly vehicle tyre wear particles, fuel combustion products and road making tars. Spilt fuel will also be collected at the interceptor, but any materials that are capable of evaporating to the air at ambient temperatures will have done so before the interceptor waste is collected.

A proportion of oil interceptors arises from manufacturing sites and collected waste industrial oils. These will have far lower concentrations of combustion products, but might have higher metal concentrations, depending on the industrial application.

Waste solvents
Waste solvents may be generated in the following industrial sectors:

- paints, coatings and paint removers
- inks
- chemical and pharmaceutical industry
- film production
- production of synthetic fibres
- rubber, plastic and resin solutions
- solvents for degreasing
- solvents for dry cleaning
- for agriculture products
- aerosol cans and dispensers.

The wastes that are considered as solvents correspond mainly to EWL codes 07, 08, 09 and 14. The final code corresponds to a category especially devoted to organic solvents. There are four main classes of solvent mixtures which make the solvent unusable in its present state and this promotes its recovery. These are:

- mixture with air. This usually occurs when the solvent has been used to dissolve a resin or polymer which is laid down by evaporating the solvent. Recovery from air can pose problems because the solvent may react on a carbon bed adsorber or be hard to recover from the steam used to desorb it
- mixture with water. Whether this arises in the solvent-based process or in some part of the recapture of the solvent, it is very common to find that the solvent may be contaminated with water. Removal of water is a simple matter in many cases but in others it is so difficult that restoration to a usable purity may prove to be uneconomic. It should always be borne in mind that the water removed in the course of solvent recovery is likely to have to been discharged as an effluent and its quality is therefore important
- mixture with a solute. A desired product is often removed by filtration from a reaction mixture. The function of the solvent in this case is to selectively dissolve the impurities (unreacted raw materials and the products of unwanted side reactions) in a low viscosity liquid phase, with a very low solvent power for the product. The choice of solvent is often limited in such cases, but significant improvements in the solvent's chemical stability can sometimes be found by moving up or down a homologous series without sacrificing the selectivity of the solvent system. A less sophisticated source of contamination by a solute occurs in plant cleaning, where the solvent power for any contaminant is of primary importance but where water miscibility, to allow cleaning and drying to take place in a single operation, is also an important property
- mixtures with other solvents. A multi stage process such as that found typically in the fine chemical and pharmaceutical industries can involve the addition of reagent dissolved in solvents and solvents that are essential to the yields or even to the very existence of the desired reaction.

Vegetable waste oils
Cooking oils from restaurants and hotels.

Waste catalysts
The spent catalysts that may be regenerated ex-situ are:

Metal catalysts
For example, platinum-alumina reforming catalysts which can be regenerated by the removal of carbonaceous deposits from the catalyst surface using a carefully controlled combustion procedure, followed by platinum redispersion and rechloriding of the catalyst support).

Noble metal catalysts
These can be regenerated by removing the coke deposits to successfully restore the activity, selectivity, and stability performance of the original fresh catalyst. Coke deposits are removed by controlled combustion.

Base metal catalysts
Hydroprocessing catalysts can be regenerated using different methods such as regenerative oxidation treatment to remove coke (ex-situ regeneration) or redispersion of the metals in the case of poisoning by the sintering of metals.

Zeolites
These can be regenerated relatively easily by using methods such as heating to remove adsorbed materials, ion exchanging with sodium to remove cations, or a pressure swing to remove adsorbed gases. However, they are not regenerated ex-situ because the structure is, in most cases, damaged and depending on the application the pores can be contaminated with heavy metals or other catalyst poisons.

Waste activated carbon
Most industrial plants tend to send their spent carbon off-site for regeneration by a large centralised carbon manufacturer. Quantities of spent carbon from industrial sources (textiles, refinery products, carpet mills, plastic industry, phenolic resins, herbicides, explosives, detergents, solvents, dyes), whilst reasonably substantial, do not approach those obtained from potable water purification. From discussions with various carbon regenerators, it appears that water treatment provides the single largest source of spent carbon. Activated carbon adsorption systems can be used for a wide variety of applications, and can potentially contain a cocktail of adsorbed pollutants. The contaminants found in spent activated carbons are typically:

- chlorine
- COD/BOD
- pesticides
- bulk organics imparting colour, taste and/or odour (i.e. humic acids)
- general organics such as phenol
- metals such as iron, aluminium, cadmium and mercury
- inorganic elements such as calcium and phosphorus
- dyes (cause of colour)
- detergents
- phenols
- explosives (only in material that comes from the manufacture of explosives).

Activated carbon products are basically available in three forms: extruded activated carbon, granular activated carbon, and powder activated carbon. The last form is not regenerated.

Waste ionic resins
A large proportion of resins sold worldwide are used in water treatment (i.e. water softening). The remaining balance is divided between chemical processing, extractive metallurgy, and food and pharmaceutical processing.

Operating ion exchange resins may concentrate toxic ions such as chromate and cyanide, or heavy metals. Due to the predominance of water applications, they may also contain pesticides, chlorine, phenol and inorganic elements such as calcium, sodium, manganese and phosphorus.

Conventional ion exchange resins are bead-shaped, and behave as plastic ball bearings when handled. They contain ion-active sites throughout their structure, have uniform distribution of activity, and can usually resist breakages resulting from handling, or from osmotic shock (i.e. a rapid change in solution environment). Most beads are sold in the 40 µm to 1.2 mm size range.

Treatment of liquid photographic waste

Parameter	Concentration (mg/l)	
Hydrocarbons	6000	emission in evaporation step (colour photo processing waste)
EOX	10	
Respiration inhibition	5 %	
Metals (Zn, Ni, Pb, Cr, Mo)	50	
Ag	50/100	black and white/colour photo processing waste
Cd	1.0	
Cu	25	
Hg	1.0	

Table 3.81: Acceptance criteria for desilvered photographic liquid waste and similar waste waters (with the same processing path)
[156, VROM, 2004]

3.4.2 Consumptions of waste treatments to obtain a recycled material

Consumptions in the re-refining of waste oils
Other than transportation, the main operating overhead relates to the generation of steam for heating waste oil.

Process	Compounds used within the process	Consumptions (values in kg/tonne of waste oil if not otherwise specified)
Acid/clay process	Sulphuric acid as a precipitate agent of heavy metals. Clay as a filtration/neutralisation agent	 36
Pretreatment of waste oil	Demulsifiers to help in the settling process	
Distillation/clay process	Clay	40
Propane de-asphalting (PDA)	Consumption of energy is higher than in the regeneration by chemical treatment or by hydrogenation	
Thin film evaporator (TFE) + clay process	Clay	60
TFE + hydrofinishing	Hydrogen and catalysts	
TFE + solvent extraction	Solvent	
TFE + chemical treatment + solvent extraction	Energy Caustic Solvent	3.2 MJ/kg of used oil 10 0.3
TFE + solvent extraction + hydrofinishing	Hydrogen catalyst Mohawk chemical Hydrogen gas	0.25 12 2
TDA (thermal de-asphalting) + clay treatment	Clay	100
TDA + hydrofinishing (high pressure)	Catalyst	0.5
PDA (propane de-asphalting) + hydro finishing (medium pressure)	Propane	8.25
With thermal clay treatment	Fossil energy resources	4.26 MJ/kg of used oil
With hydro-finishing	Energy	9.93 MJ/kg of used oil
Vacuum distillation + chemical treatment	Fossil fuel consumption Primary energy Water consumption	47 kg eq crude oil 2681 MJ 3300
Regeneration process	Fossil energy resources	42.46 MJ/kg of oil
Caustic soda and bleaching earth treatment (ENTRA)	Caustic soda Bleaching earth	30 20
Direct contact hydrogenation (DCH)	Hydrogen Catalyst	70 Nm^3/t 0.5

Table 3.82: Consumptions of different waste oil re-refining techniques
[6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [11, Jacobs and Dijkmans, 2001], [13, Marshall, et al., 1999], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

Table 3.83 gives the consumptions for the re-refining of part of the waste oil to base oil which can then be re-used as lubricating oil, together with the regeneration of the remaining waste oil to fuel oil.

	Consumptions	Units
Economics		
Capital investment expenses for treatment plant	4.85 (36)	EUR (DKK) millions
Maintenance	0.094 (0.7)	EUR (DKK) millions per year
Operation period	20	years
Labour input	10	number of persons
Resources used		
Chemicals	291.5	tonnes
Water	8000	m^3
Electricity	1150	MWh
Fuel oil	1200	m^3
Base: 26000 tonnes yearly collected waste oil to base oil (8000 tonnes), fuel oil (12000 tonnes) and asphalt (4000 tonnes)		

Table 3.83: Consumptions of waste oil re-refining activities
[12, Birr-Pedersen, 2001]

Figure 3.5 depicts a block diagram showing a comparison between the inputs and outputs of different re-refining processes.

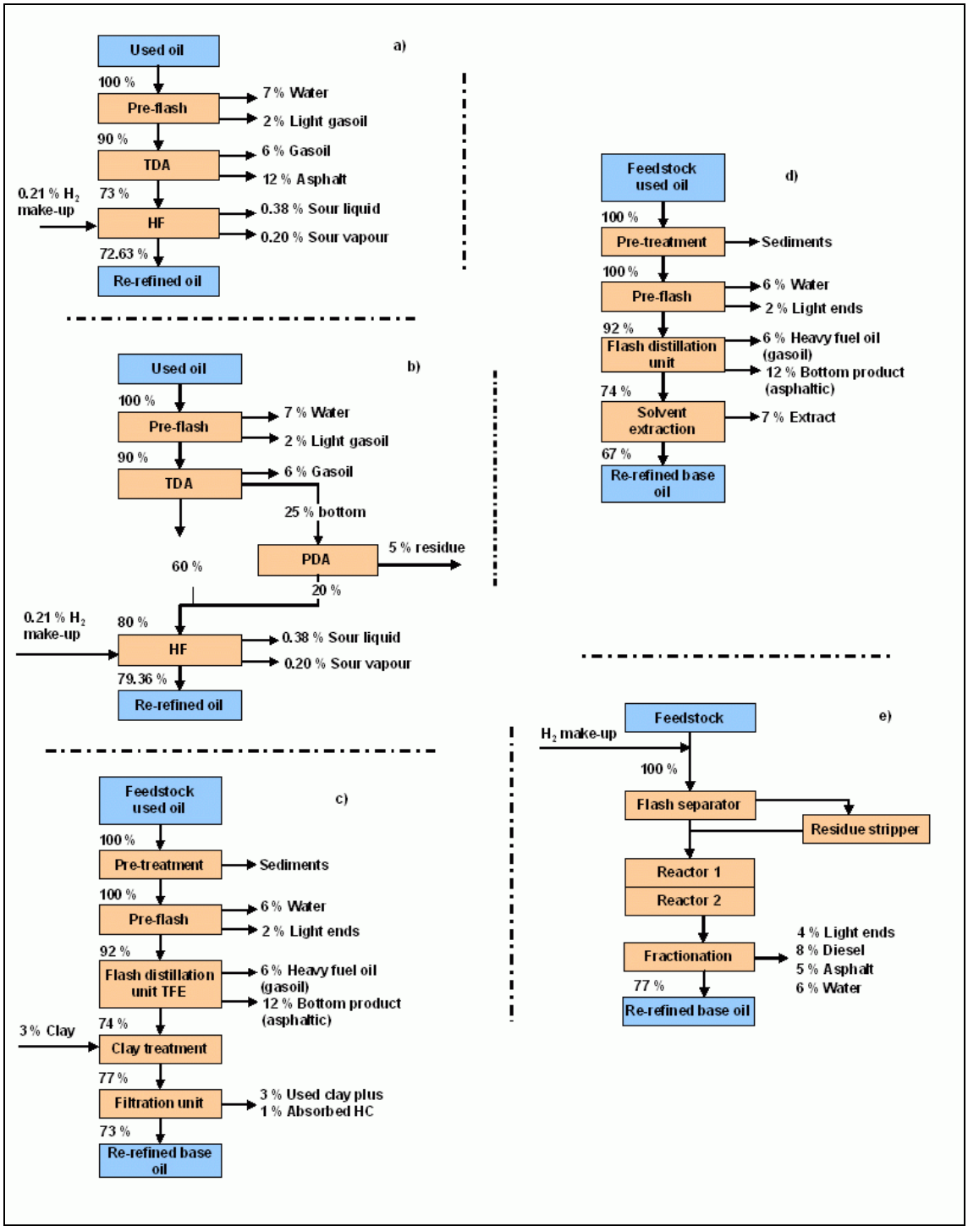


Figure 3.5: Inputs and outputs of the re-refining treatment
Note: a) TDA/HF, b)TDA/PDA/HF, c)TFE/clay treatment, d)TFE/solvent, e) DCH
HF = Hydrofinishing. % represents the amount that goes in that stream based on 100 % used oil entering the system
[36, Viscolube, 2002], [86, TWG, 2003], [150, TWG, 2004]

Table 3.84 shows the consumptions of the TDA system and the TDA combined with a PDA.

Traditional TDA/HF system						
Consumption and utilities	**PF**	**TDA**	**HF**		**Total**	**Unit**
Electrical consumption	1.5	12	20		33.5	kWh
MP steam	285	322	70		677	kg
Cooling water (make-up)(1)	1.1	5	0.3		6.4	tonne
Fuel (absorbed heat)	/	670	711		1380	MJ
Hydrogen	/		2.1		2.1	kg
Catalysts	/		0.2+0.05(2)		0.2+0.05(2)	tonne
Propane make-up						kg
High recovery system						
Consumption and utilities	**PF**	**TDA**	**HF**	**PDA**	**Total**	**Unit**
Electrical consumption	1.5	12	20	13	46.5	kWh
MP steam	285	322	70	135	812	kg
Cooling water (make-up)(1)	1.1	5	0.3	4	10.4	tonne
Fuel (absorbed heat)		670	711	920	2300	MJ
Hydrogen			2.1			kg
Catalysts			0.2 + 0.05(2)		0.2 + 0.05(2)	tonne
Propane make-up				0.8	0.8	kg

(1) Based on 10 % evaporation losses
(2) Demetalisation catalyst + Refining catalyst
Note: Consumption based upon 100 kt/yr waste oil capacity, considering 10 % water contents. All the parameters are expressed in unit/tonne of waste oil.
HF: hydrofinishing, PDA: Propane de-asphalting, TDA: Thermal de-asphalting, PF: Pre-flash, MP: medium pressure

Table 3.84: Consumption values of the TDA system and the TDA combined with a PDA processes [66, TWG, 2003], [150, TWG, 2004]

Capacity	**t/yr**	**2001**	**4600**	**6824**	**15000**	**17171**	**19960**	**46208**	**90500**
Fuel consumption	GJ/yr		19146	33486	40671	54751	16705	405883	
Electricity consumption	MWh/yr	345	225	1200	1380	2024	655	9215	
Heat consumption	MWh/yr	157			0	15208			
Water	m^3/yr	617		80000	9848	9929	1557	407000	2213000
Cooling	MJ/yr				44000				
Electricity/Plant capacity	kWh/t	172.4	48.9	175.8	92	117.9	32.8	199.4	
Heat/Plant capacity	kWh/t	78.5				885.7			

Table 3.85: Consumptions from different waste oil re-refining plants in the EU [66, TWG, 2003]

Consumptions of the regeneration of waste solvents

Table 3.86 shows consumption data for two facilities operating in the EU. Other data reported energy consumptions lower than 1 GJ/tonne.

Consumption parameter	**Units**		
Capacity	kt	12	27.5
Gas fuel	GJ/yr	19651	
Fuel consumption	GJ/yr		31628
Electricity	MWh/yr	1571	2984
Water	m^3/yr	19000	40776

Table 3.86: Consumptions of two regeneration treatment of waste solvents [66, TWG, 2003], [130, UBA, 2003]

Consumptions of regeneration of spent catalysts

Table 3.87 shows an overall material balance for an example regeneration. Almost 375 t of catalyst was recovered for re-use.

Overall material balance	Values in kg	
As received material		620982
Inert support	27099	
Unregenerated dust and fines	9569	
Total unregenerated feed to regenerator		584314
Shorts from length grading and regenerated dust and fines	37191	
Loss on ignition	172143	
Net regenerated catalyst		374980

Table 3.87: Mass balance in a commercial regeneration of CoMo catalyst [125, Ruiz, 2002]

Consumptions in treatment of solid photographic waste

The electricity consumption for shredding, washing/rinsing and electrolysis amounts to 100 to 300 kWh/t film waste. Depending on the process of desilvering, auxiliary materials are used. These are shown in Table 3.88.

Desilvering with bleach-fix	Desilvering with iron chloride
Sodium hydroxide (20 %): 6 l/t film	Iron chloride (40 %): 11 l/t film
Sulphuric acid: 6 l/t film	Hydrochloric acid (36 %): 8 l/t film
Sodium bisulphite: 12 l/t film	Sodium sulphite: 12 l/t film
	Hydrogen peroxide (35 %): 4 l/t film

Table 3.88: Used amounts of auxiliary materials for desilvering film waste [156, VROM, 2004]

Consumptions in the treatment of liquid photographic waste

Consumption of energy

The required electricity for electrolysis ranges from 12 to 46 kWh/t photographic liquid waste. The electricity consumption is dependent on the iron content. For bleach-fix, the consumption is higher due to the higher iron content. The ultrafiltration requires approximately 27 kWh_e and 13 MJ/t liquid waste for the heating of the rinse-water. The electricity consumption of chemical removal of silver is estimated on 3.5 kWh/t liquid photographic waste.

The energy consumption for evaporation is approximately 220 MJ/t waste water. If evaporation is also applied as a pretreatment, in the case of colour photo processing waste water, the energy consumption is approximately 350 MJ/t waste water. The required electricity for electroflocculation, in the case of extra desilvering, is approximately 80 kWh/t waste water. Further physico-chemical and biological treatment requires approximately 5 kWh_e/t waste water.

Consumption of chemicals

Table 3.89 shows the consumption of chemicals for sulphide precipitation/ultrafiltration of photographic liquid waste.

Chemical	Consumption (kg/t photo processing waste)	Function
Sodium sulphide (40 %)	0.1	Precipitation of silver (and other metals)
Citric acid	0.7	Cleaning of the membranes
Sodium hydroxide	0.01	Cleaning of the membranes
Detergents	0.01	Cleaning of the membranes
Water	75	Cleaning of the membranes

Table 3.89: Consumption of chemicals for sulphide precipitation/ultrafiltration [156, VROM, 2004]

For chemical removal of silver, the consumption of chemicals is estimated at 1.5 sodium borohydride and 2.5 sulphuric litres per tonne of photographic liquid waste.

In the physico-chemical treatment of desilvered photographic liquid waste, several chemicals are used. The consumptions are shown in Table 3.90. If evaporation is applied as a pretreatment, practically no chemicals are consumed in the following treatment steps. Most contaminants have already been removed in the evaporation step.

Chemical	Consumption (kg/t waste water)	Comments
Sodium hydroxide (33 %)	0.007	
$FeCl_3$	0.003	
Powder carbon	0.5	
Flocculant	5	In the case of desilvering
Na_2S (40 %)	15	In the case of desilvering

Table 3.90: Consumption of chemicals in the treatment of desilvered photographic liquid waste [156, VROM, 2004]

3.4.3 Emissions from waste treatments to obtain a recycled material

3.4.3.1 Emissions from the re-refining of waste oils

In order to evaluate emissions from the re-refining of waste oils several issues need to be considered:

- waste lubricating oils contain shorter chain organics than new lubricating oils and therefore VOCs are likely to be relevant
- sulphur and chlorine are known 'problem' compounds found in waste oils
- aromatic compounds are more polar in general than aliphatic molecules and are therefore more likely to be present in the aqueous phase.

The oil processing sector has a narrow range of operations and is the most likely to respond to a generic method of calculating emissions if the oil constituents can be identified. The following detail the different pollutants and media where they can be found. Some tables have been constructed to focus on the pollutants (Table 3.91 and Table 3.92) whereas others focus on the activities that may lead to pollution (Table 3.93).

Species	Air	Water	Waste and soil
Organic compounds			
Benzene	yes - some data, but difficult to apportion between air/water/land	yes - some data, but difficult to apportion between air/water/land. Polar compound	yes - some data, but difficult to apportion between air/water/land
Ethyl benzene (VOC)	No data available	yes (as BTEX)	yes (as BTEX)
Toluene		yes - some data, but difficult to apportion between air/water/land	yes - some data, but difficult to apportion between air/water/land
Xylenes	yes - some data, but difficult to apportion between air/water/land	yes - some data, but difficult to apportion between air/water/land	yes - some data, but difficult to apportion between air/water/land
VOCs	yes - some incomplete data, but difficult to apportion between air/water/land. Lower chain alkanes likely to go to air. Since used oil usually contains light ends such as gasoline, VOCs may be emitted from storage (from the tank and their associated pipework) for every process considered. The behaviour of oils undergoing heating and agitation generates VOCs emissions	BTEX in particular are polar molecules, but also volatile, and are present in the aqueous phase and/or evaporated to the air	
Naphthalene		Some data available	Some data available
Biphenyl		Limited data, may not be relevant	Limited data
Phenol	Not air emissions expected because too soluble in oil and water	Relevant but no data	Relevant but no data
Sulphur and nitrogen compounds	The gradual increase in sulphur and nitrogen additives in lubricating oils may require sites to monitor for these		Found in used oil sludge
PCBs and chlorinated solvents: Identified as present in some analyses		Solvents and lighter compounds are removed in the dewatering. Naphtha and light distillate cuts are typically distilled off upstream of the main processing facilities. If the hydrocarbon streams are fed to a hydrotreater, the chlorides may be removed	Used oil sludge

Species	Air	Water	Waste and soil
PAHs. These used to be a problem in re-refined base oils. However, recent tests indicate that it is possible to remove PAHs in the regeneration process of modern plants, thus avoiding the accumulation of PAHs. PAHs are destroyed by severe hydrogenation which also removes nitrogen, sulphur, metals and chlorides	PAHs are unlikely to be discharged to the air during the oil treatment processes. They are not volatile compounds, and their position as an air carcinogen is due to them being released as a combustion product from fossil fuels. Potential for PAH emission may be during the processing of oil filters. Most filters are crushed at some point, producing a fine oil mist. There may be a hood and an exhaust vent, but this is a potential mechanism to deliver PAHs to the air and the oil in oil filters have a larger concentration of particulate matter and hence PAHs. This may not be of significant importance, as it is the smaller particles that are more likely to form an air discharge. The behaviour of oils undergoing heating and agitation may generate PAHs emissions.	Relevant but no data	The heavy PAHs in the regeneration plants end up in either the residue stream and/or the asphalt blends. The lighter ones remain in the lube oil cuts. Also possibly found in a used oil sludge. Relevant but no data
Other air pollutants			
CO_2 from many combustion processes			
Odour	Odour has been identified as an important problem in re-refining installations		
Typically water and waste parameters			
Total nitrogen		Nitrogen and phosphorus additives	Nitrogen and phosphorus additives
Total phosphorus		Nitrogen and phosphorus additives	Nitrogen and phosphorus additives
TOC		Calculated from COD as 1/3 of COD	Not available except as calculated from oil content, but this will be too low (or COD)
Chloride		Additives in oil and salt on roads	Additives in oil and salt on roads
Oil		The oil itself is a visual pollutant when it floats on water, and drinking water is rapidly tainted by the taste of oil	Used oil sludge

Species	Air	Water	Waste and soil
Metals			
Metals			The metals from regeneration processes are mostly in the residue cut. The volatile metals are removed by the hydrotreatment guard reactor if they are hydrotreated. Also possibly found in used oil sludge
Arsenic	Not expected	Some data available	Some data available
Cadmium	Not expected	Some data available, but being questioned	Some data available, but being questioned
Chromium	Not expected	Some data available	Some data available
Copper	Not expected	Limited data	Limited data
Lead	Not expected	Some data available, but being questioned	Some data available, but being questioned. In the re-refining options, lead ends up in the heavy residues which results in it being 'locked up' in a bitumen product
Manganese	Not expected		
Nickel	Not expected	yes, but no data	yes, but no data
Zinc	Not expected	Some data available	Some data available

Table 3.91: Common emissions from waste oil treatment plants
[5, Concawe, 1996], [6, Silver Springs Oil Recovery Inc., 2000], [14, Ministry for the Environment, 2000], [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

The following Table 3.92 reflects how the components of the waste oil distribute emissions to air, sewer and products. As can be seen, most of the contaminants remain in the recovered oil. The main exception to this is VOCs, where there is a possibility of their transfer to the air, with the amount depending on the type of oil and whether the oil is heated during treatment.

Input substances	Hot processing			Cold processing		
	Air	Products	Water	Air	Products	Water
Benzene	0.6	0.3	0.1	0.2	0.7	0.1
Toluene	0.3	0.7	0	0.1	0.9	0
Xylenes	0.1	0.8	0.1		0.9	0.1
Naphthalene		1			1	
Biphenyl		1			1	
Benz(a)anthracene		1			1	
Benzo(a)pyrene		1			1	
Heptane	0.2	0.8			1	
Octane	0.1	0.9			1	
Nonane		1			1	
Decane		1			1	
Undecane		1			1	
Arsenic		1			1	
Cadmium		1			1	
Chromium		1			1	
Copper		1			1	
Lead		1			1	
Nickel		1			1	
Zinc		1			1	
Note: Figures correspond to the share distribution of substances in output streams. E.g. for each kg of benzene entering into the hot processing, 0.6 kg ends up as an emission to the air, 0.3 kg goes into the oil and 0.1 kg into the waste water. 1 means that all the input goes to that output						

Table 3.92: Matrix for allocating input species to air, oil and water streams for hot and cold processes
[56, Babtie Group Ltd, 2002]

	Point source emissions		
Activity/Plant	**To air**	**To water**	**To disposal**
Filter shredding	Oil mist		
Magnetic separation	Oil mist		
drum emptying/shredding	Oil mist		
Tanker unloading	Tank venting		
Coarse straining	Oil mist		
Bulk storage	Tank venting. Very few tank vents are linked together. Tank vents will discharge the 'air' that the tank contains when it is displaced during tank filling. This emission is unlikely to carry significant pollution unless the tank contents have been heated or agitated	Settled water (via treatment)	Settled sludge
Cold oil settling	Tank venting	Settled water (via treatment)	Settled sludge
Hot oil settling	Tank venting	Settled water (via treatment)	Settled sludge
Vibrating sieve	Mist and vapour		Sludge
Enclosed filters			Used elements and sludge
Bauxite towers			Spent bauxite
Vacuum dehydration	Vapour (via scrubbers)		
Product blending	Tank venting		
Pumped sludge storage/decanting	Tank venting		
Cold effluent settling	Tank venting		
Hot effluent settling	Tank venting		
Biological effluent treatment	Aeration air		
Filter press			Filter cake
Plate separator		Effluent	Settled sludges
Mechanically handled sludge/solids storage and loading			Mixed solid wastes
Waste oil fired boiler	Stack emissions		
Old interceptor waste	Since it usually comes from paved surfaces where it has already been exposured to air, it will probably have already emitted all that it is capable of emitting to the air at this stage unless it is heated during treatment		
Many sites have an accidental spillage of oils to the site base during unloading, or during the storage or transfer of materials on the site. The site base is usually designed to retain liquid spills and to return these to the plant, but there will be some evaporation in the air			

Table 3.93: Principal emission sources at oil recycling premises
[56, Babtie Group Ltd, 2002], [150, TWG, 2004]

The following table identify emissions to air, water and solid waste generated for each type of waste oil treatment. In some cases, the emissions are quantified with data in the table.

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	**Water**	**Soil and residues**
Oil separation from water stream	Could produce a range of other emissions such as metals, naphthalene, additional nitrogen, toluene, xylenes and PAHs	Could produce a range of other emissions such as metals, naphthalene, toluene, xylenes and PAHs	Could produce a range of other emissions such as metals, naphthalene, toluene, xylenes and PAHs
Laundering. Closed loop recycling of industrial oil	From the oil recovery process the emission is 20 – 40 mg/m^3 VOCs whilst heating. 262 kg VOC was released against 100 mg/Nm^3 and l0 t/yr limits	Waste water	Laundering can be considered as a closed loop system because it generates very little (if any) waste oil. The contaminated filter sludge contains 20 – 30 % oil. This waste stream is reprocessed with quicklime and made suitable for co-combustion in a cement kiln. The acceptability of one technique, which used a clay known as'fuller's earth' to remove contaminants, is waning as conditions for disposal to landfill become more stringent. The technique is still used in New Zealand, but disposal of the contaminated clay is likely to become an issue. Releases to land are: filter cake which includes solids and metal fines (<100 t/yr against a consent limit of 600 t/yr) and in some cases chlorinated solvent sludges. 80 – 85 % of drums are recycled while the others are scrapped
Reclaiming industrial lubricants		Waste water from dewatering processes	
Vacuum distillation	Vacuum distillation of waste oils produces sulphur compounds, mercaptans (odorous) and PAHs (some may be carcinogenic)		All the metals contained in the used oil end up in the vacuum residue. This residue may be blended with a crude vacuum residue in such a proportion so as to enable its use as a component in bitumen
Distillation/clay process			Produces large quantities of the oil-absorbed clay which need to be disposed of. High temperature activated clay allows a lower clay/oil ratio, thus increasing the overall yield and reducing the quantity of oily clay needing to be disposed of
Thin film evaporator (TFE) + clay treatment		Water: 90	Clay: 50 – 60 Bitumen (metals and additives): 130 Sludge and light ends: 35 The process produces residues (requiring disposal)

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	Water	Soil and residues
Acid/clay process			This process produces large quantities of sludges and solids requiring disposal. These sludges (acid tars) are highly acid and contain high concentrations of PAHs, sulphuric acid and sulphur compounds, as well as most of the metals from the used oils. These tars are unsuitable for landfill because of their physical and chemical properties. This latter constraint can sometimes be overcome by: • dispatching the acid sludge jointly with the oily clay, in granulated form, to cement factories or to contractors • incinerating, but the gases need to be treated with caustic soda and the resulting waste water needs to be dealt with. This neutralisation treatment generates in quantity as much inactive waste as the amount of acid tar treated • treating to produce sulphuric acid or SO_2. The used clay (4 % by weight of feedstock + absorbed oil content) also needs to be incinerated by the same method as described above
Vacuum distillation + chemical treatment or clay treatment.			Used clay and used chemicals need to be safely disposed of. The route currently in use is to burn them in cement kilns or in a chemical waste incinerator
Vacuum distillation and hydrotreatment	Emissions common to any process handling oil products		The disposal of spent hydrotreating catalysts needs to be handled by a specialised company familiar with this problem. The residue produced from the vacuum distillation stage is similar to asphalt and may be sold. Fuels that are taken out in the de-fuelling stage can also be used on site or sold. The catalyst used is nickel-molybdenum and is either recycled by a nickel smelter or landfilled
TFE + hydrofinishing		Water: 90	Sludge and light end: 30 Sulphur: 35 Bitumen: 130
TFE +solvent extraction		Water: 90	Sludge and light end: 30 Extract: 60 Bitumen: 130
TFE + solvent extraction + hydrofinishing		Water: 65	Sludge and light end: 20 Sulphur: 4 Bitumen: 160
TDA (thermal deasphalting) + clay treatment		Waste water: 770	Light ends/solvents: 35 Clay: 130 Bitumen (metals and additives): 120
TDA + hydrofinishing (high pressure)		Waste waters: 770	Light ends/solvents: 35 Spent catalyst: 0.5 Bitumens: 120
PDA (propane deasphalting) + hydro finishing (medium pressure)		Waste waters: 770	Light ends/solvents: 30 Bitumens: 130

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	**Water**	**Soil and residues**
Vacuum distillation + chemical treatment	1116 kg eq CO_2 2.8 kg eq SO_2 VOC: 0.04 kg eq. C_2H_4 3.6 g particulates	0.0011 kg eq phosphates in water	Waste to eliminate: 24 Waste to recover: 33
Distillation and alkali treatment (Vaxon-Cator)		None. Recycled to a product	Small
Solvent extraction and distillation (Sener-Interline)		Discharges to water are from the residuum/water separator	None
Direct contact hydrogenation (DCH)		Waste water: 60	Bitumens: 50 Spent catalyst: 0.75
Thin film evaporator (TFE)		Process water, water decanted from storage tanks and contaminated surface water is treated in the effluent plant. This presents a problem to the site; in that the water has a very high COD which can vary between 40000 to 100000 mg/l against a discharge consent limit of 80000 mg/l. It contains materials such as glycols, polyglycols, esters and glycerols	The residue from the TFE is extracted whilst still mobile and blended with other secondary fuel oils which are also produced on site. Most of the organometallic constituents of the additives end up in the residue, so their ultimate destination is in a secondary fuel oil released to air as combustion products. There is a high dilution of the residue into the secondary fuel oil formed and the blend meets fuel oil specifications. Other residues, which include storage tank and effluent plant sludges, are removed from the site and centrifuged for reclamation of the oil. The solid residue from that process then is being landfilled
Caustic soda and bleaching earth treatment (ENTRA)		Waste water: 60	Bleaching earth, caustic soda and residue: 150
Waste oil transfer station		Waste water: 102	Sludge and solids: 2.13 Shredded steel: 85
Treatment of transformer oils			Spent bauxite catalyst Non-returned drums and pallets
Treatment of oil interceptor waste, soluble cutting oils, Spray booth waste from water based paint, gully waste, leachates		Waste water: 1613	Pumpable sludge: 47 Tank and tanker 'dig out' and screened waste: 43
Re-refining of lubricant oil[1]	CO_2: 123 SO_2: 1.04 NO_x: 0.35	Waste water: 84	Oil/chemical waste – sludge: 0.088
Used solvent oils and oily waters		Waste water: 444	Solids and sludge: 171
Treatment of oil water mixtures and leachates		Effluent: 1042	Filter cake and sludge: 55

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	Water	Soil and residues
Integration in a mineral oil refinery	Provided that adequate pre-treatment of used oils is performed to remove water and light ends and to reduce the organic chloride content the emissions are related to those occurring in a refinery (see Refinery BREF)		Metals are encapsulated in asphalt, so the leaching of metals will be extremely low. However some problems of corrosion damage to the plant and loss of cracking catalyst activity need to be solved before this can be considered a viable option
Integration to a lubricant part of a refinery	It could release particulates, sulphur, halides, heavy metals and their oxides to the air		Most of the lube oil additives are bottomed out in this cut. The metals in the residue after the solvent extraction process are still leachable. There could be problems in its disposal to asphalt, especially in winter, when the market may slow. This cut would not be fit for blending in heavy fuels, not only for failing the filtration tests, but also for environmental reasons. The aromatic extracts which are contaminated with chlorine are believed to be disposed of outside the refinery
Regeneration	CO_2 equivalent (kg eq. CO_2/kg of oil) 3.19 Acidification potential (g eq. H+/kg of oil) 0.06 VOC emissions (g/kg of oil): 9.05 CO emissions (g CO/kg of oil) 9.74	COD (g COD/kg of oil): 35.02	Waste (g/kg of oil): 411
Chemical treatment + distillation + HF			

[1] Calculations were made based on the yearly treatment/usage of 26000 tonnes dehydrated waste oil and producing 8000 tonnes of base oil, 12000 tonnes of fuel oil and 4000 tonnes of asphalt

Table 3.94: Environmental issues generated by different waste oil re-refining techniques [6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [11, Jacobs and Dijkmans, 2001], [12, Birr-Pedersen, 2001], [13, Marshall, et al., 1999], [14, Ministry for the Environment, 2000], [42, UK, 1995], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [139, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

Emissions to air

The emissions to the air are partially controlled at some sites, but uncontrolled at others. VOCs are known to occur. Although the lubricating system is a semi-closed system, it is not gas tight, therefore it would be expected that the volatile gases would have boiled off and left the system during normal operating temperatures.

Abatement systems for reducing oil emissions to the air are in place in some plants. At other sites, the excess oil concentration in buildings is simply vented to the air through exhaust fans; with all the tanks having vents to the air.

Most plants will accept that there is an odour problem from the oil. The control of odour from such plants requires a high level of management control and attention. Odours are typically generated during the storage, e.g. odours problems can arise by leaving hatches open at the top of each settlement tank and oil storage tank, or in open vibrating sieves.

No generally recognised reliable figures have been found for the concentration of contaminants in the air emitted from waste oil re-refining processes. However, some matrix distributions are shown in Table 3.95.

Activity	Oil filters	25 litre oil drums	205 litre oil drums	Bulk used engine oil	Used industrial oils	Oil y waters (interceptors)	Fuel oils	Electrical oils
Filter bin unloading								
Filter bin storage								
Filter crushing								
Filter shredding	*							
Magnetic separation	*							
205 litre drum unloading								
205 litre drum storage								
205 litre drum emptying								
25 litre drum unloading								
25 litre drum storage								
25 litre drum emptying/shredding		*						
Tanker unloading								
Coarse straining								
Bulk storage								
Cold oil settling								
Hot oil settling				*	*			
Distillation				*	*			
Vibrating sieve								
Centrifuge								
Bauxite towers								*
Vacuum dehydration								*
Product blending								
Pumped sludge storage/decanting								
Effluent incineration				*	*	*	*	
Cold effluent settling								
Hot effluent settling				*	*	*	*	
Biological effluent treatment				*	*	*	*	
Effluent clarification								
Effluent balance tank								
Plate separator								
Mechanically handled sludge/solids storage and handling								
Waste oil fired boiler				*	*	*	*	
Note: The grey blocks indicate emissions are likely and the asterisks indicate the locations that are thought to be the larger sources								

Table 3.95: Air emissions matrix for all common process in oil and solvent regeneration plants [56, Babtie Group Ltd, 2002]

Capacity	t/yr		6824	15000		17171	46208		90500	
Fumes generated		Million Nm^3/yr			14.89			175.4		210.5
Oxygen	%			4		7.4	3		10	
CO_2	t/yr						24000			
PM	mg/Nm^3	kg/yr	4	0		4.23	11.17	1960	28.4	
SO_x	mg/Nm^3	kg/yr	14	4000	60000		529.7	92910	4.2	884
NO_x	mg/Nm^3	kg/yr	63.7			90	225.8	39610	802.5	168891
TOC	mg/Nm^3			0					3	
CO	mg/Nm^3	kg/yr	501.6	0		193	7.4	1300	18.9	3978
HCl	mg/Nm^3	kg/yr		0		2.8	1.5	263	0.8	
HF	mg/Nm^3			0					0.08	
Total metals	mg/Nm^3			0					0.423	
Hg	mg/Nm^3			0					0.026	
Cd + Tl	mg/Nm^3	kg/yr		0			0.0008	0	0.0008	
PAH	mg/Nm^3	kg/yr	0.0008	0			8E-07	0.000175	0.0008	
PCB	mg/Nm^3	kg/yr		0			8E-07	0		
Chlorobenzenes	mg/Nm^3	kg/yr		0			0.08	0		
PCDD/PCDF	$ngTEQ/Nm^3$	g/yr		0			0.008	0.00175	8	
CFC	mg/Nm^3	kg/yr		0			0	0		
Odour	EU $O.U./Nm^3$			0						
Noise	dB(A)			75			55			
Note: For the installations having only one column, the figures correspond to the concentration column										

Table 3.96 Air emissions from several re-refining waste oil installations operating in the EU [66, TWG, 2003]

Emissions to water

The emissions to water are generally well documented. This is due to regulations and enforced limitations regarding discharges to foul sewers or disposal by alternative routes. The quantities of effluent discharged are thus usually well known.

Discharges are typically sampled regularly, providing monitoring data to allow a calculation of emissions for the radicals on the analysis programme. Sites handling large volumes of water and that have a constant discharge to sewerage system are usually sampled daily; those where the water volume is small tend to be tested on a batch basis prior to each discharge. Table 3.97 and Table 3.98 show the concentrations of water parameters and the emission matrix of the emissions to water, generated by the re-refining of waste oil.

Water parameters	Oily water [2] (mg/l)	Process water [2] (mg/l)	Effluent concentration (mg/l)
Temperature			25 ºC
pH			7.8
Colour			clear
COD [1] (TOC)	120	17000	20 – 20000
Oil/grease			<10
Hydrocarbons			5 – 15
Anionic tensioactives			0.2 – 0.5
Non-anionic tensioactives			1.0 – 2.0
Total tensioactives			1.2 – 2.5
Benzene			364
Toluene			1306
Phenols	1.5	180	0.2 – 0.4
Naphthalene			283
Chlorinated solvents (various)			309 – 666
1, 2 Dichloroethane			<1.0
Hexachlorobutadiene			<0.001
Hexachlorobenzene			<0.001
1, 2, 4 Trichlorobenzene			<0.001
Various PCBs			<0.001
Benz(a)anthracene and benzo(a)pyrene			each below 0.02
Ammonia			4.0 – 6.0
Suspended solids			<400
Chloride			
Total nitrogen			
Total phosphorus			0.05 – 0.2
Total metals:			<10
• aluminium			<0.5
• arsenic			3.4
• barium			80
• cadmium			<0.01 – 0.34
• chromium			10
• copper			
• iron			<0.6
• lead			271
• zinc			250

[1] Partially are demulsifers and detergents
[2] Water parameters of the waste water sent to biological treatment after stripping treatment

Table 3.97: Waste water parameters from different re-refining processes of waste oil [42, UK, 1995], [56, Babtie Group Ltd, 2002], [66, TWG, 2003]

Activity	Bulk used engine oil	Used industrial oils	Oil waters (interceptors)	Fuel oils	Electrical oils
Cold effluent settling	*	*	*	*	*
Hot effluent settling	*	*	*	*	*
Biological effluent treatment	*	*	*	*	*
Effluent clarification	*	*	*	*	*
Effluent sludge filter press	*	*	*	*	*
Effluent balance tank	*	*	*	*	*
Plate Separator	*	*	*	*	*

Table 3.98: Water emissions matrix for all common process in oil and solvent recycling plants [56, Babtie Group Ltd, 2002]

Capacity	t/yr		6824	15000		17171	19960		46208		90500	
Waste water generated		m^3/yr			1800			6180		298287		375000
Waste water generated/plant capacity		m^3/t			0.12			0.3096		6.4553		4.1436
Suspended solids	mg/l	kg/yr						931	6860	22.99	0	0
TOC	mg/l	kg/yr							1490	4.99		
BOD_5	mg/l	kg/yr		4000	7200						13300	38
COD	mg/l	kg/yr		8000	14400	300		27703	25650	85.99	39550	113
Hydrocarbons	mg/l	kg/yr	0.18						430	1.44		0.4
Phenols	mg/l	kg/yr	0.4	0		0.8		42.58	14	0.04	105	0.3
AOX	mg/l	kg/yr							0	0		
BTX	mg/l	kg/yr	0.4						0	0		
Total Nitrogen (as N)	mg/l	kg/yr							10000	0.033		0.008
Nitrit N (NO_2 - N)	mg/l	kg/yr							180	0.6		0.32
CN, free	mg/l	kg/yr							0	0		0.008
Sulfid (free)	mg/l					1						0.4
F, total	mg/l											0.4
P, total	mg/l	kg/yr							2980	9.99	140	0.4
Total metals	mg/l			0.56								
Al	mg/l	kg/yr		0.08					476	1.6	140	0.4
Fe	mg/l	kg/yr		0.08					952	3.2	35	0.1
As	mg/l	kg/yr		0.08					116	0.4		0.0024
Cr, total	mg/l	kg/yr		0.08					952	3.2		0.08
Cr(VI)	mg/l	kg/yr		0.08					44	0.16		0.008
Cu	mg/l	kg/yr		0.08					92	0.32		0.024
Hg	mg/l	kg/yr		0.08					1.12	0.004		0.00032
Ni	mg/l	kg/yr		0.08					476	1.6		0.16
Pb	mg/l	kg/yr		0.08				0.291	68	0.24		0.04
Zn	mg/l	kg/yr		0.08				1.276	236	0.8		0.24
Note: when only one column exists for a certain capacity, it refers to concentration values												

Table 3.99: Water emissions from different re-refining installations operating in the EU [66, TWG, 2003]

Solid waste and discharges to land

Sludges are typically tested for metals content, oil content and moisture content. This is carried out less frequently than the testing of the aqueous waste to sewerage systems. Table 3.100 and Table 3.101 show the concentrations of water parameters and the emission matrix of the emissions to water, generated by waste oil re-refining.

Type of waste	Waste parameters				
	Metals	Moisture	HC and TOC	S compounds	Other
Sludges	Some toxic metals may be contained	X	X	X	
Tank bottom sludges			X		
Solid particulates from filters	X		X		PAH and PCBs
Interceptor waste	X	Low	X		Phosphates, PAH, non-lubricant related solids
Cleaned oil filters	X				

Table 3.100: Types of waste generated in re-refining processes of waste oil [42, UK, 1995], [56, Babtie Group Ltd, 2002], [66, TWG, 2003]

Activity	25 litres Oil drums	205 litres Oil drums	Bulk used engine oils	Used industrial oils	Oily waters (inter-ceptors)	Fuel oils	Electrical oils
Bulk storage			*	*	*	*	*
Cold oil settling			*	*	*	*	*
Hot oil settling			*	*	*	*	*
Distillation			*	*	*	*	*
Vibrating sieve			*	*	*	*	*
Centrifuge			*	*	*	*	*
Enclosed filters			*	*	*	*	*
Effluent sludge filter press			*	*	*	*	*
Mechanically handled sludge/solids stor-age and handling	*	*	*	*	*	*	*

Table 3.101: Emissions to land matrix for all common process in oil and solvent recycling plants [56, Babtie Group Ltd, 2002]

Table 3.102 gives the environmental performance criteria of different treatment systems arising from an industry survey. In the survey, a profound discussion for each figure in the table is given. Each figure represents the absolute value that is assigned to that treatment system, concerning a specific criterion and estimating the performance of the system relative to the other systems for this said criterion.

	Environmental criteria				
Process	**S-compounds**	**Metals**	**Products of in-complete com-bustion + VOCs**	**Re-use of materials**	**Re-use of energy**
Laundering. Closed-loop recy-cling (re-use)	1	1	3	1	5
Chemical re-refining without distillation	2	2	3	1	5
Re-refining with distillation	1	1	1	1	5
Blending into vacuum residue of a refinery	5	3	4	5	1
Note: S-compounds: the ultimate destination of the sulphur content originating from the waste oil Metals: the ultimate destination of the metals originating from the waste oil Products of incomplete combustion + VOCs: the emission of VOCs or products of incomplete combustion (CO, PAHs, soot, dioxins, furans, etc.) originating from the waste oil Values: 1 best performance, 5 worst – on a relative scale					

Table 3.102: Evaluation of the environmental performance of several re-use and re-refining activities
[11, Jacobs and Dijkmans, 2001]

3.4.3.2 Emissions from the regeneration of waste solvents

The most important concern in the solvent recovery sector is the volatile organic emissions, which result from waste solvent reclamation. Acidic gaseous and particulate emissions can also result from solvent recovery operations.

Acidic gaseous emissions mainly consist of gaseous chloride, hydrogen fluoride, and sulphur oxides. Since the unit operation presenting the major source of acidic gases and particulate from the solvent recovery industry is that of incineration, this issue will be part of the waste incineration BREF. Incinerator stack emissions consist of solid contaminants that are oxidised and released as particulates, unburned organics, and combustion stack gases.

In solvent recovery operations, bottom streams consist of organics such as oily wastes and sludges or an aqueous residue. If water is treated on-site, sludges or other wastes may be created. Other emissions may come from discarded containers or samples, vessel washing residues, or from volatilisation to the air. Some residues and sludges are removed hot from stills into drums and allowed to cool and solidify. They may then be removed for further treatment or disposal. In industrial systems there can be traces of impurities, which can arise from inhibitors, denaturants or plant rinsing; these impurities can cause problems, particularly when using azeotropic distillation techniques.

Emission points include storage tank vents, condenser vents, incinerator stacks and fugitive losses. VOC emissions from equipment leaks, open solvent sources (e.g. sludge draw-off and the storage to material from distillation and initial treatment operations), solvent loading, and solvent spills are classified as fugitive.

Solvents may be accidentally spilled during handling, distillation, or purification activities. Materials that are spilled onto the ground may spread over an area, vaporise, and then result in air, water, or land emissions. Emissions resulting from significant accidental situations such as spills also need to be estimated.

Releases to the air may arise from a number of sources including non-condensable vapours from distillation/fractionation operations, and breathing losses from storage tanks and local extraction vents (LEV) located at material handling or drumming off points. Emission concentrations would be expected to be high except from sources such as LEVs. Concentrations and types of emitted compounds may vary significantly. The flowrates from continuous fractionation columns operating under vacuum at steady conditions are generally very low (1 – 10 m^3/hr). However, when manifolded together, emission flows could be up to 500 m^3/hr. Where LEV systems are tied into abatement equipment this can significantly increase flowrates and the dilution of vent gases. To minimise the size of abatement equipment there is a benefit in keeping process and LEV vents separate.

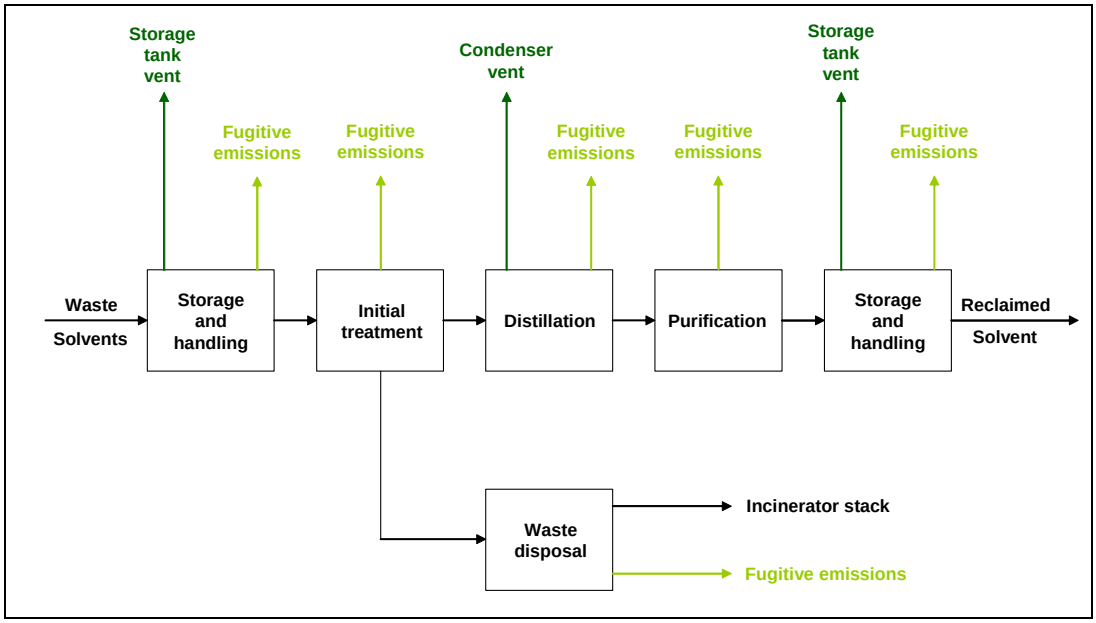


Figure 3.6: Example of a waste solvent regeneration scheme and emission points [129, Cruz-Gomez, 2002]

Activity/Plant	Emissions			Accidental Emissions
	To air	To water	To landfill	
Filter bin unloading				Drainage, spillage and bursts discharging contents to ground
Filter bin storage				Spillage to ground
Filter crushing				Spillage to ground
Filter shredding	Oil mist			Spillage to ground
Magnetic separation	Oil mist			Spillage to ground
205 litre drum unloading				Spillage to ground
205 litre drum storage				Spillage to ground
205 litre drum emptying				Spillage to ground
25 litre drum unloading				Spillage to ground
25 litre drum storage				Spillage to ground
25 litre drum emptying/shredding	Oil mist			Spillage to ground
Tanker unloading	Tank venting			Spillage to ground
Coarse straining	Oil mist			Spillage to ground
Bulk storage	Tank venting	Settled water (via treatment)	Settled sludge	Spillage to ground
Cold oil settling	Tank venting	Settled water (via treatment)	Settled sludge	Spillage to ground
Hot oil settling	Tank venting	Settled water (via treatment)	Settled sludge	Spillage to ground
Distillation	Venting and fugitive			Spillage to ground
Vibrating sieve	Mist and vapour		Sludge	Spillage to ground
Centrifuge				
Enclosed filters			Used elements and sludge	Spillage to ground
Bauxite towers			Spent bauxite	Spillage to ground
Vacuum dehydration	Vapour (via scrubbers)		Spillage to ground	
Product blending	Tank venting			Spillage to ground
Pumped sludge storage/decanting	Tank venting			Spillage to ground

Activity/Plant	Emissions			Accidental Emissions
	To air	To water	To landfill	
Incineration	Stack emissions (NO_x, CO, VOC, HCl, SO_2, etc.)			
Cold effluent settling	Tank venting			Spillage to ground
Hot effluent settling	Tank venting			Spillage to ground
Biological effluent treatment	Aeration air			
Effluent clarification				
Filter press			Filter cake	
Effluent balance tank				Spillage to ground
Plate separator		Effluent		
Mechanically handled sludge/solids storage and loading			Mixed solid wastes	Spillage to ground
Waste oil fired boiler	Stack emissions			

Table 3.103: Principal emission sources and emissions matrices of oil and solvent recycling plants [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

Parameter	Concentration value	Concentration units	Load value	Load units
Air emissions				
Fumes generated			14400000	Nm^3/yr
Oxygen	6	%		
CO_2			1268018	kg/yr
CO	49	mg/Nm^3	700	kg/yr
SO_2	86.9	mg/Nm^3	850	kg/yr
NO_x	44.1	mg/Nm^3	635	kg/yr
TOC	540	mg/Nm^3	237	kg/yr
Water emissions				
Waste water			2969	m^3/yr
Suspended solids	16	mg/l	47.5	kg/yr
COD	534	mg/l	1585	kg/yr
Phenols	0.08	mg/l		kg/yr
AOX	0.25	mg/l	0.742	kg/yr
Total N (as N)	16	mg/l	47.5	kg/yr
Total P	0.43	mg/l	1.27	kg/yr
Sulphide (free)	0.08	mg/l		kg/yr
Note: Capacity of the installation 27.5 kt/yr				

Table 3.104: Air and water emission from an EU solvent regeneration installation [66, TWG, 2003]

During storage and handling, and in the distillation process, hydrocarbons are emitted to the air. The emission of hydrocarbons (C_xH_y) through the distillation process is estimated to be 0.5 kg/t waste solvent.

Some contaminated solvents contain water. After dewatering, the water fraction contains traces of solvent. This water fraction ranges from a negligible amount to a maximum of 5 to 10 %. It is purified in a waste water treatment plant and discharged.

The amount of distillation bottom depends on the composition of the waste solvent. On average, the amount is estimated to be 25 % of the processed amount.

3.4.3.3 Emissions from the regeneration of waste catalysts

Knowing the source of the spent catalyst can often provide information on potential emissions due to the presence of acids, oils, organic contaminants (they may produce PCDD during melting processes), etc. This directly influences the potential emissions to air, water and land.

The physical state of the waste catalyst can also influence the emissions (e.g. the particulate emissions depend on the particulate size of the waste catalyst, oil content, etc.). Some potential emissions from different catalyst regeneration plants are shown in Table 3.107.

Air pollutant	**From**
Particulates	Fugitive emissions
SO_2	
NO_x	
VOC	
Dioxins	
Metals	
Water pollutants	
Suspended solids	
Oil	
TOC	
Metals	
Solid waste	
Oil	
Metals	
Dust	e.g. from abatement systems
Reference conditions of flue-gas: dry gas, 6 % O_2	

Table 3.105: Potential emissions found in different catalyst regenerators [125, Ruiz, 2002]

3.4.3.4 Emissions from the cleaning and regeneration of carbon

The main environmental issues related to the thermal regeneration of activated carbon is primarily gaseous effluents such as carbon dioxide. Acidic gases and pesticides may prove a problem if there are no control measures such as afterburners and/or scrubbers.

Figure 3.7 shows a schematic of a generic activated carbon regeneration process, including the release routes that are listed in Table 3.106.

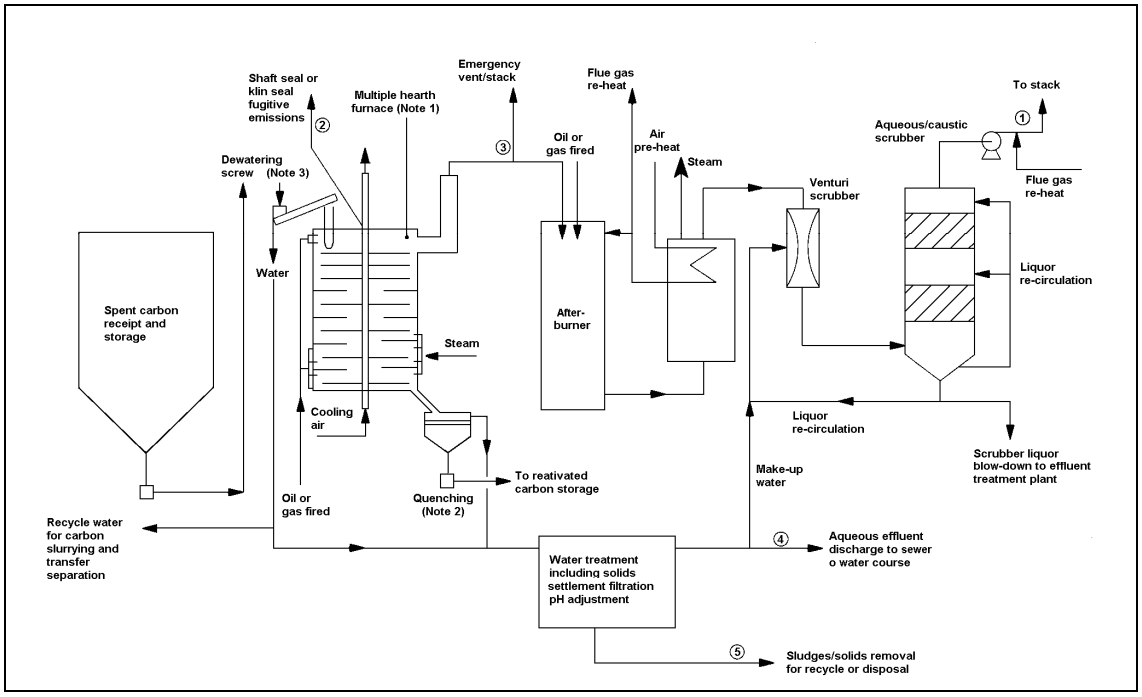


Figure 3.7: Schematic flow diagram of a generic carbon regeneration plant
[29, UK Environment Agency, 1996]
Notes: Numbers in the diagram refers to the numbers of the first column of the following Table 3.106.
Note 1 Multiple hearth furnace illustrated but thermal reactivation may also be carried out in a rotary kiln
Note 2 Carbon exiting the kiln may also be cooled by other means
Note 3 Other techniques for dewatering may be used.

Releases to the environment commonly associated with the regeneration of activated carbon processes are listed in Table 3.106.

	Source releases to:	Dust/ solids	CO + CO_2	NO_x	SO_x	Halogens	Organic compounds or partial oxidation products	Metals, metalloids or com-pounds
1	Flue-gases from flue-gas treatment	A	A	A	A	A	A	A
2	Fugitive emissions from seal leakages	A	A	A	A	A	A	A
3	Emergency vent stack (if applicable)	A	A	A	A	A	A	A
4	Aqueous effluent discharge	W					W	W
5	Effluent treatment plant sludge						L	L
Note: The releases to each medium will be determined to a significant degree by the application for which, the carbon has been used, and hence release of some substances to water and land are possible Legend: A: Air, W: water and L: residues (land)								

Table 3.106: Potential release routes for prescribed substances and other substances which may cause harm
[29, UK Environment Agency, 1996]

Emission results from different regeneration plants are shown in Table 3.107.

Air pollutant	Concentration (mg/Nm^3)
Particulates	1 – 34
CO	<3 – 160
NO_x (as NO_2)	126 – 354
SO_2	<2 – 60
HCl	<1 – 22
HF	<1
VOC (TOC)	5 – 15
Dioxins and furans PCDDs and PCDFs (TEQ)	<0.01 – 0.18 ng/Nm^3
Cd	<0.05
Hg	<0.05
Other heavy metals	0.1 – 0.5
Water pollutants	**Concentration (mg/l)**
Suspended solids	50 – 300
COD	400
Simazine	0.001
Atrazine	0.001
TEQ (TCDDs and TCDFs)	0.28 – 0.4 ng/l
Al	30
Cd	0.0005
Hg	0.0001
Mn	30
Solid waste	**Composition**
Refractory linings	
General industrial waste	
Sludge from settlement ponds	Mainly carbonaceous fines
Reference conditions of flue-gas: dry gas 6 % O_2	

Table 3.107: Range of emissions found in different carbon regenerators [42, UK, 1995]

Liquid effluent from regeneration plant

Water is used for the transport of activated carbon as slurry to and from the regenerator. This gives rise to a black water effluent which should be clarified and recycled. Water separated from the slurry will contain suspended solids and possibly prescribed substances (e.g. pesticides) and are routed to the effluent treatment plant.

The clean hot activated carbon is either dry cooled or quenched in cold water. For the wet cooling system, the water becomes alkaline and is therefore dosed with acid. This water should be purged from the system to prevent accumulation of mineral salts, with fresh/recycled water make-up as necessary.

Water is also used intermittently in large amounts to backwash activated carbon storage hoppers both to remove fines and to level the top surface of the activated carbon. Sufficient water storage needs to be provided so that this water can be clarified and recycled.

Techniques for controlling releases to land

In the regeneration of activated carbon most deliveries of carbon are made in bulk tankers. In certain circumstances drums may be used. Where this is the case, drums should be reconditioned and re-used so that disposal is minimised. Other process waste includes sludge or filter cake from filter presses or settlement tanks in an effluent treatment plant. In the case where disposal is to land the method of disposal should ensure that if the cake or sludge were to dry out, windblown dust of fine carbon particulates cannot occur. Other wastes will include refractory bricks and linings where repairs to kilns and furnaces have taken place periodically.

3.4.3.5 Emissions from the regeneration of ion exchange resins

The releases from a process of this nature are small and confined mainly to those to water. Some emissions resulting from different regeneration plants are shown in Table 3.107.

Air pollutant	**From**	**Concentration (mg/Nm^3)**
HCl	from filling of a bulk storage	<5
Water pollutants		**Concentration (µg/l)**
Effluent flowrate [2]		5 – 10 m^3/h
Cd		<0.5 – 3[1]
Hg		0.86[1]
Organic Sn		<0.3 – 2.0[1]
Solid waste		
Waste resins		
Fines		
Backwash filter	When resin is combined with activated carbon as a guard or a backwash filter	
Reference conditions of flue-gas: dry gas, 6 % O_2 [1] Values that correspond to peak values [2] Steam regeneration can produce large quantities of contaminated aqueous effluent		

Table 3.108: Range of emissions found in different ion exchange regenerators [41, UK, 1991], [42, UK, 1995]

3.4.3.6 Emissions from waste acids and bases treatments

Activity	**Air**	**Water**	**Soil and wastes**
Treatment of waste acids	Halogens: HCl and HF NO_x	Halogens: HCl and HF	
Treatment of sulphuric acid	Sulphur oxides		

Table 3.109: Emissions from the treatments of waste acids and bases [55, UK EA, 2001]

3.4.3.7 Emissions from the treatment of photographic waste

Treatment of solid photographic waste

In shredding, emissions of dust occur. These are treated with a dust filter. The emission of dust to the air ranges from 2 to 5 mg/Nm^3. The amount is estimated to be 29 g/t film waste.

Treatment of liquid photographic waste

Emissions to air

Treatment of photographic waste, especially fixers, can generate emissions to the air of ammonia, acetic acid and VOCs.

The emissions from physico-chemical treatments are reduced by treating the exhausted air in a wet oxidising scrubber. The concentrations in the exit gases of C_xH_y are approximately 600 mg/Nm^3 and of NH_3 <2 mg/Nm^3. The emissions from the biological treatment are reduced by means of a continuous automatic monitoring and regulation of the air or oxygen supply. The total C_xH_y emission is estimated to have a maximum of 20 g/t waste water.

In evaporation, some compounds will evaporate together with the water. Most of them will condense. Not condensed compounds are passed through the biological treatment that functions as a scrubber. The emissions from the evaporation step are negligible.

Emissions to water
In Table 3.110, emissions to water from physico-chemical and biological treatments are presented. Desilvered photographic liquid waste is just one of the processed waste waters. Therefore, the presented emissions give a rough indication of possible emissions from the treatment of this waste stream.

Component	Emission (g/t waste water)
Suspended solids	9
Chloride	29
Sulphur	0.3
COD	172
BOD	4
N-total (Kjeldahl)	351
Phosphorus	2

Table 3.110: Emissions to water from the treatment of photographic liquid waste and other waste waters
[156, VROM, 2004]

3.4.4 Waste OUT from re-recycling/regeneration treatments

In some cases the materials obtained by these treatments are commercial products with only minor differences compared to virgin products.

Re-refined waste oil
The quality of the base oil obtained is dependent upon the level of treatment applied, for example, severe processing involving hydrotreatment will be required in order to significantly remove PAHs.

Used oils vary according to the origin and type of oil collected. These variations are reflected in the base oil products from acid/clay treatment plants, in terms of their density, viscosity, viscosity index, sulphur level, etc. Less variation occurs in these parameters in the base oil products from vacuum distillation/hydrotreating units, with the exception of the sulphur content. Re-refined base oils from different processes and production plants vary greatly in their characteristics.

Some re-refining technologies allow the production of premium quality base oils: i.e. at least Group I according to the API base oils classification; and, when resorting to a severe hydro or solvent finishing, Group II base oils (e.g. topping purpose). The base stocks produced by the European re-refining industry today belong to Group I. Group I base stocks are solvent refined mineral oils. They contain the most saturates and sulphur and have the lowest viscosity indexes. They define the bottom tier of lubricant performance. Group I stocks are the least expensive to produce. They currently account for about 75 % of all base stocks comprising the bulk of the 'conventional' base stocks.

Almost all waste oil re-refining installations test for chlorine content and water content, and usually for PCBs. The final recovered oil is analysed because it has to satisfy specifications from the end user, but not all oil treatment plants blend a final product for sale or carry out such analyses. Table 3.111 shows an example of an analysis of the product made in an oil recovery installation, where several degrees of hydrotreatment are carried out to three different types of base oil (spindle, light and heavy lube oil).

Type of feed	**Spindle lube oil**	Low severity [*1]	High severity [#2]	**Light lube oil**	Low severity [*3]	High severity [#4]	**Heavy lube oil**	Low severity [*5]	High severity [#6]
Density 15/4	0.8678	0.8606	0.8526	0.8767	0.8699	0.8604	0.8868	0.8786	0.8676
Viscosity @ 40 °C (cSt)	26.91	23.8	21.19	56.52	49.85	38.18	117.2	97.86	70.08
Viscosity @ 100 °C (cSt)	4.76	4.5	4.2	7.78	7.32	6.37	12.24	11	9.1
Viscosity index	93	103	100	102	107	117	94	97	105
Colour	6.5	L 0.5	L 0.5	7.5	L 1	L 0.5	>8	L 2	L 0.5
Asphaltenes (w/w-%)	0.0105	-	-	0.0092	-	-	<0.01	-	-
Carbon Conradson (w/w-%)	0.63	<0.1	<0.1	0.12	<0.1	<0.1	0.33	<0.1	<0.1
Nitrogen (ppm)	280	49	<1	312	57	<1	307	137	<1
Sulphur (ppm)	0.412	0.1025	0.0005	0.526	0.163	0.0008	0.7285	0.2735	0.0021
ndM method (w/w-%)									
Aromatic carbon	12.11	10.72	8.72	11.63	10.25	8.48	11.94	10.22	8.18
Parafinic carbon	71.20	72.06	72.76	72.66	73.42	75.09	72.68	73.75	75.57
Naphthelic carbon	16.70	17.22	18.52	15.70	16.32	16.43	15.38	16.03	16.25
Gas Chromatography analysis in ppm									
Anthracene	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Benzo(a)anthracene	37	<1	<0.5	4	<1	<0.5	3	<1	<0.5
Benzo(k)fluoranthene	5	<1	<0.5	2	<1	<0.5	<1	<1	<0.5
Benzo(b)fluoranthene	25	<1	<0.5	11	<1	<0.5	4	<1	<0.5
Benzo(ghi)perilene	16	<1	<0.5	40	4.7	<0.5	12	2.30	<0.5
Benzo(a)pyrene	16	<1	<0.5	11	<1	<0.5	4	<1	<0.5
Chrisene	3	<1	<0.5	2	<1	<0.5	-	<1	<0.5
Dibenzo-ah-anthracene	<1	<1	<0.5	2	<1	<0.5	<1	<1	<0.5
Fluoanthene	24	<1	<0.5	2	<1	<0.5	<1	<1	<0.5
Indeno(123-cd)pyrene	10	<1	<0.5	27	<1	<0.5	6	<1	<0.5
Phenanthrene	2	8.7	<0.5	<1	1	<0.5	<1	1.30	<0.5
Pyrene	34	5.8	<0.5	<1	<1	<0.5	2	<1	<0.5
PNA IP 346 (w/w-%)	2.8	1	0.2	1.3	0.6	-	1	0.6	0.2

* Low severity in the hydrotreatment of light fraction: Temperature of first catalyst: 300 °C. Temperature 2nd catalyst: 280 °C. H_2 partial pressure: 105 bar

\# High severity in the hydrotreatment of light fraction: Temperature of first catalyst: 340 °C. Temperature 2nd catalyst: 340 °C. H_2 partial pressure: 105 bar

Total LHSV (h^{-1}): [1] :0.507; [2] :0.5; [3] :0.507; [4] :0.292; [5] :0.481; [6] :0.295

Table 3.111: Effect of hydrofinishing on the pollutants of the feed after de-asphalting [36, Viscolube, 2002]

Base oil produced is more dependent on the technology used to treat the waste oil than to the differences of the waste oil collected. Some examples of this are shown in Table 3.112.

Process (de-asphalting, demetalisation + finishing)	Main products (Values correspond to kg/tonne of WO unless otherwise stated)
Sulphuric acid + clay treatment	Low quality re-refined base oil: 621 PAH content of the base oils produced can be comparatively high (4 to 17 times higher than virgin base oils) Gasoil: 70
Caustic soda and bleaching earth treatment (ENTRA)	High quality re-refined base oil (Group II): 520 Light ends: 170 Diesel: 170
Vacuum distillation	In modern vacuum distillation equipment designed for processing used oils, the distillate produced has a metals content of less than 1 ppm (according to licensors)
Vacuum distillation + chemical treatment or clay treatment.	The base oils produced by clay treating or by chemical treatment have a metal content of <1 ppm. This process may not reduce the PAH content of the oil by as much as hydrotreatment
Thin film evaporator (TFE) + clay treatment	Medium quality re-refined base oil: 530 – 650 Gasoil: 150
TFE + hydrofinishing	High quality re-refined base oil: 630 Gasoil: 100
TFE + solvent extraction	High quality re-refined base oil: 600 Gasoil: 120 – 150
TFE + solvent extraction + Hydro-finishing	High quality re-refined base oil • lubricant Group II: 370 • lubricant Group I: 300 Gasoil: 85
TDA (thermal de-asphalting) + clay treatment	Medium quality re-refined base oil: 500 - 600 Gasoil: 60 – 80
TDA + Hydrofinishing (high pressure)	High quality re-refined base oil: 670 Gasoil: 70
PDA (propane de-asphalting) + hydro finishing (medium pressure)	High re-refined base oil: 660 – 700 Gasoil: 43 – 55 This process yields more marketable products than regeneration by a chemical treatment
Distillation and alkali treatment (Vaxon – Cator)	
Vacuum distillation + chemical treatment or clay treatment	As much as by hydrotreatment or solvent extraction
Direct contact hydrogenation (DCH)	Base oil (group II): 770 – 820 Light ends: 20 – 40 Heavy fuel or diesel: 70 – 80
Thermal clay treatment	
Hydro-finishing	
Vacuum distillation + chemical treatment	Base oil: 540 kg Fuel oil: 6105 MJ Bitumen fluxant: 48 kg Other fuels: 3720 MJ Fuel saving

Table 3.112: Product issues related with different waste oil regeneration techniques
[6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [11, Jacobs and Dijkmans, 2001], [13, Marshall, et al., 1999], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [139, UBA, 2003], [150, TWG, 2004]

Regenerated solvents

Probably the most desirable product of solvent recovery is one that can be used instead of a purchased new solvent in the place where it was used initially. This does not necessarily mean that the recovered solvent meets the same specifications as the virgin material. The specifications of new solvent will usually have been drawn up by a committee formed of representatives of both users and producers, who know what the potential impurities are in a product made by an established process route. The specifications have to satisfy all potential uses but for any given user, some specifications may be immaterial.

Product property	Unit	DIN 53978	PERC
Colour	HAZEN	<15	<5
Water	ppm	<50	<25
PERC	Area-%	≥99.9	>99.98
Sum of 1,1,1-trichloroethane and trichloroethylene	Area-%	0.025 ± 0.003	<0.02
Relative density	g/ml	1.620 - 1.625	1.624
Alkalinity	ppm NaOH	≤30	25
Evaporation			
Residue	ppm	≤50	25
Free chlorine		0	0
Information on a chlorinated hydrocarbon distillation installation			

Table 3.113: Specification of products for treatment of chloro-organic compounds versus DIN-Standard
[147, UBA, 2003]

Regenerated catalysts

Table 3.114 shows carbon and sulphur levels, the surface area, and the average length of the spent catalyst feed and the regenerated product from the belt-only and fine regenerations. The spent catalyst was analysed for its surface area after laboratory regeneration.

Product quality	Spent catalyst from top bed of second reactor	Belt only regeneration	Fine regeneration
Carbon, w/w-%	22	0.7	0.9
Sulphur, w/w-%	7.5	0.9	0.8
Surface area, m^2/g	185	190	197
Average length, mm	2.56	2.72	2.68
The values above correspond to the regeneration of more than 580 tonnes of spent CoMo hydrotreating catalyst from a customer's distillate hydrotreater in 1997. The unit had two reactors with two catalyst beds per reactor. The pre-job analyses showed that the catalyst could be recovered from all four beds, but, as expected, the highest quality catalyst was toward the back end of the unit			

Table 3.114: Commercial regeneration of CoMo catalyst
[125, Ruiz, 2002]

Overall, the spent catalyst was heavily loaded with hydrocarbon (15 w/w-%) and coke (total loss on ignition 30 %). The company started regenerating the highest quality catalyst from the bottom bed of the second reactor and worked back toward the catalyst at the front of the unit. The job began prior to the fine regeneration installation, so initially the catalyst was being stripped with inert gas in the belt-stripping unit.

The properties of both regenerated products compare favourably with that of the spent catalyst. The surface areas of the regenerated samples are slightly higher than those from the laboratory regeneration.

3.5 Emissions and consumptions from waste treatments aimed to produce a material to be used as fuel

[4, Langenkamp, 1997], [6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [[8, Krajenbrink, et al., 1999], Jacobs, 2001 #11], [12, Birr-Pedersen, 2001], [14, Ministry for the Environment, 2000], [16, ÖWAV Working Commitee, 2002], [37, Woodward-Clyde, 2000], [52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [57, EIPPCB, 2001], [58, CEFIC, 2002], [64, EIPPCB, 2003], [81, VDI and Dechema, 2002], [86, TWG, 2003], [119, Watco, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [128, Ribi, 2003], [150, TWG, 2004], [152, TWG, 2004]

This section contains the emissions and consumptions of treatments mentioned in Section 2.5, i.e. those devoted to processing waste in order to produce a material that will be used as fuel. The following sections (Sections 3.5.X) detail information available to site operators from their current recording record systems and highlights the areas where emissions are likely to occur. Emissions associated with ancillary treatments, e.g. transfer station operation are covered in Section 3.1.

3.5.1 Waste IN for the preparation of waste fuels

Table 3.115 shows some examples of the types of waste used for the production of solid or liquid waste fuel.

Type of waste fuel to be prepared	Type of waste	Examples
Solid waste fuel	Pasty wastes (mainly from hazardous waste)	High viscosity solvents, oil sludges, distillation residues, sludges from the treatment of industrial sludges (mechanical industry, chemical industry, pharmaceutical industry, etc.), paint and varnish sludges, ink sludges, polyol, glues, resins, grease and fats, other pasty wastes
	Powder wastes (mainly from hazardous waste)	Carbon black, toner powder, paints, spent catalysts, tensides, other powders
	Solid wastes (mainly from hazardous waste)	Polluted polymers, impregnated sawdust, sludges from waste water treatment, resins, paints, glues, spent activated carbon, polluted soils, hydrocarbon sludges, polluted absorbents, organic residues from the chemical and pharmaceutical industries, spent plastic packaging, waste woods, other solid wastes
	Liquid wastes which are not suitable for preparation of liquid waste fuel (mainly from hazardous waste)	Liquids with risk of polymerising
	Non-hazardous solid waste	Household and commercial solid wastes, packaging wastes, wood, paper, cardboard, cardboard boxes (02, 03, 15, 17, 19, 20), textiles, fibres (04, 15, 19, 20), plastics (02, 07, 08, 12, 15, 16, 17, 19, 20), other materials (08, 09, 15, 16, 19), high calorific fractions from mixed collected wastes (17, 19, 20), construction and demolition waste, source-separated fractions from MSW, monostreams of commercial and industrial waste

Type of waste fuel to be prepared	Type of waste	Examples
Liquid waste fuel by blending	Organic liquid waste fuel	Solvents, xylenes, toluenes, white-spirit, acetone, cleaning and degreasing solvents, petroleum residues, distillation residues, off-specification organic liquid products
Liquid waste fuel by fluidification	Organic liquid waste fuel	Used solvents, pasty organic wastes (ink sludges, paint sludges, adhesives wastes, etc.), oils residues, pulverulent wastes such as paint powder, filter cakes, residues from organic chemical synthesis, oil and fat, spent ion exchange resins, distillation residues, wastes from cosmetic industries
Liquid waste fuel by emulsions	Organic liquid waste fuel	Oils emulsions from mechanical and metallurgy industries, wastes and sludges containing oil from petroleum refining, from the collection and storage of oil products, wastes from oil distillation and regeneration, production failures, pasty wastes such as grease, ink and adhesives wastes, pulverulent waste such as paint powder, washing powder wastes, used bases such as sodium, used oils
Note: Numbers within brackets correspond to EWL codes chapters		

Table 3.115: Some examples of the types of waste used for the preparation of solid and liquid waste fuels
[21, Langenkamp and Nieman, 2001], [50, Scori, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

Table 3.116 shows the typical heating values of some types of waste.

Type of waste	Heating value (MJ/kg)
Hazardous waste	21.0 – 41.9
Non-hazardous industrial waste	12.6 – 16.8
Municipal waste	7.5 – 10.5
Plastic	21.0 – 41.9
Wood	16.8
Tyres	25.1 – 31.4

Table 3.116: Typical heating values of different types of waste
[4, Langenkamp, 1997], [150, TWG, 2004]

Fuel preparation plants and combustion installations that may use waste as (part of) fuel generally take in more than one type of waste. Some types of waste materials that are used for co-incineration are shown in Table 3.117.

Type of waste	Combustion plants (including district heating and marine engines)	Cement kilns	Iron and steel (blast furnaces)	Ceramics (brick kilns)	Lime kilns	Asphalt production	Pulp and paper
Animal products	Animal meal Meat and bone meal Tallow Manure Chicken litter Fat	Meat and bone meal					
Charcoal residues	Charcoal residues[1]						
Chemicals	Organic acids Liquid solvents Phosphorus oven gas	Spent solvents Paint sludges Hydrocarbons Distillation residue					
Municipal waste	RDF Waste paper Packing materials Plastics Textiles Wood	RDF Waste paper Plastics Textiles Wood	RDF Plastics Textiles Wood	RDF Textiles Wood	RDF Textiles Wood	RDF	Waste paper
Oily materials	Tar Waste oil	Waste oils Cutting oils	Waste oils		Waste oils	Waste oils	
Rubber	Shredded tyres	Used tyres Rubber Car shredding residues Carpets		Used tyres			
Sludge	Sewage sludge	Sewage sludge Paper sludge					
Vegetables	Energy crops such as willow Agricultural residues such as straw, cereal plants, pasture from landscape cultivation						
Wood	Wood residues Demolition wood Forest residues Wood chips Biomass pellets/briquettes	Waste woods					

[1] Some trials have been made on the use of waste in cupola furnaces in foundries.
Note: Table should not be interpreted as exhaustive. Other combinations not mentioned in this table may actually be used.

Table 3.117: Some types of materials used in some co-incineration processes [4, Langenkamp, 1997], [57, EIPPCB, 2001], [64, EIPPCB, 2003], [81, VDI and Dechema, 2002], [150, TWG, 2004], [152, TWG, 2004]

The following sections which have titles in bold give more detailed information on each type of waste used as fuel. Typical compositions of the type of waste are in some cases made available.

Chemicals

Paint and solvent wastes have a heating value of more than 21 MJ/kg wet matter. The contents of chlorine, cadmium and zinc may be high.

Municipal solid waste

Table 3.118 shows some characteristics of municipal solid waste, and some of its fractions which can be used as fuel.

Municipal solid waste	Heating value (MJ/kg wet matter)	Other components
Generic municipal solid waste	5 – 8	Cl: 0.5 – 1.0 % The content of some metals may be high
Residual municipal solid waste	8 – 11	Cl: 0.5 – 1.0 % The content of some metals may be high
Paper	11 – 14	0.5 % of Cl, 33 ppm of Pb and 0.3 ppm of Cd
Celulose (20 w/w-% ash content and moisture of 5 %)	12.3	
Celulose (20 w/w-% ash content and moisture of 40 %)	5.7	
Polyethylene (20 w/w-% ash content and moisture of 40 %)	16.5	
Polyethylene (0 w/w-% ash content and moisture of 40 %)	25.3	
Polyethylene (0 w/w-% ash content and moisture of 5 %)	41.5	
Polyethylene hard density (printed)		Volatiles[1] 97 %, ash[2] 2 %, fixed carbon 0.3 %
Polypropylene		Volatiles 100 %, ash <0.05 %
Polystyrene (white)		Volatiles 97 %, ash 3 %
PVC		Volatiles 92 %, ash <0.05 %, fixed carbon 8 %
Plastics	23.7 – 28.4	Cd: 0.7 - 72 ppm Cl: 1 – 4.5 % Cr: 48 ppm Hg: 1.3 ppm Pb: 98 - 739 ppm Tl: 0.3 ppm Zn: 550 ppm
Composites	13.3 – 16.2	Cd: 0.2 - 37 ppm Cl: 0.5 – 4.0 % Pb: 48 - 500 ppm
Textiles, leather and shoes	17.1	Cd: 2.2 ppm Cl: 1.2 % Pb: 96 ppm
[1] Plastics volatilise after melting by depolymerisation [2] The pure polymer is ash free, but ash comes from printing and pigments		

Table 3.118: Important characteristics of MSW, and some of its fractions, for use as fuel [4, Langenkamp, 1997], [8, Krajenbrink, et al., 1999], [16, ÖWAV Working Commitee, 2002], [81, VDI and Dechema, 2002], [150, TWG, 2004]

Waste plastic

The demonstration of energy recovery for specific waste plastic streams in full-scale tests has been going on over a sufficiently long time period to prove: the repeatable and stable operating conditions; to document the effect the waste plastics have on the operation; and also to indicate what materials and emissions will arise. An overview of the APME TEC programme is sketched out below.

Burning technology	Energy use	Packaging	Commercial	Automotive	Electrical and electronics	Agricultural	Building and construction
Grate type	District Heat and Heat/power	MPW		SR			Foams
Fluidized bed (FB)	Heat/Power	MPW, SR					
Pulverized coal	Power	MPW				Films	
Rotary kiln	Cement	MPW			Foam		
Industrial furnace	Non-Ferrous				ESR		
Circulating FB	Pulp Paper	MPW	Curb side	SR			
Note: MPW: municipal plastic waste (sometimes needs to be shredded before use); SR: shredder residue; ESR: shredder residue from white goods							

Table 3.119: The use of waste plastics from different industrial sectors as fuel [58, CEFIC, 2002] [86, TWG, 2003], [150, TWG, 2004]

Oily materials

Waste oils

More information on the composition of waste oils can be found in Section 3.4.1. Used oils may have a significant, but variable, chlorine content, including organochlorines. The fate of these chlorine compounds will vary, not only with the treatment route, but also with the form in which the chlorine is present. It is, therefore, difficult to make any general comments on the effects of chlorine other than that in the combustion routes there is a risk of dioxin formation and that in the reprocessing options there are risks of corrosion problems, acid gas emissions and contamination of the output streams.

Waste lubricating oils and oils recovered from interceptors are sold for use as fuel. Because these oils can create carbon deposits when burned, they tend to be used in applications where this is of no concern. The main users are the road stone industry and coal fired power stations, who use it for flame stabilisation and power boosts.

Waste fuel oils

Waste fuel oils arise from a variety of situations such as tank drainage from vehicle fuel tanks, when a boiler fuel store is drained when the plant converts to natural gas, or when tanks are removed during site clearances. These oils are generally not contaminated although they may have deteriorated with age and sometimes carry the 'tank bottom dirt' settled from many years of filling. In most plants, comparatively little of this type of material is accepted and it will be reasonable to consider its analysis comparable to fuel oils 'as sold'.

Gasification is specially designed to process heavy fuels, as well as a wide range of hydrocarbon wastes.

Fuel oils range in specification but, in general, they are used rather than sent for treatment and so the quantities will be small. They typically have a lower boiling point than lubricating oils, contain more of the lower chain hydrocarbons and have a higher risk of VOC emissions during treatment. However, the content of the metals is typically low (although vanadium and nickel have been found in fuel oils). PAHs are typically stable and non-volatile. Unused fuel oils have a lower boiling point range than lubricating oils. Comparisons between the compositions of fuel oils and lubricants are shown in Table 3.120 below.

	Normal carbon chain length	Boiling point range (°C)	Important compounds
Kerosene	Middle distillate, C_6 to C_{16}	150 – 300	N alkanes, cycloalkanes, low concentrations of mono aromatics, low concentrations of BTEX and PAHs
Fuel oil (N° 2)	Middle distillate, C_8 to C_{21}	200 – 325	Very low BTEX, toluene 0.06 %, ethyl benzene 0.034 %, xylenes 0.23 %, high concentrations of n-alkanes, C_8 0.1 %, C_{20} 0.35 %), lower concentrations of branched alkanes, cycloalkanes monoaromatics, napthalenes (0.22 %) and PAHs, nickel 0.00005 %
Fuel oil (N° 6)	Residual oil, C_{12} to C_{34}	350 – 700	Very low BTEX, low naphthalenes and PAHs, high n-alkanes (C_9 0.0034 % -C_{20} 0.1 %) and cycloalkanes, nickel 0.0089 %
Lube oils	Heavy end distillate, C_{18} to C_{34}	326 – 600	Low concentrations of BTEX, high concentrations of branched alkanes and cycloalkanes

Table 3.120: Typical composition of fuel oils and lube oils
[56, Babtie Group Ltd, 2002]

Rubber

Table 3.121 shows some characteristics of tyres used as fuel.

Parameter	Value	Units
Calorific value	36 – 38	MJ/kg
Chloride	0.15 – 0.25	%
As	<2	ppm
Cd	<5 – 10	ppm
Co	<5 – 27	ppm
Cr	<5 – 97	ppm
Cu	10 – 30	ppm
Hg	0.17 - <1	ppm
Mn	6 – 11	ppm
Ni	<5 – 40	ppm
Pb	<5 – 410	ppm
Sb	55 – 410	ppm
Sn	14 – 21	ppm
Tl	0.25 – 75	ppm
V	<5 – 60	ppm
Zn	14.5 – 16.1	g/kg

Table 3.121: Fuel characteristics of tyres
[4, Langenkamp, 1997]

Sludge

Sludge typically contains water. An increase in the content of water for a given dry composition of sludge decreases its heating value. For example, sludge with a content of 33 % dry matter has a heating value of less than 5 MJ/kg wet matter. The content of chlorine is typically low but the mercury content may be significant in certain sludges.

Wood

Sawdust, sawmill chips and PVC have a heating value of between 14 and 21 MJ/kg wet matter. Construction waste has a heating value of between 14 and 17 MJ/kg wet matter. Some physico-chemical parameters of scrap wood are shown in Table 3.122.

Metals	Concentration (ppm)
Lower heating value (MJ/kg)	17.3
Cl	0.1 %
Cd	0.7 – 3.4
Cr	50
Hg	0.2
Pb	53 – 1000
Tl	<0.1
Zn	1500

Table 3.122: Metals' content of scrap wood
[4, Langenkamp, 1997], [81, VDI and Dechema, 2002]

3.5.2 Consumptions of preparation of waste fuel

Consumptions in the preparation of waste oil to be used as fuel

Material consumed	Application
Chemicals antioxidants	Added to light fuel oils and light distillates fractions in order to stabilise the products

Table 3.123: Consumptions in the thermal treatment of waste oils
[119, Watco, 2002]

Waste OUT	Mainly to produce fuel oil [1]	Units (per tonne of input waste oil)
Fuel oil (700 MJ and <0.5 % S)	849	kg
Secondary fuels[2]	63	kg
Consumptions		
Fossil fuel consumption	4	eq. crude oil
Primary energy	343	MJ
Water consumption	431	kg
1 Thermal cracking: Thermal + chemical treatment (with H_2SO_4)		
2 Many of them are waste fuels generated during the process		

Table 3.124: Consumptions generated by the thermal cracking of waste oils
[7, Monier and Labouze, 2001], [152, TWG, 2004]

Output	Amount (per tonne of input waste oil)	Units
Methanol	1080	kg
Savings in the primary input of fuels typically used in gasification		
Consumptions		
Fossil fuel	109	kg eq. crude oil
Primary energy	7110	MJ
Water consumption	1350	kg

Table 3.125: Outputs generated by the gasification of waste oils
[7, Monier and Labouze, 2001]

Consumptions in the preparation of hazardous waste to be used as fuel

Consumptions	Solid waste fuel	Liquid waste fuel
Electricity (kWh/tonne waste fuel produced)	5 – 25	5 – 20
Fuel (litre/tonne waste fuel produced)	0.15 – 3	0.05 – 2
Adsorbents	Between 20 and 40 % of absorbents per tonne of waste fuel produced are used, depending on required specifications. The types of absorbents are fresh sawdust, sawdust from wood recovery, polyurethane, paper by-product, textiles, etc.	
Water (litres/tonne of waste fuel - for cleaning installation, trucks and eventually drums; maintenance, spraying installations for dust abatement)[1]	5 – 20	5 – 20
Nitrogen m^3/tonne waste fuel produced (inertising mixers, shredders or liquid storage)	1 - 2.5	1 - 2.5
Others raw materials for effluent treatment		

Notes: Energy data do not include energy consumption for ventilation and air treatment.
The electricity consumption varies widely according to the type of wastes, the packaging and on the level of automation. For example, in the case of packaged drums to be shredded, the electricity consumption can reach 25 kWh/t, while in the case of bulk wastes in a non automated process line it will be between 5 and 10 kWh/t. Moreover, when the electricity consumption is high, the fuel consumption is usually on the low side.
The fuel consumption is mainly for utility vehicles and will decrease with the automation level.
The total energy consumption represents less than 5 % of the total energy content of the waste fuel.
[1] Water consumption is related with good housekeeping of the installation. It varies widely according to the type of wastes, the packaging and the eventual use of recovered rainwater. If drums or containers need to be cleaned or rinsed for further use, an additional consumption of 2 to 20 l/tonne is required.

Table 3.126: Consumptions in the preparation of hazardous waste to be used as fuel [122, Eucopro, 2003]

Consumptions in the preparation of waste fuel from municipal solid waste
Table 3.127 below gives an overview of the plants that have provided data for this section.

Type of plant	Kind of solid waste fuel production	Capacity (kt/yr)	Energy consumption (MWh/yr)	Specific energy consumption (kWh/t input material)
Commercial waste processing plants	Soft/hard pellets	40	2400	109
Mechanical-biological waste treatment	Soft pellets, fluff	55	2300	38 – 56
Commercial waste processing plants	Soft pellets, fluff	65	1268 – 1902	40 – 59
MSW processing without a biological decomposition step		80	781	40
Mechanical-biological waste treatment	Fluff	100	5800	92
High calorific fraction from MSW processing and commercial waste processing plant	Soft pellets, fluff	100	315 – 405	32 – 41
Commercial waste processing plants	Soft pellets, fluff	100	1080 – 1620	36 – 54
Mechanical-biological waste treatment	High calorific fraction in bales	110	1870	17
Mechanical-biological waste treatment	Soft pellets, fluff	110	4000	33 – 40
Mechanical-biological waste treatment	Fluff	600	2760	
MSW processing without a biological decomposition step	Fluff	840	23650	30
Residual municipal solid waste treatment				60 Separation: 8 – 15

Table 3.127: Consumption examples for the preparation of fuels from MSW
[52, Ecodeco, 2002], [66, TWG, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

Capacity (kt/yr)	Fuel consumption (GJ/yr)	Electricity consumption (MWh/yr)	Specific electricity consumption (kWh/t)	Specific water consumption (m^3/t)
65	38475	3575	55	0.078
86	0	5831	68	0.0019
100		1050	10.5	

Table 3.128: Consumption examples for the preparation of fuel from non-hazardous waste
[66, TWG, 2003]

The big difference in energy consumption in relation to the amount of input material relates to the kind of processing plant applied and the type of generated solid waste fuel used; for instance, whether drying facilities are installed or if the generated solid waste fuel is made in different grain sizes and shapes.

Except for thermal drying processes, fuel is not required for solid waste fuel production; fuel is only necessary to run vehicles at the process area, such as fork-lift trucks or wheel loaders. One producer for thermal drying reported a gas consumption is about 21250 GJ per year. This specific consumption amounts to 1390 MJ/t input material.

In general, no further ingredients besides waste are deployed and which end up in product. To ensure failure-free operation, the process and material handling equipment have to be lubricated. Several detergents are applied. Furthermore, there are auxiliary materials applied to support the exhaust gas cleaning process, such as sodium hydroxide (consumption: 18 kg/kt) and phosphate (consumption: 3 kg/kt).

Separation, digestion and biological degradation require energy. The consumption of electricity by separation and digestion is approximately 60 kWh/t input material, of which the separation accounts to about 8 to 15 kWh. Through the incineration of the biogas in a gas engine, with an efficiency of 35 %, approximately 120 kWh_e/t waste are produced. This results in a net production of approximately 60 kWh_e/t waste. Producing the digestate requires approximately 100 MJ_e/t input materials. Biological drying requires also approximately 100 MJ_e/t input materials.

3.5.3 Emissions from the preparation of waste fuel

Emissions from the preparation of solid waste fuel from municipal solid waste
The material balance of the production of a RDF is shown in the next table.

Combustable product (e.g. RDF)	Organic matter	Non-combustable waste with an inorganic base	Metals	Water evaporated and CO_2	Others
55 – 50	20		5	20 – 25	
53 [1]		Glass: 4 White: 3 Brown: 0.5 Green: 0.5 Minerals: 4 Fine grain and dust to be disposed off: 4	Ferrous metals: 4 Non-ferrous metals: 1		Batteries: 0.05
Values in kg/100 kg of waste entrance [1] calorific value 15 – 18 MJ/kg					

Table 3.129: Examples of the emissions from the production of RDF from MSW [52, Ecodeco, 2002], [81, VDI and Dechema, 2002]

Table 3.130 gives an overview of the plants that have provided data for this section.

Type of plant	Kind of solid waste fuel production	Capacity (kt/yr)	Amount of solid waste fuel products (t/yr)	% product/ waste	Amount of exhaust gas (m^3/h)	Dust (kg/yr)	Odour (OU/m^3)	Noise distance to the location of immission (m) Acoustic pressure level day/night as technical approval (dB(A))
MSW processing without biological decomposition step	Fluff	23	17400	76.7				
Commercial waste processing plants	Soft/hard pellets	40	15300	69.5	18000			<40/<40
Commercial waste processing plants	Soft pellets, fluff	65	31700	99.1	48000			10 <70/<70
MSW processing without biological decomposition step	n.a.	80	16300	84.0				
Mechanical-biological waste treatment	Fluff	100	30700	48.7	45000	394		
High calorific fraction from MSW processing and commercial waste processing plant	Soft pellets, fluff	100	9000	90.0	48000			1000 <50/<35
Commercial waste processing plants	Soft pellets, fluff	100	27000	90.0	48000			1000 <50/<35
Mechanical-biological waste treatment	High calorific fraction in bales	110	19500	17.7	120000		406	200 50/39
MSW processing without biological decomposition step	Fluff	840	90000	11.5	90000		220	650 38/37.5

Table 3.130: Overview of some solid waste fuel production plants in the EU [126, Pretz, et al., 2003]

	Units	Installation A		Installation B		Installation C	
Capacity	kt/yr	65		86		98	
		Conc.	**Load**	**Conc.**	**Load**	**Conc.**	**Load**
Fumes	million Nm^3				394.2		
Oxygen	%			19		1.4	
CO_2	t/yr		11765		8428		
PM	mg/Nm^3 - kg/yr	0		1	394.2		
SO_x	mg/Nm^3 - kg/yr		1820	18.6	7332		
NO_x	mg/Nm^3 - kg/yr	80	4699.5	47	18527	12.5	
N_2O	mg/Nm^3 - kg/yr				0		
TOC	mg/Nm^3 - kg/yr	40	2340	1.7	670.14		
CH_4	kg/yr		26715				
CO	mg/Nm^3 - kg/yr	80	4699.5	8.4	3311.28	16	
HCl	mg/Nm^3 - kg/yr		78				
HF	mg/Nm^3 - kg/yr		26				
Total metals	mg/Nm^3 - kg/yr			0.4	197.1		
Hg	mg/Nm^3 - kg/yr			3.7	1.46		
Cd + Tl	mg/Nm^3 - kg/yr			0.4	0.197	0.08	
Chlorobenzenes	mg/Nm^3 - kg/yr			0	0.0047		
PCDD/PCDF	$ngTEQ/Nm^3$ - g/yr		0.0026	0.002	0.00079		
CFC	mg/Nm^3 - kg/yr			0.044	17.345		
Odour	EU O.U./Nm^3 - MGE/yr	0		110	43362		
NH_3	mg/Nm^3	0					

Table 3.131: Examples of air emissions from the preparation of fuel from non-hazardous waste [66, TWG, 2003]

	Units	Installation A		Installation B		Installation C	
Capacity	kt/yr	65		86		160	
		Conc.	**Load**	**Conc.**	**Load**	**Conc.**	**Load**
WW generated	m^3/yr		16965		30100		8000
BOD_5	mg/l - kg/yr			21			
COD	mg/l - kg/yr		34450	40			
Total N (as N)	mg/l - kg/yr			230			
Nitrit	mg/l - kg/yr			1.8			
Nitrates	mg/l - kg/yr						
Ammonia	mg/l - kg/yr		10400				
Nitrates	mg/l - kg/yr		650				
Sulphates	mg/l - kg/yr		325				

Table 3.132: Examples of water emissions from the preparation of fuel from non-hazardous waste [66, TWG, 2003]

Depending on the type of plant a great difference can be found in the ratio between the amount of treated waste and the solid waste fuel products. This is explained by the fact that some plants treat commercial waste and other plants treat MSW. Additionally, the producers have different ways to produce their solid waste fuel. For instance, if the fine material is added to the solid waste fuel product and this is not disposed in a landfill, the amount of product increases but the quality decreases significantly. Other plants are building up their capacities by modifications of their operation or produce solid waste fuel in a combined production with MSW processing plants.

The declared values are taken from the technical approvals. The differences seen by the wide range of the values can be explained by the location of the processing plants, and their different input materials and operating times, e.g. in some cases one, two or three shift operations.

With reference to Table 3.130, the difference between the amount of input and the amount of product output must be adjusted taking into account the amount of potential recyclables such as ferrous and non-ferrous metals in the waste. The content of potential recyclables depends on each waste composition, which can vary widely. Furthermore, residues may accrue during the waste gas cleaning process.

Depending on the processing method, there may also be some by-products generated. Depending on the quality of the by-products they might be recycled directly or treated after a further processing. The current by-products are typically ferrous and non-ferrous metals and an inert fraction. The quality of the ferrous and non-ferrous metal product depends on the waste content and on the processing method applied. Higher quality products are applicable for material recycling.

The inert fraction is sometimes used as construction materials, e.g. as road construction material or for landfill. In rare cases, a recycling material may be produced which is used directly as a raw material, e.g. some kinds of plastics and glass. Furthermore, by application of an air separator a heavyweight fraction can accrue which is applied for energetic utilisation.

The composition of the waste that is not used as fuel is different than that of the waste IN and the waste OUT. It depends on the waste IN but also the type of treatment given. Material balances showing such differences as well as showing where the different components of the waste IN end up, have not been provided.

Emissions from the preparation of hazardous waste to be used as fuel
Emissions to air

Emissions	From	Solid waste fuel	Liquid waste fuel
Dust, absorbents mainly from sawdust, powdery wastes (paints, resins, washing powder, catalysts, etc.)	Unloading and handling of absorbents and/or pulverulent wastes	m	n/a
	Processing	l/m	l (mainly for fluidification)
	Loading	m	n/a
	Achieved performance (mg/Nm^3) [1]	1 – 10	1 – 5
VOC and odour	Sampling	l/m	m/h
	Unloading operation (truck, drums, and containers)	m	m/h
	Processing	m (sieving)	l
	Achievable performance NMVOC (mg/Nm^3) [2]	10 – 50	10 – 110

Notes:
[1] by use of bag filters
[2] by regenerative thermal oxidiser for solid waste fuel and by regenerative thermal oxidiser or by activated carbon treatment for liquid waste fuel
l: low emissions – m: medium emissions – h: high emissions – n/a: not applicable

Table 3.133: Air emissions from the preparation of waste fuel from hazardous waste [122, Eucopro, 2003]

VOCs and odour
Most accepted wastes contain organic compounds. In certain circumstances, according to vapour pressure and temperature, they are more or less volatile. These volatile organic compounds (VOCs) can be potentially harmful for the environment and workers health and can also cause a bad smell. This is why these emissions need particular attention and follow up. The level of VOC emissions depends on the nature of the waste, its flashpoint, the vapour pressure of the components, and their concentration. VOC emissions are also influenced by the type of process applied and by the prevailing climatic conditions.

Noise

All the process lines and equipment need to be designed and built according to EU noise regulations for operators inside the plant and for neighbours. Incoming and outgoing transport vehicles are the main source of noise around and inside the plants.

Other noise sources include handling machines such as mechanical shovels, loaders, hydraulic shovels, screeners, shredders, grinders, pumps, agitators, motors used for the ventilation network, and VOC treatment units.

Emissions to water

The sources of waste water are cleaning water from drum cleaning, truck cleaning, the cleaning of facilities, road tankers and skips, and process water (from wastes settling during transport, from drying, etc.). In the absence of measured water parameters of the waste water from these installations, Table 3.134 shows a compilation of ranges from some permits applied to installations. With the exceptions of major accidents, these installations have no impact on groundwater. A piezometer network with analysis once or twice a year is generally used for the survey.

Physico-chemical parameters	**Permit limit values (mg/l)**
pH	5.5 – 9.5
Maximum temperature	30 – 45
TSS	30 – 60
COD	50 – 300
Hydrocarbons	2 – 10
BOD_5	30 – 40
N-kjeldahl	n.a. – 40
N global	10 – 50
Total phosphates	1 – 10
CN (free)	0.1
Cd	0.05 – 0.2
Cr(VI)	0.01 – 0.1
Cr total	0.02 – 0.5
Cu	0.03 – 0.5
Fe	10 – 15
Hg	0.05 – 0.15
Ni	0.05 – 0.5
Pb	0.05 – 0.5
Sn	0.01 – 2
Zn	0.3 – 2
Total Metals*	10 – 15
* Sb + Co + V + Tl + Pb + Cu + Cr + Ni + Zn + Mn + Sn + Cd + Hg + Se + Te	

Table 3.134: Ranges of values given in permits for some installations [122, Eucopro, 2003]

By-products and wastes generated

Effluents treatment wastes and other wastes for disposal	Composed of	Amount (kg/tonne of waste fuel produced)
Residues coming from the packaging of the delivered wastes		1.5 – 20
'Consigned' IBCs, containers or drums		
Metallic containers and drums		
Plastic containers and drums		
Palettes		
Big bags		
Plastic sheet		
Scrap extraction during the production stage	These residues are composed of metallic parts which can be voluminous	
Rotating, vibrating and static sieve/screen rejects	These residues are composed of blocks of different solid wastes (such as resins, paintings, glues, tars, bitumen, polluted soils, etc.), pieces of wood, sand, polluted plastics, lining, pieces of textile sheets	0 – 3
Effluent treatment residues	For example, activated carbon from waste water and air effluent treatment	
Laboratory residues and rejected samples		0.015
Note: the amount of by-products is strongly linked with the type of packaging. For example, in the case of small packaged wastes, the iron scrap fraction can reach up to 150 kg/tonne of waste fuel		

Table 3.135: Wastes generated in the preparation of hazardous waste to be used as fuel [122, Eucopro, 2003], [150, TWG, 2004]

The control of soil quality can be assured by the follow up/monitoring of air emissions, effluents, and groundwater quality.

Preparation of solid waste fuel by the carbonisation of contaminated wood
Contaminated wood may contain POPs, mercury, arsenic and other typical contaminants

Emissions from the treatment of waste oil to be used as fuel
Table 3.136 shows the emissions of the preparation of waste oils when producing a liquid fuel.

Emission Pathway	Medium	Through
Waste oil storage	Air	Displacement of vapour during loading 'Breathing' via vents
Boiler	Air	Combustion gases via stack. Most oil re-processing facilities generate steam from in-house boilers
Heating vessels	Air	Heating vessels are typically insulated mild steel tanks. Heat is delivered to the oil by a heat exchange system typically based on internal or 'blind' steam coils. This arrangement can be difficult to clean and maintain. This may lead to inefficient energy use related to raising steam. VOCs are emitted during the heating of oil to drive off water vapour. Emissions may consist of displaced vapour comprising water vapour and VOCs. Carbon absorption could be used but may be affected by water vapour. Condensation needs to be considered to collect the organic fraction, which can be used as boiler feed or incinerated
Warm oil receiving tank	Air	VOCs from the transfer of warm oil to receiving tanks
Warm oil filtration	Air	VOCs emitted when warm oil is passed through filters to remove solids. Warm oil from the heating vessels is typically passed over open filters to remove solids. These are situated either in open yards or buildings. The filters used are typically vibrating metal mesh more commonly used in relation to mineral aggregates. It is crucial to the sale of the recovered fuel oil that the high solids content that the warm oil retains, is removed. The action of the removal of solids is aggressive and the filters need to be robust to deal with the solids and also the warm oil. This stage is a source of VOCs and odour
Removal of oil from effluent	Air	Oil is removed from liquid effluent prior to discharge to foul sewer or other waters, usually by oil/water interceptors, tilting plate separator and or by filtration techniques. VOCs are a significant emission when drawn off from a process tank into open channels and also when this is warm and passed over a tilting plant separator
Removal of oil from effluent	Water	Effluent to sewer. VOCs are released from warm water to sewer
Separation water	Air	VOCs released during watering off
Recovered oil storage	Air	VOCs displacement
	Land	Removal of sludge from storage and heating vessels and filtration units

Table 3.136: Emissions generated from the preparation of waste oils to be used as fuel [55, UK EA, 2001]

Table 3.137 shows some mass balances of four different treatment plants (A - D).

Site	Waste IN (excluding non oil/solvent items such as batteries)	Products	Discharge to sewer	Waste for processing off-site	Waste to landfill
A	Bulk waste oil: 14340	Fuel oil for the asphalt industry: 12800			
	Hydraulic fluid: 15				
	Mixed oily waste: 100				
	Used oil filters: 1355				
	Paints and solvents 100				
B	Mixed waste oils: 15000	Fuel oil: 13000	Waste water: 700	Compacted oil filters: 30	Sludge: 500
	Used oil filters: 90				
C	Contaminated water from factory interceptors: 14000	Fuel oil for further treatment or blending: 2000	High COD waste water: 13600		Pumpable sludge: 300
	Used oils from garages and factories: 2000				
	Surplus fuel oils: 100				
D	Used motor lubricating oil (In tankers): 80000	Used lube oil treated for use as fuel: 72000	Waste water with traces of hydrocarbons: 2500		Sludge from sieves: 6
	Used lube oils in drums: 100				Tank bottom sludge: 6
	Surplus fuel oils: 300	Kerogas (mixed lube and fuel oil): 1000			Cut pieces of 25 litres oil drums: 10
					Debris, rags, etc: 5
Note: Values within cells correspond to the annual amount in tonnes of the mentioned material					

Table 3.137: Inputs and outputs for waste oil treatment plants producing a material to be used as fuel
[56, Babtie Group Ltd, 2002]

Waste IN			
Type of waste oils	**Annual amount (tonnes)**	**Oil content (% oil)**	**Water content (% water)**
Waste motor oil	62000	97	3
Interceptor waste	25000	4	96
Soluble oils	16000	25	75
Fuel oils	7000	98	2
Oils from transfer stations or the processing of oil filters	4000	97	3
Other oil bearing waste streams	200	99	1
Waste OUT and residues			
Product			
Cleaned waste oil to be used as fuel	75150	99.5	0.5
Disposal to sewer		**Oil (mg/l)**	**COD (mg/l)**
Sewer discharge	40000	200	
Disposals to landfill		**% Oil (dry solids)**	**Water content (% water)**
Landfill: screenings	6000	11	25
Landfill: process sludge	12000	5	50
Landfill: other waste	4000	2	40
Other liquid disposal	4000	2	98
Other solid disposal	3000	5	95

Table 3.138: Example of emissions from an oil recycling plant that heats the oil during the process
[56, Babtie Group Ltd, 2002]

Outputs	Mainly to produce fuel oil [1]	Mainly to produce gasoil [2]	Units (per tonne of input waste oil)
Fuel oil (32 of 700 MJ and <0.5 % S)	849		kg
Secondary fuels [3]	63		kg
Gasoil		706	kg
Naphtha		51	kg
Bitumen		38	kg
Emissions			
CO_2	2845		eq. kg
SO_2	9.8		eq. kg
VOC	0.08		kg eq. C_2H_4
Particulates	0.4		g
Phosphates in water	0.0012		kg eq.
Waste to eliminate	18		kg
Waste to recover	24		kg
Waste water		50	kg
Solvents		29	kg
Heavy residues		61	kg
Naphtha		36	kg
Off-gases		29	kg

[1] Thermal cracking: thermal + chemical treatment (with H_2SO_4)
[2] Thermal cracking adjusted to produce primarily gasoil. Finishing with purification and stabilisation stages
[3] Many are waste fuels generated during the process

Table 3.139: Emissions generated by the thermal cracking of waste oils
[7, Monier and Labouze, 2001], [152, TWG, 2004]

For co-gasification with coal, the metals contained within the used oil can be fixed in an inert, non-hazardous bottom ash. Sulphur compounds are converted to hydrogen sulphide and removed by conventional scrubbing and converted to elemental sulphur. There are no metals, fugitives or dioxin emissions from the gasification process.

Outputs	Amount (per tonne of input waste oil)	Units
Methanol	1080	kg
Saving of primary input of fuels typically used in gasification		
Emissions		
CO_2	1431	kg eq.
SO_2	0.21	kg eq.
VOC	0.05	kg eq. C_2H_4
Phosphates	0.0079	kg eq phosphates in water
Waste to eliminate	1	kg
Waste to recover	36	kg

Table 3.140: Outputs generated by the gasification of waste oils
[7, Monier and Labouze, 2001]

Emissions to air

Some emissions commonly caused by the processing of waste oils to produce a product that can be used as fuel are shown in the following table (Table 3.141).

Environmental issue in the processing of waste oil	Comments
Chlorinated hydrocarbons	They increase the level of chlorine in the waste oil
Dioxins	They have been cited by environmental health officials in a recent used oil regeneration and basestocks fire
Lead	In the reprocessing option, lead will end up in the heavy residues, which will result in it being 'locked up' in a bitumen product. Due to the changing of gasoline specifications, lead contamination is of diminishing importance
Metals	In the thermal cracking process, at least 98 % of the metals are removed as a non-leachable solid powder, collected in sealed containers, and used as an additive to asphalt
Non-volatile metals	The other metals likely to be present may be retained in the bitumen residue, as with lead
PAHs	PAHs used to be a problem in processing base oils from a health and environmental point of view. These are formed during an incomplete combustion of organic matter. PAHs are relatively difficult to break down. However, recent tests indicate that it is possible to remove PAHs in the regeneration process of modern plants, thus avoiding the accumulation of PAHs
Sulphur compounds	Odour and SO_x emissions, if used as fuel within the processing plant

Table 3.141: Environmental issues related to the processing of waste oils to be used as fuel [6, Silver Springs Oil Recovery Inc., 2000], [11, Jacobs and Dijkmans, 2001], [56, Babtie Group Ltd, 2002]

Emissions to water

Waste oil preparation may give rise to miscible or dissolved organic substances, for example, demulsifers and detergents, within the effluent.

3.5.4 Waste fuels (waste OUT)

The intention of this section is to give an overview of the type of specifications that waste fuel typically has to have in order to be used in different combustion processes. Waste fuel is the term used in this document to name the fuel prepared from waste. As stated in the Scope chapter, descriptions of the combustion processes themselves are not covered in this document. Combustion is covered in the other industrial sector BREFs covered by IPPC.

The co-incineration of waste materials impacts on plant efficiency, and/or emissions to air and water, and also effects the quality of combustion residues and by-products. The impact of using waste as a fuel instead of using conventional fuels is determined by the different properties of the waste from the main fuel. For example, the emissions caused by the burning of waste oils in a coal fired power plant, in a fuel oil fired power plant or in a cement kiln are different because the nature of the process and the applied abatement techniques, e.g. solid vs. liquid fuel, end-of-pipe techniques, alkalinity of the cement kilns, temperature of the combustion (from 800 °C for fluid bed furnaces up to 2000 °C for cement furnaces), and the type of combustion plant (power plant, district heating or CHP) can be very different in each case. Consequently, those issues are covered in each industrial sector BREF, together with the discussion on the applied combustion process; and hence these issues cannot be covered here.

Part of the heating value of the waste to be used as fuel and the other important fuel properties that determine whether a specific fuel can be applied in a combustion plant arise from its chemical composition and physical properties. Fouling, slagging and corrosion of the boiler, when used in combustion power/heat plants, are possible negative aspects that are also related to its chemical composition, in particular to the presence of certain components in the total fuel mix such as alkali metals, chlorine and sulphur. These components may therefore have great influence on the availability of the combustion power/heat plant – as they can lead to plant downtime; they can also affect the ash characteristics, e.g. sintering and melting behaviour. Ash composition can be an important factor in the economics of the combustion plant. Polluting elements, such as heavy metals, can negatively influence the options for ash use, resulting in high costs for ash disposal. The physical form in which the fuel occurs is also of importance because the feeding systems must be capable of handling the fuel without problems and particles must be small enough for complete burn out in the relevant combustion technology. Pellets, fluff, briquettes and bales are the most commonly applied physical forms for solid waste fuel.

Futhermore, for combustion process the volatiles are an important fuel parameter with regard to flame stability and burn out of the fuel. Generally, solid waste fuels consist of wood, paper and plastics which are high in volatiles, e.g. compared to coal.

3.5.4.1 Solid waste fuel prepared from municipal solid waste

The range of compositions of solid waste fuel in Europe is shown in Table 3.142 below

Property	Range	Units
Dry matter	75.3 – 78.0	%
Humidity	1.6 – 50	%
Calorific value	10 – 40	MJ/kg
Ash	0.7 – 20	w/w-%
Composition of the ash		w/w-%
aluminium	6.9 – 9.2	
calcium	17.6 – 21.8	
iron	1.6 – 2.2	
potassium	1.9 – 2.2	
magnesium	1.4 – 1.7	
sodium	1.9 – 2.7	
silicon	17.9 – 20.8	
titanium	1.0 – 1.6	
Chlorine	<0.01 – 1.77	w/w-%
Fluorine	0.001 – 0.02	w/w-%
Sulphur	0.02 – 0.6	w/w-%
Carbon	47.1 – 50.7	w/w-%
Hydrogen	6.6 – 7.0	w/w-%
Nitrogen	0.5 – 0.8	w/w-%
Oxygen	30.4 – 34.4	w/w-%
As	<0.4 – 160	ppm
Be	0.2 – 0.3	ppm
Cd*	0.16 – 6	ppm
Cd + Hg	7	ppm
Co	0.4 – 7.4	ppm
Cr	2.5 – 226	ppm
Cu	6.8 – 1340	ppm
Hg	<0.02 – 1	ppm
Mn	22 – 590	ppm
Ni	<2.5 – 40	ppm
Pb	2.4 – 300	ppm
Sb	1 – 39	ppm
Se	0.8 – 1.7	ppm
Sn	2 – 27.6	ppm
Te	0.6 – 1.58	ppm
Tl	<0.1 – 0.8	ppm
V	2.3 – 10.2	ppm
Zn	225 – 500	ppm
EOX	31 – 42	ppm
* Around 70 % of the Cd that may be present in the MSW is transferred to the combustible products.		

Table 3.142: Ranges from the analyses of solid waste fuel prepared from MSW in Europe [4, Langenkamp, 1997], [8, Krajenbrink, et al., 1999], [21, Langenkamp and Nieman, 2001], [81, VDI and Dechema, 2002]

Parameter	Units	Median	80th percentile	Number of samples
Net calorific value	MJ/kg	20.6	25.1	179
Moisture content	%	13.4	18.8	346
Ash content	% DM	13.8	20.6	151
Chlorine total	%	0.7	1.1	171
Fluorine total	mg/kg DM	100.0	400.0	55
Sulphur total	%	0.1	0.4	110
Antimony	mg/kg DM	10.8	42.4	284
Arsenic	mg/kg DM	1.0	2.0	257
Beryllium	mg/kg DM	0.2	0.3	230
Cadmium	mg/kg DM	2.2	4.9	266
Chromium	mg/kg DM	48.0	82.9	259
Cobalt	mg/kg DM	2.9	4.7	245
Copper	mg/kg DM	97.5	560.0	286
Lead	mg/kg DM	89.0	160.0	265
Manganese	mg/kg DM	61.0	94.0	229
Mercury	mg/kg DM	0.2	0.3	249
Nickel	mg/kg DM	13.1	26.3	243
Selenium	mg/kg DM	0.4	1.7	235
Tellurium	mg/kg DM	0.4	1.0	222
Thallium	mg/kg DM	0.4	0.5	241
Tin	mg/kg DM	4.0	12.2	192
Vanadium	mg/kg DM	3.6	5.3	241
PCB	Sum DIN 51527	0.2	0.5	21
Notes: DM = dry matter All percentages are by mass The MSW used at this time did not include the high calorific fraction of household waste. It contained the high calorific fraction from construction and demolition waste and from commercial waste, which explains the stated value of the net calorific value.				

Table 3.143: Solid waste fuel produced from the high calorific fraction of demolition waste [21, Langenkamp and Nieman, 2001]

Parameter	Units	Source-separated raw materials from apartments, offices, etc.[1]	Source-separated raw materials from industries and companies[2]
Moisture	%	33.6	16.6
Gross calorific value	MJ/kg DM	23.1	21.2
Net calorific value	MJ/kg DM	22.3	20.1
Net calorific value	MJ/kg	14.0	16.8
Energy content	MWh/tonne	3.9	4.7
Ash content	%	10.2	6.7
Volatile matter	%	74.8	78.3
Chlorine	%	0.4	0.3
Aluminium	%	0.6	0.2
Metallic aluminium	%		0.03
Sulphur	%	0.2	0.1
Nitrogen	%	1.5	1.4
Sodium	%	0.4	0.1
Sodium soluble	%	0.3	0.1
Potassium	%	0.3	0.1
Potassium soluble	%	0.2	0.1
Mercury	mg/kg DM	0.3	0.1
Cadmium	mg/kg DM	1.2	
Chromium	mg/kg DM	140	
Copper	mg/kg DM	80	
Nickel	mg/kg DM	20	
Zinc	mg/kg DM	340	
Manganese	mg/kg DM	210	
Arsenic	mg/kg DM	8.8	
Lead	mg/kg DM	52.4	
Notes: DM = dry matter All percentages are by mass [1] Mean derived from 742 samples [2] Mean derived from 490 samples			

Table 3.144: Recovered fuel produced from source-separated fractions from MSW and other combustible waste (Finland)
[21, Langenkamp and Nieman, 2001]

Parameter	Units	Median	80th percentile	Number of samples
Net calorific value	MJ/kg	22.9	25.3	1402
Moisture content	%	11.5	17.2	1849
Ash content	% DM	9.6	11.6	1308
Chlorine total	%	0.4	0.7	1475
Fluorine total	mg/kg DM	100	400	200
Sulphur total	%	0.1	0.1	307
Cadmium	mg/kg DM	0.8	3.2	443
Mercury	mg/kg DM	0.2	0.4	402
Thallium	mg/kg DM	0.5	1.5	410
Arsenic	mg/kg DM	1.5	1.7	394
Cobalt	mg/kg DM	2.0	3.8	383
Nickel	mg/kg DM	6.2	16.0	384
Selenium	mg/kg DM	1.0	2.5	318
Tellurium	mg/kg DM	1.0	5.0	322
Antimony	mg/kg DM	9.4	33.9	547
Beryllium	mg/kg DM	0.2	0.3	343
Lead	mg/kg DM	25.0	64.4	406
Chromium	mg/kg DM	20.0	43.9	417
Copper	mg/kg DM	48.0	118	504
Manganese	mg/kg DM	28.0	47.0	369
Vanadium	mg/kg DM	3.3	10.0	347
Tin	mg/kg DM	7.0	12.4	114
PCB	Sum DIN 51527	0.2	0.5	134
Notes: DM = dry matter All percentages are by mass				

Table 3.145: Recovered fuel produced from monostreams of commercial and industrial waste (data from one German company)
[21, Langenkamp and Nieman, 2001]

Solid waste fuel to substitute coal

The main difference between coal and solid waste fuels is the contents of sulphur, chlorine and heavy metals. In many cases, for instance, if solid waste fuels with plastics are considered and compared to coal, the chlorine of the recovered fuels are higher (typically 0.5 – 1.0 %) and the sulphur is lower. Also generally, the heavy metals content will be in a similar range (ppm range) or may even increase. Solid waste fuel is sold in different physical forms. Table 3.146 gives an overview of the different physical forms of waste fuel.

Waste fuels	Determining physical and chemical characterisation
Fluffy	Particle size, bulk density, moisture content, net calorific value, ash content, chemical composition
Soft pellets	
Hard pellets	
Chips	
Powder	

Table 3.146: Overview of the different physical forms of the waste fuel (waste OUT)
[126, Pretz, et al., 2003], [152, TWG, 2004]

The user requirements often define the product quality and the waste fuel characterisation. Power plants, cement and lime works, gasification plants, multifuel boilers etc. have different standards for the use of solid waste fuel dependent on their technology, waste gas treatment and product specification.

Dried sewage sludge
Large volumes of dried sewage sludge with calorific values between 3 and <10 MJ/kg are used in power plants.

3.5.4.2 Specifications of waste fuel to be used in cement kilns

The two tables below (Table 3.147 and Table 3.148) contain examples of specifications used by cement kilns in some countries. These tables do not contain the full picture of what is actually happening in Europe, so it should be considered that the information given here is not exhaustive.

The sampling and measurements required for accepting substitute fuels in cement kilns in some countries is shown in Table 3.147.

Substances or criteria to be measured	Units	United Kingdom	Flanders [1] (Belgian region)	Italy [2]	New Zealand [3]
Calorific value	MJ/kg	23 – 29	>15	>15	
Water/solvent separation		not detectable			
Water content	%			<25	
Total S	%	<0.3	<0.4	<0.6	0.1 – 2.8
Total Cl	%	<2	<0.5	<0.9	0.03 – 0.76
Total F, Br, I	%	<0.5			
F	%		<0.1		
Total Br, I	%		<0.01		
Total N	%		<1.0		
Al	ppm				10 – 1000
As	ppm	<50	<10	<9	<50 – 60
Be	ppm		<1		
Cd	ppm		<10		<10 – 20
Cd + Tl	ppm	<40			
Cd + Hg				<7	
Co	ppm	<100			
Cr	ppm	<200		<100	<10 – 80
Cu	ppm	<600		<300 [6]	<10 – 165
Hg [4]	ppm	<20			<10
Hg, Tl	ppm		<2		
Mn	ppm	<250		<400	
Mo	ppm		<20		
Ni	ppm	<50		<40	
Pb	ppm	<500	<200	<200 [5]	10 – 1080
Sb	ppm	<50			
Sn	ppm	<100			
V	ppm	<50	<200		
Zn	ppm		<500		108 – 3670
Sb, As, Cr, Co, Cu, Pb, Mn, Ni, Sn, V	ppm	<1800			
Solid and ash content	%	Depends on the type of waste fuel		<20	
PCB content					<10
Other species		Depends on the type of waste fuel			

[1] It has been reported that no cement kiln is now operating in Flanders
[2] An SRF producer reported production of a waste fuel with the following characteristics: calorific value of more than 18.8 MJ/kg, water content of less than 20 %, total chlorine content of less than 1 % and an ash content of less than 6 %
[3] For waste oil used in a cement kiln
[4] Lower values have been reported (2 – 5 ppm if the facility is equipped with a bag house filter with activated carbon and less than 1 ppm if such equipment is not implemented) but no reference to any country or installation was given
[5] refers only to volatile Pb
[6] refers only to soluble Cu compounds
More data can be found in the German legislation (Table 1 of Stellungnahme der LAGA zu RAL GZ 724) and in the work carried out by CEN/TC 343 WG 2

Table 3.147: Examples of specifications of a waste to be accepted as fuel in some countries' cement kilns
[4, Langenkamp, 1997], [37, Woodward-Clyde, 2000], [52, Ecodeco, 2002], [150, TWG, 2004], [152, TWG, 2004]

Table 3.148 shows some examples of specifications applied to different types of waste to be accepted in French cement kilns.

Substances or criteria to be measured	Units	Catalysts	Industrial sludges	Polluted water with high COD contents (>10000 ppm)	Animal meal	Animal fat	Waste oil
PCB/PCT	ppm	<50	<50	<50			<50
Pentachlorophenol		none	none	none			none
Hg	ppm	<10	<10	<10			
Hg + Cd + Tl	ppm	<100	<100	<100			
Sb + As + Pb + Cr + Co + Ni + V + Sn + Te + Se	ppm	<10000	<2500	<2500			
Heavy metals	%						<1
pH			3 – 12	3 – 12			3 – 12
Calorific value	kJ/kg		8400	8400	18800	38500	38500
Total hydrocarbons	%	<0.5					
CaO + SiO_2 + Fe_2O_3 + Al_2O_3	%	>80 *					
Water	%	<10	40 – 70				<15
Alkalis (Na_2O + K_2O)	%	<5	<1.5	<5			<5
Total Cl	%	<0.6	<0.3	<0.6	<0.6	<0.1	<0.6
Total S	%	<5	<2	<2	<0.4	<0.1	<2
Total P (as P_2O_5)	%	<2	<5				
F	%	<2					
Br	%	<0.5					
I	%	<0.5					
F + Br + I	%		<1	<1			<1
Solid residue at 900 °C	%		<30	<5			<5
Viscosity at 20 °C	cp			250			250

Notes:
* on a dry basis
The types of wastes not accepted for processing in cement kilns in France are radioactive products, explosives, peroxides, perchlorates and strong oxidants, tear compounds, mineral cyanides, hospital waste, waste polluted with pathogenic microbes and highly flammable liquids.
Some of the wastes listed here correspond to wastes that are directly sent from the waste producer to the cement kiln, and then, these are not treated before being used in the cement kilns. Some wastes listed here do not correspond strictly to use of waste as fuel.
Some substances mentioned here have an impact on the cement kiln process or product (e.g. alkalis, phosphorous, viscosity). For more information see the Cement and Lime BREF.

Table 3.148: Examples of specifications of different types of waste to be accepted as waste fuel in the French cement kilns
[46, Szabo, 2002], [150, TWG, 2004], [152, TWG, 2004]

Substance	A		B	C
	mg/MJ	mg/kg (at 25 MJ/kg)	mg/kg	mg/kg
Ag	0.2	5	-	-
As	0.6	15	20	30
Ba	8	200	600	1000
Be	0.2	5	3	3
Cd	0.08	2	0.8	1
Co	0.8	20	30	100
Cr	4	100	100	200
Cu	4	100	100	200
Hg	0.02	0.5	0.5	0.5
Ni	4	100	100	200
Pb	8	200	50	75
Sb	0.2	5	1	5
Se	0.2	5	1	5
Sn	0.4	10	50	30
Tl	0.12	3	1	2
V	4	100	200	300
Zn	16	400	400	400
Toxic organic compounds	No standard value. However, some restrictions are mentioned if PCB, dioxins or similar toxic compounds are suspected or organic compounds are present			

Column A applies to wastes used as fuel introduced either in the main burner at the clinker outlet of the rotating kiln or the inlet of the rotating kiln. The standard values in colum A (mg/MJ) are based on the lower calorific value of the waste. For reasons of clarity, the standard values in (mg/kg waste) are based on a lower calorific value of 25 MJ/kg. The value of 25 MJ/kg corresponds to the calorific value of hard coal. If the calorific value of the waste is less than or greater than 25 MJ/kg, the permissible heavy metal content changes proportionally
Column B applies to wastes used as alternative raw materials in producing clinker. This waste substitutes part of the raw material normally used or serves to correct the raw meal composition, i.e. the calcium, iron, silicon or aluminium content
Column C applies to waste used at the grinding stage in the production of Portland cement. Portland cement consists of 90 – 95 % ground cement clinker and 5 – 10 % gypsum, as well as other materials added at the grinding stage

Table 3.149: Standard values for pollutant content of waste used in the cement kilns used in Switzerland
[150, TWG, 2004]

3.5.4.3 Waste oil used as fuel

Used oils have some valuable properties for their use as a fuel oil blendstock, e.g. they have a lower sulphur content and viscosity in comparison to other heavy fuels. Blending into fuel oil at the refinery could be a viable option for oils when it can be shown that the contaminant levels are within acceptable limits for the fuel oil specification.

Waste oil is used as a fuel in a number of power stations in the UK. A typical specification is shown in Table 3.150 below. It is reported that waste oil suppliers consistently have difficulty in meeting the chlorine specification because of the contamination of used oils in the UK. This arises from other wastes such as transformer oils and chlorinated greases.

PROPERTIES	Units	Min.	Max.
Physical			
Density at 15 °C	g/cm^3	0.88	0.95
Flashpoint	°C PMCC	65	
Net calorific value	GJ/tonne	40	
Viscosity @ 40 °C	Centi Stokes	30	55
Chemical			
Water content	w/w-%	0	3
Sulphur	w/w-%	0	1
Chlorine	ppm	0	1100
PCB	ppm	0	10
Lead	ppm	0	200
Vanadium	ppm	0	50
Copper	ppm	0	50
Cadmium	ppm	0	10
Chromium	ppm	0	30
Nickel	ppm	0	50

Table 3.150: Typical specification for recovered fuel oil supplied to UK power stations [56, Babtie Group Ltd, 2002], [67, DETR, 2001]

Waste OUT from the mild reprocessing of waste oils

The cleaned waste oils from these processes are typically blended with other fuel oils. The processed waste oil will still contain heavy metals, halogens and sulphur.

Waste OUT from the thermal cracking of waste oils

Table 3.151 gives a summary of the components present in the products from the thermal cracking of waste oils.

Environmental issue	Comments
Chlorinated hydrocarbons	If the cracked fuel is hydrotreated, chlorinated compounds are removed. Heavy PCBs (boiling point higher than the waste oil) are destroyed during this process. Light PCBs are only partly destroyed during this process. Organic chloride compounds may still remain in the distillate
Chlorine	A maximum specification for chlorine of 50 ppm was set by the Dutch government
Metals	The efficiency of the vacuum column enables the production of distillates with metal contents of less than 1 ppm. All metals present in the used oil end up in the bottom of the cracking section
PAHs	The heavy PAHs are cracked, and are burned with light naphtha. The lighter PAHs are added to the pool of light fuels
Sulphur	The gasoline will have a sulphur content that depends on the sulphur level in the used oil feed and the stabilisation method applied

Table 3.151: Components of waste OUT from the thermal cracking of waste oils [6, Silver Springs Oil Recovery Inc., 2000], [150, TWG, 2004]

It is likely that in order to meet EU requirements for the sulphur content in liquid fuels (automotive and/or heating oil) that the resulting cracked products will require either treatment for sulphur reduction or will have to be blended away in lower sulphur products (thereby making use indirectly of someone else's desulphurisation capability).

Outputs	Units (per tonne of input waste oil)	Mainly to produce fuel oil [1]	Mainly to produce gasoil [2]
Fuel oil (32 of 700 MJ and <0.5 % S)	kg	849	
Secondary fuels [3]	kg	63	
Gasoil	kg		706
Naphtha	kg		51
Bitumen	kg		38
1 Thermal cracking: Thermal + chemical treatment (with H_2SO_4) 2 Thermal cracking adjusted to produce primarily gasoil. Finishing with a purification and stabilisation stage 3 Many are waste fuel generated during the process			

Table 3.152: Outputs generated by the thermal cracking of waste oils
[7, Monier and Labouze, 2001], [152, TWG, 2004]

Waste OUT from the gasification of waste oil

For co-gasification with coal, the metals contained within the used oil can be fixed in an inert, non-hazardous bottom ash. Sulphur compounds are converted to hydrogen sulphide and removed by conventional scrubbing and converted to elemental sulphur. There are no metals, fugitives or dioxin emissions from the process.

Outputs	Units	Amount (per tonne of input waste oil)
Methanol	kg	1080
Saving of primary input of fuels typically used in gasification		

Table 3.153: Outputs generated by the gasification of waste oils
[7, Monier and Labouze, 2001]

3.5.4.4 Quality assurance systems

The information given in this section presents a survey about existing quality assurance systems and the recent developments.

European CEN/BT/TF 118

The CEN Task Force 118 'Solid Recovered Fuels' was established in April 2000. The Task was to prepare a technical report about the production and the application of solid waste fuel within the EU as well as the development of a work programme as the basis for an European standard in the future. The European classification model is based on solid waste fuel characteristics, source material and origin. The report concluded that it is necessary to develop a European standard. CEN was given the mandate to develop, as a first step, a set of technical specifications concerning solid waste fuel, and produced exclusively from non hazardous wastes, for energy recovery in waste incineration or co-incineration plants. As a second step, CEN was given a mandate to transform this set of technical specification into European Standards.

German RAL

Early in 1999, a german association started its endeavours to install the quality label for solid waste fuel from non-hazardous waste. The label is awarded to solid waste fuel producers which comply to the requirements by guaranteeing constant qualities. The standards firstly relate to cement industry and power stations. Accordingly, solid waste fuel has to fulfil the criteria given in annexes 1 and 2 to the quality assurance system. Annex 1 contains a list with all allowed wastes which are applicable as a basic principle. In annex 2, values are given which have to be met. These values are shown in Table 3.154. The inspections in acknowledging as well as in the supervision procedure occur in two phases. These systems include sampling matters, how to

calculate mean values, acknowledging procedure (first inspection), self-monitoring, independent supervision and re-inspection.

	Content of heavy metals [4]	
Parameter	**Median (mg/kgDM)**	**80th percentile (mg/kgDM)**
Calorific value		
Humidity		
Ash content		
Chlorine content		
Cadmium	4	9
Mercury	0.6	1.2
Thallium	1	2
Arsenic	5	13
Cobalt	6	12
Nickel	25 [1] 80 [2]	50 [1] 160 [2]
Selenium	3	5
Tellurium	3	5
Antimony [5]	50	120
Lead	70 [1] 190 [2]	200 [1] - [3]
Chromium	40 [1] 125 [2]	120 [1] 250 [2]
Copper	120 [1] 350 [2]	- [3] - [3]
Manganese	50 [1] 250 [2]	100 [1] 500 [2]
Vanadium	10	25
Tin	30	70
Beryllium	0.5	2

[1] For solid recovered fuel from production specific waste
[2] For solid recovered fuel from the high calorific fractions of municipal waste
[3] Restriction not until a secured database is given by the fuel processing
[4] The heavy metal contents are valid up to a calorific value NCV_{DM} of ≥ 16 MJ/kg for the high calorific fractions from municipal waste and up to a calorific value NCV_{DM} of ≥ 20 MJ/kg for production specific waste. For calorific values falling below, the values need to be lowered accordingly, an increase is not allowed.
[5] Values adapted in case of digestion with aqua regia in a closed microwave system

Table 3.154: Heavy metal contents which have to be complied with according to BGS/12/ [126, Pretz, et al., 2003], [150, TWG, 2004]

Finnish SFS 5875

The Finnish waste disposal system is based on a separate collection of wastes for the recycling and for solid waste fuel production. Different solid wastes and Finnish boilers with a high technical standard are used for a highly efficient production of energy followed by low emission levels. The application of solid waste fuel in the Finnish multifuel boiler is estimated as 'well suited'. The regulations concern separate collected, dry solid, high calorific fractions or for dry, high calorific fractions derived from household wastes. The regulation defines operations and demands to control the solid waste fuel production and also refers to the complete waste management chain, from the waste recovered paper source up to the disposal. For each part of the disposal chain, the standard requires a person in charge to monitor the technical and quality requirements.

Analogical to the German standard, the annexes of the Finnish standard define concrete requirements concerning thresholds for heavy metals as well as for the framework of analysis, sampling, etc. The thresholds are predefined which have to be adhered to as well as regulations as regard to the matter of contracts. It includes supervision operation, quality requirements and quality classes.

In comparison to the German standard, the Finnish standard divides wastes into three quality classes. For categorisation of solid waste fuel in Finland, seven elements are analysed. Table 3.155 presents the criteria for the classification of quality classes.

Parameter	Unit	Quality classes		
		I	II	III
Chlorine	weight -%	<0.15	<0. 5	<1.5
Sulphur	weight -%	<0.2	<0.3	<0.5
Nitrogen	weight -%	<1.0	<1.5	<2.5
Potassium and Sodium	weight -%	<0.2	<0.4	<0.5
Aluminium (metallic)	weight -%	- [1)]	- [2)]	- [3)]
Mercury	mg/kg	<0.1	<0.2	<0.5
Cadmium	mg/kg	<1.0	<4.0	<5.0

[1)] Metallic aluminium is not allowed, but is accepted within the limits of reporting precision.
[2)] Metallic aluminium is minimised by source-separation and by the fuel production process.
[3)] Metallic aluminium content is agreed separately.

Table 3.155: Quality classes according to SFS 5875/13/ [126, Pretz, et al., 2003]

Austrian ÖG SET

Within a joint project of the Austrian association (Österreichische Gütegemeinschaft für Sekundärenergieträger), a quality assurance concept for solid recovered fuels (SRF) has been worked out.

Objective

In order to meet the requirements for the thermal utilisation of wastes/residues in industrial co-incineration, the waste/residue quality has to be accurately defined. During production of waste fuels, special attention has to be given to the quality assurance of these predefined fractions. For the technical feasibility on an industrial scale, practical experience showed that not only the chemical contents and the composition, defined by the origin of the waste, but also the physical parameters like particle size and agglomeration, defined by the mechanical pretreatment, in order to comply with these requirements of the ÖG-SET are decisive.

In order to reach those requirements, the ÖG-SET aims with the following as the basis for a quality mark:

- preparing regulations for sampling and sample preparation
- evaluating the implications of the prepared regulations on the application of solid recovered fuels in industrial co-incineration, power and heat production
- preparation of a quality assurance concept.

Organisation

The main prerequisite to put the resulting regulations in action is a wide support from the companies concerned who deal with the production and the thermal utilisation of solid recovered fuels.

Activities

The following activities are carried out:

- catalogue criteria for the utilisation of SRF in different industrial incineration/energy and heat production plants
- preparation of regulations for the sampling of SRF
- carrying out an inter-laboratory test for the determination of standard deviations in mean contents resulting by sampling, sample preparation and analysis
- preparation of a quality assurance concept
- definition of the basic requirements for a quality mark.

Taking into account five industrial branches and the applied technologies for thermal utilisation (e.g. coal dust burners, rotary ovens, fluidised beds), five working groups (cement industry, pulp/paper and board industry, electric power stations, steal industry and wood industry) were established. In each group producers and users of SRF were taking part to ensure a holistic approach. For the different utilisation technologies, essential criteria were gathered and defined for the thermal utilisation of waste and residues. Principally, three different types of quality attributes were distinguished:

- exclusion criteria
- physico-chemical quality attributes
- other quality attributes.

These quality attributes contain a compendium of the criteria and quality attributes defined by the working groups. Every plant manager taking into account his plant's requirements, can choose attributes for his required SRF quality from the lists. For sourcing, the criteria can be included in the specification of the SRF.

Preparation of the basis for specification
The preparation of a specification sheet facilitates the communication between the SRF producer and user. For the sourcing of SRF, additional criteria like the following ones can be made:

- transport and storage criteria (e.g. bulk density)
- type of transport (e.g. by road, by rail).

The additional information can ease the handling of SRF considerably.

Inter laboratory test
Two SRF (one less and one more heterogeneous) test schemes have been worked out. One test was carried out for guide parameters defined with the statistic evaluation of existing data. The chemical parameters from the criteria list were investigated as well. The first step was the calculation of the sample mass and sample number, based on the framework provided by CEN TC 292 WG1 'Characterisation of waste – Sampling techniques for waste' (draft from 02/2001). The sample volume and sample number were calculated by using a targeted total deviation, the particle size, the bulk density and the heterogeneity of the waste expressed by the standard deviation reached in earlier examinations. Based on the results of the inter laboratory test, the guidelines for sampling and sample preparation were defined.

Preparation of a quality assurance concept
To ensure the required quality criteria, a quality concept is currently under preparation, which takes into account the special demands of the application and utilisation of SRF.

Company quality assurance
There are internal quality assurance systems existing in some companies. Table 3.156 gives an overview about the system.

Process step	Measures	Supplementary measures
Origin (waste producer, sorting plant, mechanical biological processing)	Collection of wastes, avoidance of impurities, contractual arrangements about allowed qualities of wastes, declaration analysis, documentation of disposed amounts	Instruction courses for waste producers, periodic controls of the waste producing company by the disposer
Processing plant (delivery)	Regular sampling and analysis, reserve samples, documentation of input and processed amounts	Regular sampling and analysis of the outgoing materials by an external official expert
Processing plant (output)	Regular sampling and analysis, reserve samples, documentation of the delivered amounts	
Cement and lime kilns, power plants	Regular sampling and analysis, reserve samples, documentation of the input amounts	

Table 3.156: Quality assurance system of RWE Umwelt AG (Germany)
[126, Pretz, et al., 2003]

3.6 Emissions and consumptions from end-of-pipe treatments (abatement)

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003]

This section covers the emissions arising from those processes/activities, commonly called end-of-pipe or abatement techniques, used in the waste sector for the treatment of waste gas, waste water and process produced solid waste before those streams are disposed of. The main objective of these processes is to reduce the concentration of pollutants in the output streams. The loads and concentrations of pollutants in these streams will be reduced by end-of-pipe and abatement processes, but some pollutants may remain in the streams and others may be generated. The actual techniques are not decribed in this section, since they are techniques to consider in the determination of BAT and, thus they are analysed in Chapter 4. Some of the descriptions given are only in shortened forms in this document since they are available in other BREF documents (e.g. waste gas and waste water BREF).

Emissions and consumptions of waste water treatments

Effluents from waste treatment installations typically contain organic chemicals (e.g. measured as TOC or COD), nitrogen, phosphorus, and chloride, since most wastes originally contain some organic materials, even if only in association with fuel/oil spills from vehicles at the site or from surface de-icing. Large quantities of COD, nitrogen, phosphorus and chlorine could affect the performance of the sewage treatment works.

The main emissions from waste water treatment systems will be carbon dioxide, methane and nitrous oxide to air, and TOC, nitrogen, phosphorus and chloride to water or sewer. The aqueous discharges are usually monitored, but emissions to the air are rarely monitored. There is generally some information on waste input that would allow large inputs of nitrogen rich wastes to be identified, and a minimum emission of nitrogen to the air to be calculated on a mass balance basis using the discharge data. If there is TOC/COD information at the waste IN, then a rough calculation of carbon dioxide emissions could be made.

In addition, there could be any number of additional emissions depending upon the waste IN, as indicated in Table 3.157 or depending on the waste water treatment plant step.

WWTP part	Emissions		
Reception	It is important in liquid waste biotreatment systems that the flow of substrate is relatively constant, so reception pits or equalisation tanks are an important feature of the process. These are usually filled from road tankers or from a pipe to the source. There is potential for spillage and emissions to the air (potentially air stripping) when the waste is transferred or mixed by aeration units within these tanks. Volatile chemical constituents are the most likely to result in fugitive air emissions if any		
Primary processes	The initial stages of treatment usually provide for the removal of gross or fine solids. These may include coarse and/or fine screening, primary sedimentation or dissolved air flotation. The main potential sources of emissions are from transfer activities to and from these processes. Some components may preferentially concentrate in the solids, which are collected and stored after primary treatment. Flocculants or other additives may be used in clarification and can add additional species to the flow		
Secondary processes	Predominantly these include an aerobic stage where the effluent is aerated with oxygen or air (HRT 0.5 – 3 days) to convert soluble organics to micro-organisms (sludge) and final effluent. Emissions can occur from the vigorous activity in the aeration tank and may result in an air stripping of volatiles. It is usually assumed that if the waste is treatable in this way, the emissions are not hazardous since the process is biological. Although this is the usual case, it is not necessarily the case and in one (past) instance, a known carcinogen was released through air stripping in the aeration tank, while the performance of the plant remained unimpaired. It is not easy to determine all the potential intermediate compounds that can occur as complex organics are broken down during the process, or their volatility under these circumstances. After the aeration tank, the final effluent is invariably separated in another clarifier or sedimentation tank. Again, some organic constituents and metals can bioaccumulate in the sludge		
	Gaseous emissions to air *	*Aqueous emissions to sewer or controlled waters*	*Sludge/compost for re-use or for onward disposal to landfill*
Aerobic waste water systems	Carbon dioxide, odours (mainly due to organic compounds), microbes	TOC/N/P/Cl	TOC/N/P
Anaerobic waste water systems	Methane, carbon dioxide, microbes	TOC/N/P/Cl	TOC/N/P
* The actual range of gases produced is much larger and is likely to include ammonia and carbon monoxide in all processes, but these are small compared with the main degradation products.			

Table 3.157: Emissions from the different steps of a waste water treatment plant [56, Babtie Group Ltd, 2002]

Table 3.158 gives some qualitative values of the emissions from waste water treatments and advises how these can be calculated.

	Emission to air	Emission to surface waters/sewer	Emissions to land and solid waste
Ammonia	Low. Where high ammonia wastes are accepted it may be possible to do a mass balance at some sites. Ammonia may be also generated in the removal of colloidal solids when using vacuum filtration		
Carbon dioxide (kg)	It may be possible to estimate the emission from $TOC_{output} - TOC_{input}$		
Methane	Low		
Nitrous oxide	Low		
Other species: metals and organics		It may be possible to estimate the intake from waste analysis and then to either undertake calculations based on analytical data from the outlet at the site, or the review the likelihood of discharges to air, water and sludge	
TOC			
COD			
BOD		10 – 20 mg/l (flow weighted monthly average), for any incoming load	
Total N			Nitrogen and phosphorus in the effluent will arise from the treatment of nitric acid, ammonia compounds, amines, etc. and phosphoric acid
Total P			
Chloride			
Fluoride		Fluoride is not a common part of the effluent, unless the site actively accepts wastes with this content	
Heavy metals			Where sources of mercury or cadmium cannot be eliminated or reduced by control at source, abatement will be required to control releases to water. In biological treatment 75 - 95 % of these metals will transfer to the sludge. Levels are unlikely to cause problems for the disposal of sludge but care will need to be taken to ensure that levels in the receiving water are acceptable

Table 3.158: Relevant emissions for waste water treatment
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

VOC emissions
Emissions from aerobic treatment can occur from the aeration tank as the aeration is vigorous and may result in the air stripping of volatiles. It is often assumed that if the waste is treatable in this way, the emissions are not hazardous since the process is biological. This is not necessarily true and in one (past) instance, a known carcinogen was released (through air stripping in the aeration tank) while the performance of the plant remained unaffected. It is not easy to determine all the potential intermediate compounds that can occur as complex organics are broken down in the process, or their volatility under different circumstances. It can be expected that feedstocks containing a known volatile organic contaminant would release air emissions at this point in the process. A similar scenario would occur for feedstocks with excess nitrogen.

Emissions of ammonia to the air
Ammonia is often generated by air stripping systems in waste water treatment plants treating high nitrogen wastes such as landfill leachate.

Sludge
After the aeration tank, the final effluent is invariably separated in another clarifier or sedimentation tank. Once again, some organic constituents can bioaccumulate in the sludge.

3.7 Monitoring

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

This section gives an outline of the monitoring and reporting practices found in the waste treatment sector. This section aims to cover practices already in use in Europe in order to provide better guidance to the permitting authorities on the selection of the appropriate monitoring methodologies, the frequency of monitoring, compliance assessment criteria and appropriate environmental monitoring. However, this section does not select any specific type of measurement methology, frequency or evaluation procedures or discuss specific compliance assessment criteria. Some guidance information on these issues may be found in the Monitoring reference document (see back of the front page).

The compounds or parameters monitored and the frequency of monitoring are very variable in the waste treatment sector. They depend on the type of waste processed, as well as on the type of processes/activities carried out. Monitoring should be adapted to the type of emissions (e.g. batch release or continuous release) and on the type of treatment (e.g. whether there is likely to be NO_x emissions). Table 3.159 and Table 3.160 indicate some monitoring practices applied in some EU countries.

Compound or parameter to monitor	Purpose and/or typical monitoring frequency
Process variables	
Efficiency of the treatment process as a whole. The precipitation of metals from solution for removal in the filter cake. The degree of transfer between the incoming waste and the emissions (to air, solid waste to land and liquid effluent to sewer of, for example, pesticides or solvents)	Continuous
Reaction monitoring (acid/alkali neutralisation) to ensure that the reaction is under control and proceeding towards the anticipated result	Continuous and automatic monitoring of pH and temperature
Cyanide treatment. pH to be maintained at >10	Continuous pH; continuous free chlorine and continuous CN content
Treatment of phenolic solutions. Reaction monitoring	Process temperature, pH and redox potential continually monitored
Waste oil reprocessing. Temperature in heating vessels and condenser outlets at <90 °C	Continuous and recorded
Stabilisation	To ensure product (from each batch) meets declared specification
Fresh water use across the installation and at individual points of use	Normally continuous and recorded
Energy consumption across the installation and at individual points of use	Normally continuous and recorded
Air emissions	
Point source emissions, e.g. scrubbers from reactors, mixing vessels, storage vessels, drum crushers, vents from extraction systems, biofilters, e.g. total carbon and speciated VOCs	Daily to weekly – under a representative range of operating conditions
Waste oil reprocessing – heating vessels, warm oil receiving tanks and filtration plant	Weekly – under a representative range of operating conditions
Oil process tanks and condenser outlets	Continuous temperature
Combustion emissions	Quarterly, or less frequent stack testing for CO, NO_x, and possibly SO_x, particulates depending upon process
Fugitive emissions: boundary fence monitoring to detect releases from, for example, drum storage areas, total carbon and speciated VOCs	Weekly – under a representative range of operating conditions
Odour	Daily as well as dynamic dilution olfactometry at appropriate intervals

Compound or parameter to monitor	Purpose and/or typical monitoring frequency
Noise	Usually only if required by regulator or if there is a potential for community nuisance. Normally takes the form of a one-off survey by external consultants
Dichloromethane	Most sites that are expected to receive cleaning solvents are required to monitor this compound
Water emissions	
AOX	
BTEX	
COD/BOD	Flow weighted sample or composite samples, weekly analysis, reported as flow weighted monthly averages
Dissolved oxygen	Continuous
Flowrate	Continuous and integrated daily flowrate. Flow proportional samplers are commonly used to take composite samples. These may be supplemented as well by spot samples on bulk tanks ready for discharge
Metals	Daily, twice a week, weekly or monthly depending upon process. In some countries, this depends on the effluent rate (e.g. <10 m³/day, <100 m³/day, >100 m³/dday)
Nitrogen	Daily, twice a week, weekly or monthly depending upon process. In some countries this depends on the effluent rate (e.g. <10 m³/d, <100 m³/d, >100 m³/d)
Odour	
PAHs	
pH	Continuous
Phenols	
Phosphorus	Daily, 2 times per week, weekly or monthly depending upon process. In some countries this depends on the effluent rate (e.g. <10 m³/d, <100 m³/d, >100 m³/d)
Suspended solids	Continuous
Temperature	Continuous
TOC	Continuous. This parameter is typically easier to control than COD or BOD when there is chlorine in the water release
Turbidity	Continuous
Waste emissions	
Amount	These data are reported at least annually to the authorities

Table 3.159: Monitoring practices applied to waste treatment plants in the EU
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

Waste treatment sector	Monitoring practices
Chemical plants	Sites that have extensive abatement systems are unlikely to undertake regular monitoring of the exhaust gases. A typical monitoring programme is a quarterly stack analysis, however this is highly unlikely to coincide with any peaks in the discharge rate of particular species
Transfer stations, bulking processes and storage	Simple formulae are available to assess the discharge of VOCs through the filling of storage tanks, decanting liquids into bulk containers, venting of liquids from containers, and washing of tanks, drums or tankers. Essential data will depend on the activity concerned, but will generally consist of information such as numbers of tankers/drums/containers, their size and the composition of the waste stream. As waste generally originates from a number of different sources and is usually mixed, data pertaining to composition of the waste stream are likely to be difficult for operators to accurately determine and detailed records are not routinely kept. Without these data, emission calculations will need to be based on the primary constituent of the waste or on the waste source. There are four types of techniques for emission estimation: sampling or direct measurement; mass balance; fuel analysis or other engineering calculations; or by emission factors (see the Monitoring BREF)
Oil treatment plant	A draft computer model has been developed in the UK to calculate emissions from basic information about intake tonnage and the quantity and oil content of discharges to sewer and landfill. The model requires adjustment to give answers that are compatible with the specification for residual fuel oils used in power stations and the known content of residuals in sewer discharges and sludges to landfill. The computer model does not provide an estimation for total nitrogen, phosphorus, chloride or COD to sewer and these will have to be calculated from monitoring data where this is available
Waste oils processing	Discharges to the air are more complex to calculate only having the knowledge from input, as releases are less defined and the behaviour of oils undergoing different processes is not clear
Waste solvent	Rigorous daily sampling regimes at tank vents and biofilters (where applicable) for TOC. Also an analysis of chemical compounds every fortnight at a series of process and fenceline monitoring points.

Table 3.160: Monitoring practices for some waste treatment processes used in the EU [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Monitoring practices in physico-chemical treatment plants of waste waters

The monitoring issues with the physico-chemical treatment of waste waters cover:

- wastes containing phosphorus: not all sites are required to monitor regularly for total phosphorus so it may be easier to make an estimate of this emission from the intake of phosphoric acid
- occasional inorganic wastes: for example wastes containing arsenic. Again, it is easier to calculate the annual emission from occasional waste IN data than to extend the monitoring programme.

Emissions to the air are the least well monitored discharges from physico-chemical treatment plants.

The main discharges to the air could be based on monitoring, but fugitive emissions will need to be estimated, as will the possibility of organic contaminants.

Almost all Ph-c sites have a complex set of conditions relating to water discharge that regulate sampling and monitoring frequency, and which set both the maximum concentration allowed for different species in the effluent and a maximum daily, weekly or monthly quantity of different species. This requires flow proportional monitoring, or the monitoring of each batch before discharge of a set volume. Either system provides the data to calculate annual emissions for a number of main species. The problem in estimating emissions to water is restricted to those species that are known to exist, but for which there is no monitoring data, and to unexpected species that arrive with particular waste streams. Other inorganic species, such as arsenic, could probably be estimated from site intake data since treatments of wastes contaminated with those components are typically occasional activities.

Monitoring and sampling practices applied to the preparation of waste fuel from hazardous waste

More information on sampling is available in Section 2.1.1. Each type of waste needs a specific sampling protocol based on the physico-chemical properties of the waste [150, TWG, 2004].

Sampling of individual waste deliveries

Liquids (from tank trucks, i.e. solvents, waste oil)

Samples are taken with the 2.5 m sampling tube from each compartment of the truck or container (around 1 – 2 litres each). The sampling tube has to be rinsed with the liquid prior to sampling. The tube is inserted slowly down to the bottom of the tank with the valve end down. After closing the valve, the tube is lifted and the liquid is filled into an aluminium can.

Samples are combined and, after homogenisation (agitation), a volume of around 0.5 litre is transferred to a plastic bottle and sent to the laboratory for analysis. The tube must be cleaned after each set of samples to avoid contamination of the next sample.

The plastic bottle must be carefully labelled with sample identification, date, etc.

Bulked solids (e.g. from open containers)

6 – 8 samples of around 0.5 - 1 kg each are taken with the sampling shovel from different parts and levels of the container. The samples are combined, manually homogenised and split by quartering. The finished sample of around 1 kg (plastic bottle or bag) is adequately labelled and transferred to the lab.

The sampling shovel must be cleaned with a rag after each set of samples. The rags are disposed of in a separate waste bin.

Drums (200 litres)

Depending on the nature of the waste (liquid, pasty or solid), samples are taken with either the short sampling tube, the aluminium shovel or the spoon from each drum (around 0.125 litres each). One sample of around 1 litre per every eight drums is combined and homogenised. One finished sample of around 1 litre is blended and homogenised from several individual batches of eight drums and transferred to the lab. The remaining sample quantity is returned to a selected disposal drum.

Drums with liquid and pasty materials together in one shipment batch must be sampled separately. The prepared sample must be carefully labelled.

Cans (small volume)

A representative and random sampling of each load must be carried out. The sampling procedures correspond to the procedures applied in the sampling of drums.

Blended and homogenised samples of around 1 litre for each physical state (liquid, pasty, solid,) are transferred to the lab. Several spot samples should be kept for reference.

Due to the inherent problems in sampling heterogeneous wastes from a large number of small volume containers, it is recommended to add a secondary (automatic) sampling station prior to the pre-mixer of the blending installation.

Upon receipt in the laboratory, all samples are registered in a specific receiving log.

Storage of samples

Samples must be retained in carefully labelled and sealed bottles in a separate storage room close to the lab. The storage room must be equipped with adequate air ventilation, temperature/humidity control and an exhaust air filter system (active carbon) to the outside.

Duration of sample storage (if not otherwise specified in the operating permit):

- around 3 years for reference samples from the waste qualification tests
- around 3 months for daily delivery samples
- around 3 months for finished product or dispatch samples.

Parameters	Examples of analysis principles
Density	Weighing
Viscosity	Viscosimeter
Flashpoint	Open or closed cup
LHV	Calorimeters
Water content	Karl Fisher
pH	pH meters
Ash contents	Calcination at 900 – 975 °C
Chlorine	Calcination/titrimetry, ionic chromatography
Fluor	Calcination/potentiometry, ionic chromatography
Brome	Calcination/titrimetry, ionic chromatography
Iode	Calcination/titrimetry, ionic chromatography
Heavy metals	ICP, fluorescence X
PCB	GC/ECD
PCP	GC/ECD
Sulphur	ICP, fluorescence X, ionic chromatography, colorimetry
Alkalis	ICP, fluorescence X, atomic absorption
Compatibility test	Function of waste received

Table 3.161: Examples of parameters and analysis principles used in sampling [122, Eucopro, 2003], [150, TWG, 2004]

One of the most important measures is environmental monitoring by collecting samples of the environmental media and testing for the presence of hazardous substances that may have been released by the facility. The objective is to detect potential problems before they impact on human health and the environment. Early detection should allow sufficient time for the adequate warning of potentially affected individuals and allow effective implementation of remedial measures. Important monitoring points are groundwater wells for storage, land disposal facilities, and air monitoring stations at critical locations around the facility. Monitoring could also include surface water, employees (e.g. blood samples), and flora and fauna.

Air emission monitoring

Dust monitoring (for all types of substituted fuel production)

- channelled emissions: one control per year carried out at a certified laboratory
- air treatment systems: follow up of the efficiency of the cyclone and bag filters by pressure drop or opacity measures
- diffuse emissions of dust can be assessed by measurements with an owen gauge located on the site.

VOC monitoring

- odour: standardised tests for odour detection (e.g. EN 13725, European Reference Odour mass, EROM) can be used to identify the influence of the process on neighbours and on the workers environment. Bag samples may also be made for qualification and quantification of the pollutants in a laboratory
- diffuse emissions: diffuse emissions are measured inside and outside workshops by taking samples. Quantitative and qualitative analyses can be carried out
- channelled measures: VOCs are measured either continuously by a FID system or according to spot measurements campaigns. These conditions are defined in the permit.

Noise monitoring

Due to the relatively low noise level, no specific monitoring is usually requested. But, measures can be carried out for workers health and safety and especially for environmental impact evaluation, notably when new equipment is commissioned.

4 BEI DER FESTLEGUNG DER BVT ZU BERÜCKSICHTIGENDE TECHNIKEN

In diesem Kapitel werden Techniken dargestellt, die in den Anwendungsbreich des Dokuments fallen, und die nach einer allgemeinen Betrachtung das Potential dazu haben, ein hohes Umweltschutzniveau zu erreichen.

Enthalten sind Managementsysteme, prozessintegrierte Techniken und end-of-pipe Maßnahmen, die sich aber zur Erreichung der optimalen Ziele in einem gewissen Maß überschneiden. Vermeidung, Kontrolle, Minimierungen und Recyclingprozesse sind ebenso berücksichtigt wie die Wiederverwendung von Materialien und Energie.

Techniken werden einzeln oder in Kombination vorgestellt, um die Ziele von IVU zu erreichen. Anhang IV der Richtlinie enthält eine Liste allgemeiner Erwägungen, die bei der Bestimmung von BVT berücksichtigt werden müssen. Die Techniken in diesem Kapitel werden jeweils eine oder mehrere dieser Erwägungen ansprechen. Für die Darstellung der einzelnen Techniken wird soweit wie möglich eine Standardstruktur verwendet, um somit einen Vergleich der Techniken und eine objektive Bewertung im Rahmen der Definition von BVT in der Richtlinie zu ermöglichen.

Der Inhalt dieses Kapitel ist keine abschließende Liste von Techniken. So können andere existieren oder in Entwicklung sein, die im Rahmen von BVT gleichermaßen gültig sein können.

Im allgemeinen wird eine Standardstruktur verwendet, wie sie in Tabelle 4.1 beschrieben wird, um jede einzelne Technik zu beschreiben.

Bezeichnung der Art der Informationen	***Art der enthaltenen Informationen***
Beschreibung	Technische Beschreibung der Technik
Erreichter Nutzen für die Umwelt	Wichtigste Umweltauswirkung(en) der (Prozess- oder Minderungs-) Technik, darunter Emissionswerte (normalerweise als Bereich) und Effizienz. Umweltvorteile der Technik im Vergleich zu anderen
Medienübergreifende Auswirkungen	Alle Nebeneffekte und Nachteile für andere Umweltmedien, die die Anwendung der Technik verursacht. Umweltprobleme der Technik im Vergleich zu anderen und Möglichkeiten zu deren Vermeidung oder Lösung
Betriebsdaten	Daten über Emissionen/Abfälle und Verbrauch (von Rohmaterialien, Wasser und Energie). Weitere nützliche Informationen über Betrieb, Wartung und Überwachung der Technik, einschließlich Sicherheitsaspekte und Anwendungsbeschränkungen der Technik
Anwendbarkeit	Technisch-ökonomische Anwendbarkeit. Berücksichtigung des Anlagenalters (Alt- oder Neuanlage), der Anlagengröße (groß oder klein) und zu berücksichtigende Faktoren bei der Nachrüstung (z.B. Platzbedarf). Informationen darüber, welche Abfallbehandlung im Einzelfall angewendet werden kann, sind ebenso enthalten.
Wirtschaftlichkeit	Informationen über Kosten (Investitions- und Betriebskosten) und Ersparnisse (z.B. verminderter Verbrauch von Rohmaterialien, verringerte Abfallgebühren) bezogen auf die Anlagenkapazität (z.B. EUR/Mg). Werte in Nicht-EURO-Währungen wurden nach den mittleren jährlichen Umrechnungsfaktoren von 2002 umgerechnet. In solchen Fällen sind die ursprünglichen Kostendaten mit Jahr und Währung auch (in Klammern) enthalten.
Anreize zur Anwendung	Lokale Bedingungen oder Anforderungen, die zur Anwendung der Technik geführt haben. Informationen über nicht umweltbedingte Gründe für deren Anwendung (z.B. Verbesserung der Produktqualität, verbesserte Ausbeute oder Erträge).
Beispielanlagen	Bezug auf Anlagen, die die Technik in Europa und im Rest der Welt anwenden. Wenn die Technik bis lang noch nicht im betrachteten Bereich oder in der EU angewendet wurde, eine kurze Erklärung der Gründe
Referenzliteratur	Literaturquellen für detailliertere Informationen zur Technik

Tabelle 4.1: Aufschlüsselung der Informationen zu jeder in Kapitel 4 beschriebenen Technik

Wenn möglich werden in diesem Kapitel Informationen über derzeit durchgeführte oder in der Umsetzung befindliche Aktivitäten in diesem Sektor, einschließlich der damit verbundenen Kosten, aufgeführt. Wo immer es möglich ist, geben die bereitgestellten Informationen Zusammenhänge an, in denen die Technik effektiv angewendet werden kann.

Gliederung des Kapitels

Wie in den vorhergehenden Kapiteln 2 und 3 behandelt jeder Abschnitt dieses Kapitels eine spezifische Tätigkeit der Abfallbehandlung und führt die Prozess- und Minderungstechniken auf, die bei der Bestimmung von den BVT berücksichtigt werden. Wenn verschiedene Prozesstechniken für eine Tätigkeit angewendet werden können, werden sie innerhalb der einzelnen Abschnitte erörtert. Die Abschnitte 4.1 bis 4.5 des Kapitels wurden gleich strukturiert, d.h. der Abschnitt führt zuerst Emissionsvermeidungstechniken auf, die für den spezifischen Prozess/Aktivität anwendbar seien können, und zweitens die end-of-pipe Techniken die zur Verringerung der Emissionen aus diesem Prozess/Aktivität angewendet werden können.

Diese end-of-pipe (EOP) Techniken werden auf Basis von Medien/Schadstoffen geordnet, um die Reihenfolge der anwendbaren Techniken zu klären, da in einigen Fällen die Anzahl anwendbarer end-of-pipe Techniken ziemlich umfangreich ist.

Die Struktur sollte nicht als Versuch einer Leitlinie interpretiert werden, ob eine Abfallbehandlung einer Verwertung (R) oder Beseitigung (D) nach der EU-Abfallgesetzgebung entspricht.

Am Ende dieses Kapitels werden drei Abschnitte aufgeführt, die end-of-pipe Techniken für Abgas, Abwasser und prozessbedingte Abfälle aufführen.

Diese Abschnitte beschreiben „übliche“ end-of-pipe Techniken, die für mehr als einen Prozess/Aktivität anwendbar sind. Folglich befinden sich die Beschreibungen dieser end-of-pipe Techniken in ihren eigenen Abschnitten, d.h. in den Abschnitten 4.6, 4.7 und 4.8, nicht aber in den davon getrennten Abschnitten über Prozesse/Aktivitäten.

In einigen Fällen werden Techniken/Verfahren zusammen gruppiert und unter derselben Überschrift analysiert. Das ist das Resultat des Findens eines Gleichgewichtes zwischen den notwendigen Informationen zur Bestimmung von BVT und einem nutzerfreundlichen Umfang.

Zum Beispiel enthält dieses Dokument zahlreiche Informationen zu Annahmeprozeduren, die in Abfallbehandlungsanlagen angewendet werden. Für diese Fälle wurde entschieden, alle jene Verfahren unter derselben technischen Überschrift zusammenzufassen und dann alle verwandten Punkte/Themen unter dieser Überschrift zu diskutieren. Ohne diese Herangehensweise wäre dieses Dokument wesentlich umfangreicher und es würden viele Wiederholungen auftreten.

4.1 Bei der Festlegung der BVT zu berücksichtigende übliche Techniken

In diesem Abschnitt werden Techniken aufgeführt, die aus Sicht der Umwelt ein gutes Betriebsverhalten besitzen (z.B. Verwendung eines guten Energiesystems) oder die zu einer guten Umweltperformance führen können (z.B. Umweltmanagementsysteme). Die Mehrheit dieser Techniken wird auf Anlagenebene angewendet und bezieht sich nicht speziell auf einen der einzelnen Prozesse, die in den Abschnitten 4.2 bis 4.5. beschrieben werden.

4.1.1 Techniken zur Verbesserung der Kenntnisse über den Abfallinput

Dieser Abschnitt deckt jene Techniken ab, die dem Betreiber helfen, den zu behandelnden Abfall-Input zu charakterisieren. Die Strenge, mit der die Charakterisierung durchgeführt wird, ist essentiell für nachfolgende Abfallbehandlungsverfahren. Das Versäumnis einer adäquaten Überprüfung der Abfallproben vor Annahme und einer Bestätigung der Zusammensetzung bei Ankunft auf der Anlage hat in der Vergangenheit oft zu Folgeproblemen geführt, einschließlich einer unangemessenen Lagerung und Vermischung von unvereinbaren Substanzen, eine Anreicherung von Abfällen sowie einer unpassenden[1] Behandlung und folglich zu unvermuteten Emissionsprofilen.

4.1.1.1 Charakterisierung der Abfallzusammensetzung

Beschreibung
Die verschiedenartige Natur der Abfallindustrie und die großen Unterschiede der in jedem Wirtschaftszweig erzeugten Abfälle führen dazu, dass Abfälle, die in den Anlagen behandelt werden, nomalerweise variieren. Abfälle bestehen aus komplexen Mischungen zuweilen unbekannter Bestandteile. Aus diesem Grunde ist es wichtig, ein verbessertes Wissen über die Hauptbestandteile sowie ebenso über die Herkunft zu haben. Neben der direkten Bestimmung der Abfallzusammensetzung, z.B. mittels Abfallanalysen, gibt es andere indirekte Herangehensweisen, darunter:

- die Analyse von Marktforschungsdaten. Bei dieser Technik wird der Schwerpunkt auf produzierte Güter gelegt. Dabei wird vorausgesetzt, dass alle Güter früher oder später zu Abfall werden. Unter Berücksichtigung bestimmter Einflussfaktoren ist es zum Beispiel durch Nutzung der Marktforschung möglich, die Menge an Gütern zu bestimmen, welche als Siedlungsabfall enden. Eine ähnliche Methode kann verwendet werden, indem man den Input in private Haushalte betrachtet.
- die Analyse des Outputs der Abfallbehandlung[2]. Nach dem Gleichgewichtsprinzip ist der elementbezogene Input gleich dem elementbezogenen Output. Bei Betrachtung der Produkte[3] von Abfallbehandlungen, sollte es möglich sein, die stoffliche Zusammensetzung des Abfallinputs anhand von Routinemessungen zu bestimmen.
- zusätzlich ist zu erwähnen, dass es selbstverständlich einige Abfälle gibt, die aus einer Mischung von Abfällen zusammen gesetzt sind und die schon an der Anfallstelle gemischt wurden. Normalerweise kennt der Abfallerzeuger die Zusammensetzung dieses Abfallstroms. Wenn der Abfallerzeuger ein gutes Abfallmanagementsystem verwendet, wird er den Abfallsammler über die Abfallzusammensetzung informieren. Dieses ist wichtig, weil die Einstufung und Identifizierung des Abfalls nicht als erstes dem Abfallsammler überlassen werden soll, sondern in erster Linie in der Verantwortung des Abfallerzeugers liegt. Dieses System steht in direkter Verbindung mit dem in Abschnitt 4.1.2.9 aufgeführten System.

Indirekte Analysemethoden zur Bestimmung der Abfallzusammensetzung können eine Ergänzung zu direkten Analysemethoden sein. Einige Techniken, die besonders in Betracht zu ziehen sind, werden in der folgenden Tabelle 4.2 aufgelistet:

[1] Anm.d.Übers.: Im Originaltext wird von „unerwarteten“ Behandlungen gesprochen.
[2] Anm.d.Übers.: Hiermit ist die sogenannte “Abfall-Produkt-Anlayse” gemeint, die im folgenden Kapitel „Anwendbarkeit“ noch mal aufgeführt wird.
[3] Anm.d.Übers.: Mit „Produkte“ werden hier die Outputs der Abfallbehandlungsanlagen beschrieben.

Technik	Informationen
Identifikation der Hauptbestandteile	Wenn die Hauptbestandteile des Abfallstroms bekannt sind, ist es möglich, ihm ein "hohes", "mittleres" oder "niedriges" Emissionspotential zuzuweisen. Ein Beispiel dafür könnte die Bewertung anhand der Flüchtigkeit der Bestandteile laut den Angaben des Abfallerzeugers sein.
Identifizierung der Abfallherkunft	Die Kenntnis der Herkunft des Abfalls (z.B.Farbenindustrie, pharmazeutische Industrie, Automobilindustrie) liefert gute Anhaltspunkte über mögliche Bestandteile des Abfalls. Dies gestattet die Anwendung einer einfacheren Methode zur Einstufung des Abfalls. Das EAV verwendet dieses System. Doch sind die verfügbaren Daten normalerweise unzureichend, um diese Methode zurzeit zu entwickeln. Es wäre nötig, mehr zu forschen, um die üblichsten Quellen der Abfallströme, deren Zusammensetzung und die Konsistenz dieser Zusammensetzung zu erfassen
Kenntnis des Organik-Gehalts des Abfalls	Einige farbmetrische Methoden können z.B. einen Hinweis auf den Organikgehalt der angelieferten Abfälle geben. Dennoch sind diese nicht geeignet für organische Lösemittel (in solchen Fällen ist Gaschromatographie geeigneter)
Sicherstellung adäquaten Wissensaustauschs zwischen den Abfallbesitzern	Wie mit anderen Abfallströmen ist eine entscheidende Kontrollmaßnahme die Sicherstellung eines adäquaten Wissensaustauschs zwischen den Abfallbesitzern. Dies sollte gewährleisten, dass die Bestandteile von Abfällen, die zusammen geführt wurden, um ein Gemisch zu bilden, bekannt und aufgezeichnet sind.

Tabelle 4.2: Techniken zur Charakterisierung der Abfallzusammensetzung
[56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

Die Art der Untersuchungsmethode zur akkuraten Charkterisierung des Abfalls ist abhängig von der Natur des Abfalls selbst, dem genutzten Prozess und den bereits vorliegenden Kenntnissen über den Abfall. Die Ergebnisse aller Untersuchungen müssen innerhalb des Überwachungssystems aufbewahrt werden. Die Angaben können Informationen enthalten über:

- Überprüfungen hinsichtlich der Bestandteile, die der Abfallerzeuger/-besitzer deklariert hat um sicher zu stellen, dass der Abfall zur Genehmigung, für die Spezifikationen der Behandlungsanlage und endgültige Beseitigungsoption passt. Diese Überprüfung beinhaltet auch die Prüfung der Anwesenheit von jeglichen Bestandteilen, die potentiell einen schädigenden Einfluss auf den Behandlungsprozess haben können.
- alle gefährlichen Charakteristika (z.B. Entflammbarkeit, Explosivität, Infektiosität)
- physikalisches Erscheinungsbild (z.B. Konsistenz)
- Bewertung der Kompatibilität (z.B. Reaktionen mit Wasser und anderen Stoffen)
- Farbe
- Azidität und Basizität
- Bewertung von Anwesenheit, Stärke und Beschreibung von Geruch
- Anwesenheit von Oxidantien
- TOC
- CSB
- Ammoniak
- Flammpunkt und Verbrennungseigenschaften unter normalen Bedingungen
- Anwesenheit von Sulfid(en)
- Anwesenheit von Cyanid(en)
- Halogenhaltige Bestandteile
- Schwefel
- Metalle (z.B. Schwermetalle)
- VOCs
- POPs (z.B. PCBs).

Eine Liste von Parametern, die bei der Erzeugung von Brennstoff aus gefährlichen Abfällen analysiert werden können, werden in Tabelle 4.3 gezeigt.

Parameter	Vor-Annahme	Annahme	Aufbereitung von Brennstoff aus Abfall [1]	Dispatch
Dichte	Ja	Optional	Optional	Optional
Viskosität	Optional	Optional	Optional	Optional
Flammpunkt	Ja	Ja	Optional	Ja
Hu	Ja	Ja	Ja	Ja
Dampfdruck	Optional	Optional	Optional	Optional
Wassergehalt	Ja	Ja	Optional	Ja
pH	Ja	Ja	Optional	Ja
Aschegehalt	Ja	Optional	Optional	Ja
Aschezusammensetzung	Optional	Optional	Optional	Optional
Chlor	Ja	Ja	Ja	Ja
Fluor	Optional	Optional	Optional	Optional
Brom	Optional	Optional	Optional	Optional
Jod	Optional	Optional	Optional	Optional
Schwermetalle • Flüchtig (Cd, Hg, Tl) • Sonstige	 Ja Ja	 Ja Ja	 Optional Optional	 Ja Ja
PCB	Ja	Ja	Optional	Ja
Pentachlorphenol (PCP)	Optional	Optional	Optional	Optional
Schwefel	Ja	Optional	Optional	Optional
Alkalien	Optional	Optional	Optional	Optional
Korrosionstest	Optional	Optional	Optional	Optional
Kompatibiltätsstest	Ja	Ja	-	-
Radioaktivität	Optional	Ja	-	Optional

Anmerkungen:
[1] abhängig von der Art der Produktion
Optional abhängig von Abfallart, Betriebsprozessen (flüssige oder feste Brennstoffherstellung) und entsprechend den Anforderungen der Endnutzer
Kursiv Mindestanforderungen an die Überwachung im Standardprozess

Tabelle 4.3: Liste der Untersuchungsparameter, die üblicherweise bei der Brennstoffherstellung aus gefährlichen Abfällen berücksichtigt werden
[122, Eucopro, 2003]

Gute Annahmekriterien enthalten üblicherweise die Kenntnis folgender Parameter für Altöle.

Parameter	Annahme	Abfertigung
Wassergehalt	Ja	
Feststoffgehalt	Ja	
Flammpunkt	Ja	
Destillationskurve	Ja	
PCB	Ja	
Gesamt-Cl	Ja	
S	Ja	
Pb, Cr, V, Cu, Ni	Ja	
Synthetische Ester und Fettöle	Ja	
Farbe		Ja
Viskosität		Ja
Viskositätsindex		Ja

Tabelle 4.4: Liste typischer Analyseparameter für die Aufbereitung von Altöl
[42, UK, 1995], [55, UK EA, 2001], [119, Watco, 2002]

Erreichter Nutzen für die Umwelt

Es verbessert die Kenntnis hinsichtlich potentieller Umweltprobleme im Zusammenhang mit den zu behandelnden Abfall und verringert das Risiko von Unfällen und ungünstigen Betriebsabläufen.

Medienübergreifende Auswirkungen
Nicht bekannt.

Betriebsdaten
Auf den Anlagen werden orientierende Tests durchgeführt, um zu bestätigen, dass der Abfall innerhalb der erlaubten Anlagenparameter liegt. Hierbei können jedoch normalerweise nicht alle potentiellen Kontaminationen im Abfallstrom identifiziert werden. Deshalb ist die Charakterisierung durch Abfallerzeuger und Betreiber von Abfallbehandlungsanlagen Teil der Allgemeinen Anforderung für alle Standorte und liefert eine Anleitung für effektive Untersuchungsmethoden. Zum Beispiel dauert eine vollständige Analyse für Altöle etwa zwei Stunden.

Anwendbarkeit
Diese Methode ist vollständig anwendbar für alle Abfallbehandlungsanlagen die Abfall annehmen. Der Nachteil der „Abfall-Produkt-Analyse“ besteht in der Tatsache, dass eine vollständige Bestimmung der Materialien im allgemeinen nicht erreicht wird.[4] So ist es z.B. nicht möglich, den Gehalt an Papier, Kunststoff oder organischen Subtstanzen aus der Zusammensetzung[5] von Verbrennungsrückständen zu ermitteln.

Diese Methode ist begrenzt auf die Analyse der elementaren Zusammensetzung wie etwa der Parameter wie Energiegehalt, Wassergehalt und Gehalt an anorganischen und organischen Bestandteilen.

Wirtschaft
Eine Schätzung zeigt, dass Investitionen für die analytische Ausrüstung einer Altölaufbereitungsanlage im Bereich von 75000 EUR (50000 GBP) pro Standort liegen.

Anreize zur Anwendung
Eine gute Durchführung verringert prozessbezogene und ökonomische Risiken. Der Wasser- und Feststoffgehalt wird in Altölen für Qualitäts- und Vergütungszwecke untersucht. Zum Teil wurde dies durch Qualitätsanforderungen duch Nutzer der aufbereiteten Öle angeregt. Allerdings handelt sich nicht um einheitliche Anforderungen.

Beispielanlagen
Die Analysen von Abfallbehandlungsprodukten werden in vielen Ländern angewendet. In manchen Fällen wird eine erste Eingangsanalyse durchgeführt.(z. B. auf Schwefel, Gesamtchlor, Wasser und Flammpunkt für die Altölaufbereitung). Wenn das Öl diese Tests durchlaufen hat, wird es isoliert, bevor weitere Analysen durchgeführt werden. Diese beinhalten die Messung der Viskosität und eine Infrarotanalyse zur Prüfung von bestimmten Verbindungen, darunter etwa synthetische Ester und Fettöle. Im Rahmen der Arbeit der CEN/TC 343, WG 2 ‘Specifications and classes’ finden sich weitere Informationen zu festen Brennstoffen aus Abfall. Ebenso befinden sich weiterreichende Informationen für Altöle im Abschnitt 4.5.1 dieses Dokuments.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [81, VDI and Dechema, 2002], [86, TWG, 2003], [119, Watco, 2002], [131, UBA, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

[4] Anm.d.Übers.: Eine „Abfall-Produkt-Analyse“ umfasst eine Analyse der Outputmateralien einer Abfallbehandlungsanlage, über deren Ergebnisse Aussagen über den Input gemacht werden können (Erklärung im Originaltext nicht vorhanden).
[5] Anm.d.Übers.: Elementarbezogen. Dieser Verweis ist im Originaltext nicht vorhanden.

4.1.1.2 Voruntersuchungen zur Bewertung, ob Abfall zur Lagerung und /oder Behandlung in der Anlage geeignet ist

Beschreibung
Systeme und Verfahren können eingesetzt werden, um zu gewährleisten, dass Abfälle einer angemessenen technischen Abschätzung unterzogen werden, um die Eignung des beabsichtigten Behandlungswegs zu gewährleisten. Einige Voruntersuchungsmethoden und -verfahren zur Bewertung von Abfällen sind:

a. Durchführung geeigneter Prüfungen, bevor eine Entscheidung zur Annahme des Abfalls getroffen wird
b. Durchführung eines ersten Screenings, das die Bereitstellung von Informationen und repräsentativen Stichproben des Abfalls beinhaltet. Der Abfallerzeuger sowie der Betreiber am Annahmestandort gewährleisten, dass verlässliche und umfassende Informationen bereitgestellt werden, um die Eignung des Abfalls für die in Frage kommende Behandlung (oder Verwertung) zu bestimmen. Dies kommt auch zur Anwendung, wenn Abfälle in der Anlage nur gelagert oder zusammengeführt werden sollen, so dass die Information an den nächsten Abfallbesitzer weitergegeben und der letztendliche Beseitigungsweg bestimmt werden kann.
c. Bereitstellung von Einzelheiten über die Art des/der Prozesses/e, in denen der Abfall erzeugt wird, einschließlich Prozessschwankungen. Da die Umstände der Abfallerzeugung variieren, ist eine fundierte professionelle Beurteilung erforderlich, um zu gewährleisten, dass die relevanten Fragen gestellt werden. Betreiber müssen gewährleisten, dass die technische Abschätzung durch geeignetes, qualifiziertes und erfahrenes Personal durchgeführt wird, das die Möglichkeiten der Anlage versteht. Diese Mitarbeiter sollten unabhängig vom Verkaufspersonal sein, welches für die Kundengeschäfte zuständig ist.
d. Bereitstellung der chemischen Zusammensetzung des Abfalls, der Anforderungen an seine Behandlung und seiner Gefahren
e. Bereitstellung und Analyse repräsentativer Stichprobe(n) des Abfalls aus dem Produktionsprozess von dem derzeitigen Besitzer
f. Durchführung einer umfangreichen Charakterisierung des Abfalls bei jeder neuen Anfrage
g. Einfordern einer Verifizierung der vom Abfallbesitzer gelieferten schriftlichen Informationen. Dies kann einen Besuch beim Abfallerzeuger erforderlich machen, da beim direkten Umgang mit dem in der Abfallerzeugung involvierten Personal zusätzliche Faktoren sichtbar werden können.
h. Sorgfältige Verifizierung der bei der Voruntersuchung erhaltenen Informationen, einschließlich der Details des Abfallerzeugers sowie der vollständigen Beschreibung des Abfalls hinsichtlich seiner Zusammensetzung und Gefährlichkeit. Dies kann auch durch direkten Umgang mit dem Abfallerzeuger durchgeführt werden.
i. Aufbewahrung aller Aufzeichnungen der Voruntersuchungen auf der Anlage, damit sie für Verweise und eine Prüfung bei der Abfallannahme zu Verfügung stehen. Die Dauer der Aufbewahrung der Aufzeichnungen muss festgelegt werden. Die erfolgt unter Berücksichtigung ob der Abfall derzeit an der Anlage angeliefert wird, oder wann es voraussichtlich soweit ist.
j. Anwendung von Geruchskriterien, um Mercaptane, Amine mit niedrigen Molekulargewicht, Acrylate oder sonstige geruchsintensive Stoffe zurückzuweisen, die nur zur Annahme unter besonderen Handhabungsbedingungen geeignet sind.
k. Bereitstellung und detaillierte Prüfung der Abfallschlüsselnummern nach dem Europäischen Abfallverzeichnis (EAV)
l. Anfrage an den Betreiber der Abfallbehandlungsanlage, ob die in Frage kommende Anlage zur Behandlung des beschriebenen Abfalls zugelassen ist und ob der Anlagenbetreiber auf die Annahme der Abfälle vorbereitet ist (siehe Kommentare in dem Kapitel zu den Betriebsangaben)
m. Durchführung einer Maßnahme der Risikobewertung
n. Ausstellung einer Annahmeerklärung durch den Betreiber der Abfallbehandlungsanlage, die alle notwendigen Voraussetzungen und Maßnahmen beschreibt, die der Kunde (z.B. der Abfallerzeuger) beachten muss. Ebenso sollen alle internen Vorschriften innerhalb der Anlage, in der der Abfallstrom behandelt wird, gleichzeitig in schriftlicher Form niedergelegt werden.

Erreichter Nutzen für die Umwelt
Diese Methoden können Betreibern helfen, Abfälle zu identifizieren und bei ungeeigneten Abfällen, die zu nachteiligen Reaktionen oder unkontrollierten Emissionen während der Abfallbehandlung führen können, diese auch abzulehnen. So wird gewährleistet, dass nur Abfall, der für die jeweilige Abfallbehandlung geeignet ist, am betreffenden Standort angenommen wird.

Bisherige Erfahrungen mit diesen Methoden haben gezeigt, dass man sich alleine auf diese Methoden nicht verlassen kann, um immer ausreichende Informationen zu bekommen. Es ist nicht unüblich, dass zwischen Abfallerzeuger und Betreiber ein Dritter und in manchen Fällen sogar drei oder vier Beteiligte stehen. Dabei kann es sich um Transportunternehmer, Makler oder um Betreiber von Umladestationen handeln. Bei einer langen Kette können Informationen verloren gehen oder ungenau wiedergegeben werden. Dennoch erlauben diese Methoden den Betreibern, die Eignung des Abfalls vor der Behandlung festzulegen, bevor Vorbereitungen zur Annahme des Abfalls getroffen werden. Andere Vorteile umfassen:

- die Bereitstellung von Informationen hält die Anzahl der Verknüpfungen in der Informationskette niedrig. Dies hilft Informationsverluste oder falsche Darstellungen zu vermeiden.
- die Hilfe für den Betreiber, ungeeignete Abfälle herauszufinden und damit potentielle Probleme zu vermeiden
- die Bestätigung der detaillierten Zusammensetzung, die es gestattet, eine Anzahl der Überprüfungsparameter zu identifizieren, um den Abfall bei der Ankunft am Standort kontrollieren zu können
- die Hilfe zur Identifikation von Abfallinhaltsstoffen, die den Behandlungsprozess beeinträchtigen oder mit anderen Stoffen reagiern könnten
- die Hilfe zur genauen Bestimmung der Risiken, die vom Abfall ausgehen
- die Identifizierung von Substanzen im Abfall, die durch den Abfallbehandlungsprozess möglicherweise nicht umgewandelt werden und die deswegen in unveränderter Form im Rückstand oder im Abwasser zu finden sind
- eine Hilfe zur Bestimmung der Kosten der beabsichtigten Beseitigung
- die Gewährleistung der Erfüllung gesetzlicher Vorschriften (abhängig vom Land).

Medienübergreifende Auswirkungen
Diese leiten sich jeweils von der durchgeführten physikalisch-chemischen Analyse ab.

Im Zusammenhang mit der Technik k (siehe obige Beschreibung) geben Abfallschlüsselnummern in vielen Fällen nicht viele Informationen über die Zusammensetzung des eingestuften Abfalls. Abfälle derselben Abfallschlüsselnummer können völlig unterschiedliche Zusammensetzungen und Eigenschaften aufweisen.

Betriebsdaten
Enthalten sind Verwaltungs- und Laborarbeit.

Im Zusammenhang mit Technik c (siehe obige Beschreibung) gibt es Fälle, in denen die Zusammensetzung des Abfalls nicht festgestellt werden kann (u.a. bei der Sammlung von gefährlichen Abfällen aus Haushalten). In diesen Fällen müssen Unternehmer, die solche Abfälle sammeln und annehmen, die notwendige Erfahrung zum sicheren Umgang mit ihnen aufweisen.

Im Zusammenhang mit Technik k (siehe obige Beschreibung) ist es die Pflicht des Abfallerzeugers, über eine sachgemäße Abfallschlüsselnummer des EAV zu entscheiden. Dies ist nicht Aufgabe des Betreibers der Abfallbehandlungsanlage.

In einigen Fällen sollte die Überprüfung, auf die sich Technik 1 der obigen Beschreibung bezieht, vor dem ersten Kontakt mit dem Betreiber der Abfallbehandlungsanlage und der Voruntersuchungen und/oder vor der Unterzeichnung der Vereinbarung stattfinden.

Anwendbarkeit
Die Forderung nach der Charakterisierung des Abfalls, einschließlich der Probenahme und Analyse, bezieht sich gleichermaßen auf den Abfalltransport wie auch auf die Behandlungsanlagen. Oft besteht bei Dritten ein Unwille, die Identität des Abfallerzeugers preiszugeben, da dies von geschäftlichem Nutzen sein kann. Dennoch kann dies nicht die grundsätzliche Anforderung an den Betreiber aufheben, die Informationen des Abfallerzeugers (und nicht nur die des augenblicklichen Besitzers) über den Abfall zu überprüfen. Denn der Erzeuger ist natürlicherweise in der besten Position den Abfall zu verifizieren. Einige Anwendungsbeispiele werden im Folgenden dargestellt:

Voruntersuchungen für die Altölaufbereitung

Als allgemeine Anforderung ist dieser Schritt für eine Altölaufbereitungsanlage nicht entscheidend, aber man würde ihn fordern, wenn der Abfall zum Beispiel zur Behandlung in einer Raffinerie bestimmt ist. Normalerweise kommt der Abfall von einer großen Anzahl kleiner Quellen, wie etwa Kfz-Werkstätten, aber seine Zusammensetzung ist im Wesentlichen gleichbleibend.

Voruntersuchungen, zur Sammlung von Informationen, müssen bei einen einmaligem Aufkommen von Altöl mit industrieller Herkunft durchgeführt werden und ebenso bei Herkünften in denen andere Chemikalien und potentiell verunreinigende Substanzen verarbeitet werden, zum Beispiel in der chemischen Industrie. Verunreinigungen von Altöl durch Substanzen wie etwa Lösemittel kommen vor und obwohl sich der Betreiber auf relativ geringe Verunreinigungen insofern einstellen kann, dass sie den Verkauf des aufbereiteteten Öls nicht beeinträchtigen, muss die Verunreinigung ermittelt werden. Lösemittel mit niedrigem Flammpunkt führen zu Verarbeitungsproblemen, wenn die Anlagen nicht dafür ausgelegt ist, mit entflammbaren Materialien umzugehen. Oft liegen Verunreinigungen mit Benzin vor. Diese setzten den Flammpunkt des Materials deutlich herunter und erhöhen somit das Unfallrisiko beträchtlich. Eine geeignete Methode der Flammpunktbestimmung sollte sorgfältig ausgewählt und interpretiert werden. Lösemittel werden auch im Aufheizprozess freigesetzt, woraus steigende VOC-Emissionen resultieren. Durch Verunreinigungen mit PCBs können PCBs entweder ins Produkt übertragen werden, welches bei einer Nutzung in Verbrennungsprozessen zu erhöter Dioxinbildung führen kann, oder in den Ölschlämmen des Tankbodens oder aber ins Abwasser.

Voruntersuchungen bei Laborabfallkleinmengen
Wenn Fässer für Laborabfälle benutzt werden, wird eine Liste der Inhaltsstoffe erstellt und unter dem Deckel im Fass beigelegt. Genauso wird für andere Arten von Verpackungen, die Laborabfallkleinmengen enthalten, eine Liste des Inhalts erstellt und in angemessener Weise in oder an das Gebinde befestigt. Jedes bepackte Fass (oder andere Gebinde) wird dann nach den Gefahrgutvorschriften für den Transport (u.a. ADR) beschriftet. Das Niveau der Überwachung oder des Managements für diesen Fall hängt von mehreren Faktoren ab. In jedem Fall muss eine vollständige Liste über den Inhalts erstellt werden. Betreiber, die von ihren Kunden verpackte Abfälle annehmen, stellen ihren Kunden üblicherweise Verpackungsanweisungen zur Verfügung. Abfallerzeuger benötigen schriftliche Anweisungen zur Trennung, der Verpackung und Kennzeichnung von Laborabfallkleinmengen.

Festlegung des Untersuchungsrahmens für chemisch-physikalische Behandlungsanlagen
Standorte von CP-Anlagen müssen eine Studie zur Festlegung des Untersuchungsrahmens durchführen, um Stoffe zu identifizieren, die nicht durch das Abwasserüberwachungsprogramm abgedeckt sind, aber am Standort angenommen werden. Die wichtigsten zu berücksichtigenden Abfälle sind:

- Wässrige Abfälle die Lösemittel enthalten, die aufgrund der Prozesswärme emittiert werden können
- Abfälle mit hohem Stickstoffgehalt, die ein Potential für Ammoniakemissionen in die Luft besitzen
- Phosphorhaltige Abfälle: Nicht alle Standorte sind verpflichtet, den Gesamt-Phosphor-Gehalt regelmäßig zu überwachen, folglich kann es an diesen Standorten einfacher sein, die Emissionen über die Aufnahme von Phosphorsäure abzuschätzen.
- Gelegentlich anfallende anorganische Abfälle, wie z.B. arsenhaltige Abfälle. Auch hier wird es in den meisten Fällen einfacher sein, die jährlichen Emissionen aus den gelegentlichen Abfallinputdaten zu berechnen, als das Überwachungsprogramm auszuweiten.

Wirtschaftlichkeit
Zusätzliche Verwaltungskosten (z.B. durch Verpackung und Beschriftung).

Anreiz zur Anwendung
Üblicherweise sind diese Verfahren in der nationalen Gesetzgebung verschiedener Länder, in Anleitungen oder in Genehmigungsbescheiden der Anlagen aufgeführt. Oft sind auch die chemischen Bestandteile und Parameter definiert, die untersucht werden müssen.

Die Probenahme aus heterogenen Abfällen ist besonders schwierig und erfordert erfahrene Anlagenbetreiber. Die Arbeiten der CEN TC 292 oder die deutschen LAGA-Papiere über die Abfallprobenahme können Anleitungen bieten.

Beispielanlagen
Viele dieser Methoden werden in der Abfallbehandlungsbranche üblicherweise genutzt. Zum Beispiel verlangt ein Betreiber von chemisch-physikalischen Behandlungsanlagen in Großbritannien von allen Kunden die Vorlage einer genauen Abfallbeschreibung und einer Abfallprobe, die vor der Annahme am Standort analysiert wird. Die Standorte müssen die Abfallzusammensetzungen kennen, damit sie ein geignetes Endprodukt herstellen können, welches die Abwassereinleitungstandards einhält und einem deponierbaren Rückstand[6] entsprechen.

Literatur
[16, ÖWAV Working Commitee, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [131, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.1.3 Annahmeverfahren bei Ankunft des Abfalls an der Abfallbehandlungsanlage

Beschreibung
On-site Überprüfung und Übereinstimmungsstests müssen durchgeführt werden, um 1) die Identität des Abfalls, 2) die Beschreibung des Abfalls, und 3) die Übereinstimmung mit Informationen der Voruntersuchung und der vorgeschlagenen Behandlungsmethode zu bestätigen. Einige Annahmetechniken und –verfahren (nach der Voruntersuchung), die zur Bewertung von Abfällen angewendet werden, sind in den folgenden Listen aufgeführt. Diese schließen ein:

a. Abfälle an der Anlage sind abzulehnen, sofern nicht eine klar definierte Behandlungsmethode und der Weg für eine Beseitigung/Verwertung festgelegt wurde und ausreichend Kapazitäten in der Anlage vor der Annahme des Abfalls verfügbar ist. Außer reinen Chemikalien und Laborabfallkleinmengen sollten keine Abfälle ohne Probenahme, Überprüfungen und Tests in der Anlage angenommen werden. Ein alleiniges Vertrauen auf bereitgestellte schriftlichen Informationen ist nicht akzeptierbar und eine physikalische Überprüfung und analytische Bestätigung ist erforderlich.

b. Ausführen von Probenahmeverfahren (siehe Abschnitt 4.1.1.4)
c. Für Abfallbehandlung und –transport sollte der größte Teils der Charakterisierungsarbeiten im Stadium der Voruntersuchung durchgeführt werden. Dies gewährleistet, dass mit den Annahmeverfahren bei Ankunft des Abfalls am Standort die Eigenschaften des Abfalls bestätigt werden können
d. Einführung von Maßnahmen zur vollständigen Dokumentation und zum Umgang mit akzeptierten Abfällen, wie etwa ein Vorbuchungssystem z.B. um zu gewährleisten, dass ausreichend Kapazität verfügbar ist
e. Durchsetzung von Anforderungen, dass mit den Abfällen Informationen zu der physikalischen und chemischen Zusammensetzung, der gefährlichen Eigenschaften, der Anwesenheit unverträglicher Substanzen und zu jeglichen Vorsichtsmaßnahmen zur Handhabung, mitgeliefert werden. Gefährliche Abfälle müssen auch von Übergabedokumenten begleitet werden, aus denen der ursprüngliche Abfallerzeuger hervorgeht.
f. Klare und unmissverständliche Kriterien für die Ablehnung von Abfällen und Berichterstattung über alle Nichtübereinstimmungen
g. Nutzung eines Labors zur Durchführung der Analysen mit geeigneten zertifizierten Untersuchungsmethoden
h. Detailierte Überprüfung der Abfallschlüsselnummer entsprechend dem Europäischen Abfallverzeichnis (EAV)
i. Nutzung eines Verfahrens zur Risikoabschätzung zur Auswahl und, wenn nötig, zur Analyse des Abfalls. Ein Beispiel wird im Abschnitt zu den Beispielanlagen aufgeführt.

[6] Anm.d.Übers.: Originaltext „cake“; wahrscheinlich ist ein Filterkuchen gemeint

Andere Aspekte, die von dem Annahmeverfahren betroffen sein können, sind:

- Wartezonen für Fahrzeuge, Kontrolle der Ladung, Probenahmestellen und Entladungsbereiche
- Verkehrskontrollen
- Verfahren zu Prüfung der Papiere, die mit der Ladung geliefert werden
- Verfahren für die Entladung zur Begutachtung und Probenahme
- Standorte ausgewiesener Probenahmestellen
- Visuelle/organoleptische Kontrolle der Ladung (bei manchen Ladungen, wie flüssigen Abfällen und gefährlichen Abfällen, kann dies möglicherweise nicht anwendbar sein)
- Verfahren zur Beschriftung von Fässern und Verpackungen
- Infrastruktur wie etwa Eindämmungen und Probenahmezonen
- Bewertung der Übereinstimmung mit den Informationen der Voruntersuchung und der vorgeschlagenen Behandlungsmethode
- Syteme zur Probenrückstellung, mit Blick auf die Bestimmung der angemessenen Dauer der Rückstellung
- Dokumentation zu Einzelheiten des Abfallerzeugers, Untersuchungsergebnissen und Behandlungsmethoden
- Prozeduren zur regelmäßig Überprüfung der Informationen der Voruntersuchung
- Abfertigungskonditionen

Erreichter Nutzen für die Umwelt
Diese zweite Annahmephase umfaßt Verfahren bei der Ankunft des Abfalls am Standort und dient zur Bestätigung der Eigenschaften des vor-akzeptierten Abfalls ohne den Zeitdruck und die potenziellen Gefahren bei der vollständigen Überprüfung des Abfalls im Eingangsbereich. Diese Techniken verhindern, dass ungeeignete Abfälle angenommen werden, die sonst zu nachteiligen Reaktionen oder unkontrollierten Emissionen führen könnten. Dieses Vorgehen gewährleistet somit die Eignung des angenommenen Abfalls für die Art der Abfallbehandlungsmaßnahme. Des Weiteren wird die Zeit minimiert in der das Fahrzeug, das den Abfall liefert, warten muss, was Probleme z.B. infolge von Unfällen oder Leckagen vermeiden kann. Diese Vorgehensweise verhindert auch, dass der Abfall zurückgewiesen und auf öffentliche Straßen zurückgeschickt wird.

Medienübergreifende Auswirkungen
Wie bei den Vor-Untersuchungsmethoden.

Betriebsdaten
Wie bei den Vor-Untersuchungsmethoden. In einigen Fällen kann es schwierig sein, eine angemessene Probenahme durchzuführen (z.B. Fässer mit benutzten und verunreinigten Kleidungsstücken oder Handschuhen).

Anwendbarkeit
Einige Anwendungsbeispiele aus der Industrie werden im Folgenden beschrieben:

<u>Altölaufbereitungsanlagen</u>
Üblicherweise legen diese Anlagen einen größeren Wert auf die letzte Annahmeuntersuchung, als auf die Phase der Vor-Untersuchung.

<u>Annahme von Laborabfallkleinmengen</u>
Die Verfahren bei der Annahme von Laborabfallkleinmengen auf der Anlage sind im Wesentlichen identisch mit denen für Abfälle die in Fässern angeliefert werden. Sie unterscheiden sich von ‘normalen’ Abfall-Inputs dadurch, dass sie in einer reinen, konzentrierten Form vorliegen. In Situationen, in denen der Betreiber die Identifizierung und Verpackung im Auftrag des Kunden durchgeführt hat, kann sich die Überprüfung an der Anlage darauf beschränken, die Fässer zu öffnen, um zu prüfen, ob die Behälter unbeschädigt sind. In solchen Fällen wird die Ladung von Dokumenten begleitet, die die Kontrolle und Verpackung bestätigen. In Fällen, in denen das Fass vom Kunden bepackt wurde, muss der Anlagenbetreiber eine adäquate vollständige Überprüfung durchführen. Die Kontrolle der Verpackungen und die Trennung umfasst eine Leerung des Fasses, die so bald wie möglich durchgeführt werden soll (zum Beispiel innerhalb einiger Tage), und die Wiederverpackung des Abfalls, sobald alle notwendigen Untersuchungen durchgeführt worden sind. Falls bei der Öffnung eines Fasses entdeckt wird, dass der Behälter unverträgliche Materialien enthält oder dass die Materialien nicht adäquat verpackt wurden, muss das Fass sofort sortiert sowie neu verpackt werden und die Prozeduren der Anlage bei Nicht-Übereinstimmung müssen folgen.

Chemisch-physikalische Behandlungsanlagen

Auf den Anlagen wird der Abfall bei Ankunft durch eine visuelle Inspektion und durch Probenahme überprüft. Die Probenahmesysteme variieren entsprechend des Umfangs der Analyse und der Häufigkeit der Probenahme. Hierbei kann es sich um einen einfache Überprüfung des Flammpunkts und des pH-Werts oder auch um eine Probenahme für eine schnelle Laborbestimmung der Bestandteile und des Metallgehalts und um eine grobe Überprüfung der Organik handeln. Die Häufigkeit der Probenahme wird teilweise durch die Abfallherkunft bestimmt: Die meisten Anlagen legen den Schwerpunkt ihrer Probenahme und Analytik auf unregelmäßige Abfallströme und verringern die Probenahmehäufigkeit bei Abfällen aus Prozessströmen, die regelmäßig angenommen werden.

	Prozentsatz der Anlagen, in denen diese Praxis angewendet wird (%)
Eingehauste Anlage oder auf völlig undurchlässigem Grund	77
Rückführung von Regenwasser (mit Ausnahme der Verwaltung, Gebäude, Dächer) und Tankwaschflüssigkeiten zur Anlage	77
Probenahme für größere Abfallströme oder von einem bestimmten Anteil	62
Wiegen des Inputs	54
Teilweise Abgaswäsche	38
Vollständige Abgaswäsche	15
Probenahme für alle Abfälle	8
Anmerkung: Die Daten beziehen sich auf 13 verschiedene untersuchte chemisch-physikalische Behandlungsanlagen	

Tabelle 4.5: Überwachungsprozeduren in chemisch-physikalischen Behandlungsanlagen [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Chemisch-physikalische Behandlungsanlagen müssen einen Teil der ankommenden Abfallströme überprüfen, wobei neue Abfallströme immer überprüft werden, und müssen angemessene Informationen über den angenommenen Abfall besitzen, um ihren Prozess effektiv zu betreiben. Die Anlagen benötigen Abfallproben, um vor Annahme des Abfalls in der Anlage erste Untersuchungen durchzuführen, des Weiteren führen sie Routineüberprüfungen durch, wenn der Abfall angeliefert wird.

Verbrauchte Katalysatoren

Die Materialien werden auf unerwartete Verunreinigungen und Kontaminationen überprüft, dies kann insofern kosteneffektiv sein, da ein saubereres Produkt beibehalten wird und Emissionen verringert werden.

Verbrauchte Aktivkohle

Zum Zwecke der Regeneration angenommene Aktivkohle muss als einzelne Charge betrachtet und untersucht werden, so dass die während der Behandlung zu desorbierenden Substanzen bekannt sind und bestätigt werden kann, dass die Anlage in der Lage ist, sie innerhalb der Vorgaben ihrer Genehmigung zu verarbeiten. Der Auftraggeber sollte die Arten der Verunreinigung der Aktivkohle, die zurückgewonnen werden soll, klar deutlich machen.

Wirtschaftlichkeit

Die Kosten zur Charakterisierung und Analyse der Abfälle zum Anlagenschutz sind üblicherweise hoch. So kann die Analyse eines Prüfstandversuchs, der den Einfluss des Abfalls auf die Abwasserbehandlung nachahmt, bis zu 3000 EUR (2000 GBP) kosten.

Anreiz zur Anwendung

Die Durchführung solcher Analysen wird im Allgemeinen durch die nationale Gesetzgebung und Genehmigungen geregelt. Die Gesetzgebung zu gefährlichen Abfällen zum Beispiel gewährleistet, dass Lagerung, Umschlag, Einstufung, Verpackung und Beschriftung des Abfalls korrekt durchgeführt werden.

Beispielanlagen

Angewendet im gesamten Abfallbehandlungssektor. Ein Beipiel für die Nutzung einer Methode zur Risikobewertung um eine Abfallanalyse auszuwählen und, falls nötig, durchzuführen ist im 1. Fall: Abfälle mit einer hohen Risikoeinstufung werden immer bei der Anlieferung untersucht; im 2. Fall: Abfälle mit einer niedrigen Risikobewertung werden gelegentlich auf Übereinstimmung mit den Daten der Vorabprüfung getestet.

Literatur
[29, UK Environment Agency, 1996], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [125, Ruiz, 2002], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.1.1.4 Probenahme

Beschreibung
Die Probenahme beruht normalerweise auf einer Risikobewertung, in der die Gefährlichkeit des Abfalls und die Informationen des vorherigen Abfallbesitzers berücksichtigt werden. Eine gute Probenahme berücksichtigt die folgenden Punkte:

a. den physikalischen Zustand des Abfalls (Homogenität/Heterogenität)
b. die Anzahl und Größe der Proben, wenn der Abfall nicht in Behältern angeliefert wird
c. die Anzahl und Größe der Proben, wenn Abfälle in Behältern angeliefert werden
d. Probenahmeprozeduren für alle angelieferten Abfälle, einschließlich Massenabfällen (flüssige und feste), Abfälle in Fässern und Containern sowie Laborabfallkleinmengen. Die Anzahl der gezogenen Proben steigt mit der Anzahl der Behälter. In Sonderfällen müssen alle kleinen Behälter mit den Begleitpapieren verglichen werden. Die Prozedur sollte ein System zur Aufzeichnung der Probenanzahl und dem Grad des Informationsstandes beinhalten.
e. ein System zur Gewährleistung, dass die Abfallproben untersucht werden
f. Details der Abfallprobenahme aus Fässern unter Angabe der vorgesehenen Lagerung, z.B. Zeitraum nach Annahme
g. Überprüfungs- und Übereinstimmungstests, um Identität und Beschreibung des Abfalls zu bestätigen
h. Aufbewahrung des Probenahmeprotokolls für jede Fracht auf der Anlage, zusammen mit der Begründung für die Wahl jeder Option
i. Probenahme von Abfällen aus Tanks vor der Annahme. Auf diesem Weg ist keine Lagerung der Abfälle vor der Probenahme notwendig
j. Rückstellproben werden auf der Anlage für eine bestimmte Zeit aufbewahrt (z. B. 0,5-2 Monate), nachdem der Abfall behandelt oder aus der Anlage entfernt wurde, einschließlich aller Reststoffe aus seiner Behandlung
k. Extern gezogene Proben oder Analyseergebnisse, d.h. der Fahrer des Fahrzeugs, der den Abfall auf der Anlage anliefert, führt eine bereits gezogenen Probe oder eine bereits durchgeführte Analyse mit sich. Das ist normalerweise eine Ausnahme und wird nur in Betracht gezogen, wenn:
    - wenn Gesundheits-, Sicherheits- und Umweltgesichtspunkte vorliegen, die eine Probenahme schwierig machen, z.B. mit Wasser reagierende Substanzen
    - die folgenden schriftlichen Informationen mit geliefert werden: physikalische und chemische Zusammensetzung, gefährliche Eigenschaften, Anwesenheit unverträglicher Substanzen, Vorsichtsmaßnahmen zum Umgang und Informationen über den Abfallerzeuger und den abfallerzeugenden Prozess.
    - wenn der Abfall direkt von der Produktionsanlage zur Abfallbehandlungsanlage verbracht wurde
    - das Probenahmepersonal eine geeignete Qualifikation und/oder Ausbildung vorweisen kann.

Einige spezielle Punkte, die bei der Probenahme von gemischten flüssigen Abfällen beachtet werden müssen sind:

l. Anlieferungen in Tankfahrzeugen können von einem Reinigungszertifikat oder einer Erklärung hinsichtlich der vorherigen Ladung begleitet werden, so dass eine Verunreingung über diesen Pfad überprüft werden kann
m. Proben werden normalerweise von einer der drei Stellen des Tankfahrzeugs genommen:
    - Obere Luke
    - Hinterer Schieber
    - Sichtglas

n. Die Kernanforderung besteht im Erhalt einer Probe, die repräsentativ für die Ladung ist. Das heißt, die Probe muss alle Variationen und Aufteilungen innerhalb der gemischten Ladung berücksichtigen, so dass worst-case-Szenarios berücksichtigt werden können. Eine Probenahme von der Oberfläche der Flüssigkeit, welche durch die obere Luke durchgeführt wird, muss nicht repräsentativ sein, aber kann nützlich bei der Bestimmung sein, ob es eine Schicht von z.B. einem Lösemittel oder einer anderen unmischbaren Substanz gibt, die für die Behandlung ungeeignet ist. Von oben gezoge Proben müssen einen Querschnitt der Ladung abbilden, das heißt, es sollte eine Kernprobe genommen werden.
o. Brücken können errichtet werden, um die Notwendigkeit zu umgehen, Proben vom hinteren Schieber der Tankfahrzeuge zu nehmen, was etwa zu kleinen Verschüttungen führen kann.

Für die Probenahme von Abfall aus Fässern (abhängig vom Typ des Gebindes) sind folgende spezifische Punkte zu beachten:

p. Die Inhaltsstoffe können nur mit Sicherheit bestimmt werden, wenn jeder Behälter beprobt wird. Für die Annahme der Abfälle wird deshalb die Beprobung jedes Behälters vorausgesetzt, doch die Analyse einer Mischprobe ist bei diesem Probenahmesystem im allgemeinen akzeptabel. Eine repräsentative Probe wird erzielt, indem eine Kernprobe vom Boden des Containers gezogen wird.
q. Deckel, Pfropfen und Ventile müssen unmittelbar nach der Probenahme wieder eingesetzt werden
r. Visuelle Kontrollen aller Behälter und des Probenahmeverfahrens müssen unter Aufsicht des Betreibers festgelegt werden.
s. Nutzung der Öffnung, für visuelle Kontrolle und geeignete Probenahme aller Fässer ab einem bestimmten Volumen, z.B. von mehr als 200 Litern.
t. Beprobung von verpackten Abfällen in geschlossenen Bereichen in denen Unterdruck herscht oder in speziell dafür eingerichteten Kammern mit Abzugshauben für den Fall, dass der Abfall flüchtige Bestandteile enthält.

Zum Beispiel wird für die Vergärung von Schlamm die Probenahme durchgeführt, um zu gewährleisten, dass die Chargen weder toxisch noch hemmend für die Vergärung sind. Zusätzlich gilt allgemein für alle Arten der Probenahme aus Abfall, dass das Probenahmeverfahren sicherstellen sollte, dass eine adäquate Probenahme und Analyse zur Charkterisierung des Abfalls durchgeführt werden kann. Die Anzahl der gezogenen Proben beruht auf einer Risikobewertung potenzieller Probleme. Probenahmesysteme müssen in der Phase der Voruntersuchung nicht notwendigerweise die Beprobung aller Fässer beinhalten. Zum Beispiel kann die Regel “Quadratwurzel aus (n+1)”, unter der Voraussetzung angewendet werden, dass bei der Annahmeuntersuchung jeder Behälter beprobt wird. In manchen Fällen ist eine physikalische Probenahme nicht notwendig, zum Beispiel im Fall von Gaszylindern oder Altbatterien. In anderen Fällen, wie bei Abfällen aus Fässern wird eine große Anzahl von Proben notwendig sein, weil für die Charakterisierung die Beprobung aller Behälter notwendig ist. Bei der Beprobung von Prozessabfällen müssen die Schwankungen im Prozess berücksichtigt werden, und etliche Proben können erforderlich sein, um den Abfall ausreichend zu charakterisieren. Der Abfallerzeuger kann sicherstellen, dass die Probe repräsentativ für den Abfall ist, verlässlich ist und von einer Person gezogen wurde, die technisches Verständnis für den Probenahmeprozesses besitzt, indem er folgende Informationen beifügt:

- Ort der Probenahme, z.B. der Abwassertank
- Fassungsvermögen des beprobten Behälters (für Proben aus Fässern wäre ein zusätzlicher Parameter die Anzahl der Behälter)
- Methode der Probenahme, z.B. Probenahmehahn (mittlerer Durchfluss), von „oben“ gezogene Probe
- Anzahl der Proben und Grad der Konsolidierung
- Betriebsbedingungen zum Zeitpunkt der Probenahme, z.B. Normalbetrieb, Stillstand, Wartung und/oder Reinigung.

Zudem kann der Abfallerzeuger die Repräsentativität der Probe sicherstellen durch:

- Klare Beschriftung der Proben und aller identifizierter Gefahren
- Dem Einbeziehen von Systemen zur Rückverfolgung der Probe und Nachvollziehbarkeit innerhalb der Anlage.

Anreize zur Anwendung

Die Probenahme ist eine Kernaufgabe beim Aufbau einer guten Kenntnis über den zu behandelnden Abfall und folglich zur Vermeidung von Problemen bei der Behandlung. Einige Techniken verhindern auch flüchtige Emissionen (z.B. die Gerüche verursachen), während der Probenahme.

Betriebsdaten
Eine spezielle Laborausrüstung ist für die Probenahme notwendig.

Anwendbarkeit
Für alle Abfalltypen sind irgendwelche Probenahmeverfahren anwendbar.

Anreiz zur Anwendung
Eine Reihe von Entwürfen zu europäischen Probenahmstandards sind erhältlich, z.B. 'Sampling of liquid and granular waste materials including paste-like materials' erarbeitet von dem Technischen Ausschuss CEN/TC 292 – Charakterisierung von Abfällen. Der Technische Ausschuss CEN/TC 343 hat auch eine technische Norm über die Probenahme aus festen Brennstoffen aus Abfall erarbeitet.

Andere international konsolidierte Standards sind zum Beispiel ISO 10381 (Probenahme von Boden) und ISO 5667 (Probenahme von Abwasser, Schlamm und Sedimenten). Diese Standards beinhalten technische Spezifikationen für die Handhabung und Konservierung von Proben.

Beispielanlagen
Alle Abfallanlagen führen irgendeine Art der Probenahme durch.

Literatur
[16, ÖWAV Working Commitee, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [122, Eucopro, 2003], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.1.1.5 Annahmeeinrichtungen

Beschreibung
Normalerweise gibt es für eingehende Abfälle einen Annahmebereich, in dem Abfall visuell begutachtet und dabei mit den Angaben der Begleitpapiere verglichen wird, sowie weitere Proben gezogen werden, bevor der Abfall zugewiesen wird. Anlagen tendieren dazu, spezifische Abfallströme zu beproben. Einige gute Umweltpraktiken, die in Annahmeeinrichtungen angewendet werden, sind:

a. Vorhandensein eines akkreditierten Labors auf dem Gelände, um Abfallproben im Rahmen der Voruntersuchungen sowie bei der Annahme zu untersuchen. Dies kann ergänzt werden indem sicher gestellt wird, dass das Labor, das die Analysen durchführt, ein fundiertes Qualitätssicherungssystem, Methoden der Qualitätskontrolle und eine geeignete Aufzeichnung der Analyse und Dokumentation hat.
b. Ausrüstung der Laboratorien mit Kontrolleinrichtungen und Geräten, die für eine Qualitätssicherung notwendig sind. Eine Selbstkontrolle wird üblicherweise nicht offiziell anerkannt.
c. Vorhandensein eines speziellen Quarantänebereichs zur Lagerung von Abfall, sodass der Abfall vorübergehend sicher gelagert werden kann, wenn er die Annahmekriterien nicht erfüllt (dazu gehören z.B. beschädigte, korrodierte oder unbeschriftete Fässer). Eine solche Lagerung muss maximal für fünf Werktage vorgehalten werden. Im Fall kalter Umgebungstemperaturen darf die Lagerzeit fünf Werktage überschreiten, um eine Beprobung nach dem Auftauen zu ermöglichen. Nach Annahme kann der Abfall zu einem anderen Lagerbereich verbracht werden (für Sperrmüll ist dies üblicherweise ein Schüttgutbereich). Schriftliche Handlungsanweisungen müssen für den Umgang mit Abfall im Quarantänebereich und für die Erfassung und Überwachung des maximalen Lagervolumens vorhanden sein. Schriftliche Handlungsanweisungen müssen für die Wiederverpackung des Abfalls vor dem Zurücksenden an den Abfallbesitzer und für den Verpackungsvorgang selbst vorhanden sein.
d. Markierung der Überprüfungs-, Entladungs- und Probenahmebereiche auf dem Lageplan des Betriebsgeländes sowie das Vorhandensein eines geeigneten abgedichteten Drainagesystems. Vorhandensein von separaten Abscheidern für Verschüttungen und für Regenwasser. Des Weiteren ist ein versiegelter Untergrund erforderlich, der sicher gegen die zu behandelnden Abfälle abgedichtet ist. (Dies steht im Zusammenhang mit den Techniken in Abschnitt 4.8.2)

e. Vor bevorstehender Annahmeuntersuchung muss die Entladung von Abfällen in Behältern in einen dafür bestimmten Empfangsbereich stattfinden. Solch eine Lagerung erfordert eine maximale Zeitdauer von einer Woche. Während dieser Periode dürfen die gelagerten Abfälle nicht vermengt oder die Fässer gemischt oder die Inhalte der Fässer in Sammelbehälter umgefüllt werden. Abfälle müssen im Annahmebereich sofort, entsprechend ihrer Verträglichkeit, nach dem Entladen getrennt gehalten werden.
f. Sofortige Bewertung der Abfälle, die sich im Annahmebereich befinden
g. Sofortige Getrennthaltung von Abfällen, um möglichen Gefahren aufgrund ihrer Unverträglichkeit vorzubeugen, was dazu führen kann, dass der Abfall die Annahmebedingungen nicht erfüllt
h. Vorhandensein einer ausgewiesenen Probenahmestelle oder eines Annahmebereichs. Diese müssen sich in unmittelbarer Nähe zum Labor/Überprüfungseinrichtung befinden und sichtbar gekennzeichnet sein.
i. Sicherstellung, dass die Entladungs-, Beprobungs-/Annahme- und Zwischenlagerbereiche eine undurchlässige Oberfläche mit einer in sich geschlossenen Drainage aufweisen, um zu verhindern, dass Überläufe und Verschüttungen in Lagersysteme eindringen oder aus dem Betriebsgelände entweichen
j. Sicherstellung, dass inkompatible Substanzen nicht in Kontakt mit Verschüttungen aus der Probenahme kommen, wie etwa in einem Sumpf an der Probenahmestelle. Absorbtionsmittel müssen zur Verfügung stehen, um Verschüttungen zu handhaben
k. Sicherstellung, dass das Betriebspersonal, das an der Probenahme, Überprüfung und Analyse beteiligt ist, geeignet qualifiziert und angemessen geschult ist, und dass die Schulungen regelmäßig wiederholt werden
l. Sobald die Analyse bestätigt, dass der Abfall angenommen werden darf, sollte eine Charge für die Behandlung oder eine Ladung zur off- site Abnahme zusammengestellt werden. Sobald eine Charge für die Behandlung zusammengestellt wurde, kann der Betreiber zum Zweck der Analyse vor der Behandlung eine Mischprobe ziehen. Der jeweilige Umfang der Analyse richtet sich nach der beabsichtigten Behandlung, muss aber immer spezifisch bestimmt werden
m. Sicherstellung, dass bei jedem Schritt der Abfallannahme auf der Anlage (Voruntersuchungen, Annahmeprozeduren, Annahmeeinrichtungen) das Personal, dass Proben zieht und handhabt, das notwendige Wissen und Erfahrung besitzt
n. Vorhandensein eines ausgelegten Lagerbereichs auf der Anlage, der für angelieferte Abfälle geeignet ist
o. Vorhandensein einer klar festgelegten Vorgehensweise für Abfälle, bei denen während der Inspektion und/oder Analyse festgestellt wurde, dass sie die Annahmebedingungen der Anlage nicht erfüllen oder nicht mit der Beschreibung des Abfalls aus den Voruntersuchungen übereinstimmen. Diese Vorgehensweise sollte alle erforderlichen Maßnahmen (z.B. aus Genehmigungsbescheiden oder der nationalen/internationalen Gesetzgebung) enthalten, um die zuständigen Behörden zu informieren, um die angelieferten Abfälle für eine Übergangszeit sicher zu lagern oder um den Abfall abzuweisen und ihn zurück zum Abfallerzeuger oder einem anderen zugelassenen Empfänger zu senden.

Einige spezifische Techniken, die bei der Ankunft der Ladungen angewandt werden:

p. Wiegen aller ankommenden Ladungen, sofern nicht zuverlässige volumetrische Verfahren in Verbindung mit Daten über das spezifische Gewicht zur Verfügung stehen
q. Keine Annahme irgendeiner Ladung auf dem Betriebsgelände, wenn keine ausreichende Lagerkapazität vorhanden ist
r. Gewährleistung, dass alle Dokumente überprüft und abgenommen werden, und dass alle Unstimmigkeiten vor Annahme des Abfalls beseitigt werden
s. Visuelle Prüfung der Ladung – nach Möglichkeit sollte die Prüfung vor dem Entladen durchgeführt werden. In jedem Fall müssen die Überprüfungen unmittelbar nach der Ankunft der Ladung an der Anlage durchgeführt werden
t. Prüfung jedes Behälters, um die angelieferten Mengen mit den Angaben in den Begleitpapieren zu vergleichen. Alle Behälter müssen eindeutig beschriftet sein und mit genau passenden Deckeln, Kappen und Ventilen versehen sein, die sicher sind und sich an der richtigen Stelle befinden. Behälter ohne richtige Angaben müssen zurückgewiesen werden. Nach der Prüfung muss der Abfall in einen ausgewiesenen Probenahme-/Annahmebereich entladen werden.
u. Anwendung eines Systems zur Rückverfolgung der Abfälle vom Punkt der Annahme bis zum ersten Behandlungsschritt, in welchem der physikalische oder chemische Charakter des Abfalls verändert wird, z.B. mittels Identifikationssystems (z.B. Label oder Code) für jeden Behälter der auf der Anlage gelagert wird. Diese Informationen können alle notwendigen Daten hinsichtlich Gesundheit, Sicherheit, der weiteren Behandlung, der Abfallschlüsselnummer, des ursprünglichen Erzeugers und des Datums der Ankunft auf der Anlage usw. umfassen.
v. Wenn die Inhalte von Behältern zusammengestellt werden, wird auf den Sammelbehälter das Ankunftsdatum desjenigen der Abfälle übertragen, der am frühesten auf der Anlage angekommen ist.

Ereichte Vorteile für die Umwelt
Ermittlung von Herkunft und Zusammensetzung des Abfalls, sowie der gefährlichen Eigenschaften. Dies verhindert die Annahme von Abfällen, die ohne schriftliche Informationen angeliefert werden. Die meisten Verschüttungen und Leckagen während der Probenahme sind nur von geringem Umfang, z.B. stammen sie aus Freisetzungen des hinteren Ventils eines Tankfahrzeugs, wenn die Probe von dort gezogen wurde.

Betriebsdaten
Für die chemische Analyse der Proben wird ein Labor benötigt. Im Zusammenhang mit der Technik a (siehe obige Beschreibung) werden manche Proben nicht zum Zweck der unmittelbaren Überprüfung und Analyse genommen. Manche Proben werden für den Fall zurückgestellt, falls Behörden weitere Überprüfungen verlangen.

Anwendbarkeit
Voll anwendbar für alle Standorte, obwohl es in manchen Situationen (z.B. bei Anlagen die keine gefährlichen Abfälle behandeln) nicht praktikabel oder unwirtschaftlich sein kann, das Labor auf dem Betriebsgelände zu haben.

Wirtschaftlichkeit
Annahmeeinrichtungen für Abwasserbehandlungsanlagen, zum Beispiel für das Entladen von Tankfahrzeugen und der Lagerung, können um 1,5 Millionen EUR (1 Million GBP) kosten. Die Betriebskosten sind relativ gering und beinhalten vor allem administrative Kosten.

Techniken	**Investtionskosten (GBP)**	**Betriebskosten (GBP)**
Analytisches Labor [1,2]	40000	20000
Geräte zur kontinuierlichen Überwachung [2]	10000	1000
Technische Beschreibung		
Kapazität	10000 t/a	
Ölarten	gebrauchte Schmieröle	
Betriebsführung	Batch	
Abgasfluss	0 – 50 Nm^3/h	
Alter der Anlage	10 Jahre alt	
Alter der Techniken zur Schadstoffkontrolle	2 Jahre alt	
Anmerkungen: 1. unter den Voraussetzungen, dass kein neues Gebäude benötigt wird und die Laboreinrichtung relativ einfach ist. Das Personal besteht aus einem Vollzeit-Techniker. 2. Die Kosten der Geräte zur kontinuierlichen Überwachung variieren enorm je nach der Anzahl der überwachten Substanzen, der benutzten Analysetechniken und dem gewählten Lieferanten.		

Tabelle 4.6: Wirtschaftliche Daten zur Labor- und Überwachungsausstattung in einer Altölaufbereitungsanlage [42, UK, 1995], [150, TWG, 2004]

Treibende Kraft für die Anwendung
In allen Abfallbehandlungsanlagen ist eine Art Annahmeeinrichtung für zu behandelnde Abfälle notwendig. In manchen Ländern ist es nicht obligatorisch einen Quarantänebereich vorzuhalten, noch ist dort eine externe Akkreditierung des Labors gesetzlich vorgeschrieben.

Beispielanlagen
Alle Abfallbehandlungsanlagen haben irgendeine Art von Annahmeeinrichtung. An vielen Standorten werden Systeme genutzt in denen die Abfälle vorab angemeldet werden müssen. In diesen Fällen besitzt der Annahmebereich eine Liste mit den Inhalten jeder Ladung die an diesem Tag erwartetet wird. Manche Anlagen haben einen eingedämmten und überdachten Annahmebereich, andere haben wiederum verschiedene eingedämmte und überdachte Annahmebereiche für verschiedene Gruppen von Abfällen. Die Gaschromatographie und Massenspektrografie können zur Bestimmung von Lösemittel- und Altölkomponenten benutzt werden, doch die Nutzung erfordert geschulte Interpretation und die Kosten sind hoch.

Abhängig von den gelieferten Abfällen kann der Annahmebereich/Bunker mit technischen Feuerlöscheinrichtungen ausgestattet werden, denn manche Abfälle, insbesondere Abfälle mit einem hohen Organikgehalt, neigen zur Selbstentzündung. Biologische Abbauprozesse können hohe Temperaturen verursachen, was in manchen Fällen zu Bränden führen kann. Darüber hinaus können die beseitigten Abfälle bereits glühende Bestandteile, wie z.B. unvollständig verbrannte Kohle, enthalten.

Der Annahmebereich ist normalerweise eingehaust, und die Türen sind oft wegen Geruchs-, Staub- und Lärmemissionen geschlossen. Der Annahmebereich oder Bunker verfügt über eine Einrichtung zur Lüftung, mit der die Abluft erfasst wird. Damit keine Luft nach draußen entweicht, besitzen manche Anlagen ein Belüftungssystem, mit dem ein Unterdruck im Annahmebereich oder dem Bunker erzeugt wird.

Literatur
[29, UK Environment Agency, 1996], [55, UK EA, 2001], [86, TWG, 2003], [119, Watco, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [126, Pretz, et al., 2003], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.1.2 Managementsysteme

Dieser Abschnitt umfasst Managementmethoden, die typischerweise auf Abfallbehandlungsanlagen als Ganzes angewendet werden.

4.1.2.1 Techniken zur Bestimmung der Abfallbehandlungsart für jeden einzelnen Abfall

Beschreibung
Sobald die Zusammensetzung sowie die Eigenschaften des Abfalls (z.B. Gehalt gefährlicher Stoffe) bestimmt wurde, und abgesichert ist, dass der Abfall der Beschreibung des Anlieferungs-/Annahmebereich entspricht (Annahmeprozedur), sollte eine Behandlungmethode oder –möglichkeit für den Abfall festgelegt werden. Es bestehen drei grundsätzliche Prinzipien für die Auswahl einer angemessenen Behandlung eines spezifischen Abfalls: 1) adäquate Charakterisierung des Abfalls, 2) Sicherstellung der Eignung des Abfalls für die vorgeschlagene Behandlung und 3) Gewährleistung der betrieblichen Kontrolle des Behandlungsprozesses, einschließlich Inputs und Überwachung der Reaktionen und einer klaren Zielsetzung hinsichtlich der Endpunkte. Einige anwendbare Techniken, die dazu beitragen, diese Ziele zu erreichen, sind:

a. Beschreibung und Berücksichtigung der in der Anlage durchgeführten Tätigkeiten sowie der vorgeschlagenen Techniken zur Vermeidung und Minderung des Anfalls von Abfall sowie Stoff- und Wärmeemissionen (einschließlich der Anfahr- und Abfahrphasen, kurzzeitigen Betriebsstopps, Leckagen oder Fehlfunktionen)
b. Ermittlung der Abfallarten, die Gegenstand der einzelnen Prozesse sind, einschließlich aller enthaltenen Schadstoffe
c. Ermittlung der chemischen Vorgänge im Verfahren und des Verbleibs aller Abfallbestandteile und Reaktionsprodukte
d. Ermittlung geeigneter Verwertungs- oder Minderungsmöglichkeiten, insbesondere für Bestandteile, die schädlich für die Umwelt sein können und die während der Behandlung nicht zerstört werden, sondern von einem Umweltmedium ins andere verlagert werden. Dies kann die Verfolgung solcher Substanzen umfassen, die im Stande sind die Umwelt zu verschmutzen und die unverändert aus dem Behandlungsverfahren freigesetzt werden können.
e. Ermittlung einer geeigneten Behandlungmethode bei jeder neuen Anfrage zur Behandlung von Abfall
f. Es soll sichergestellt werden, dass die Eingangsstoffe des Prozesses keine Substanzen wie etwa Lösemittel enthalten, die in einem nachfolgenden Arbeitsschritt verwertet werden könnten, zum Beispiel durch Trocknung und anschließende Destillation in verschiedene Bestandteile
g. Vorhandensein einer eindeutigen Methode zur Bewertung der Abfallbehandlung unter Berücksichtigung der physikalisch-chemischen Eigenschaften des individuellen Abfalls und der Beschreibungen für den behandelten Abfall
h. Berichten, ob es Anweisungen zu vorrangigen Abfallbehandlungsarten (z.B. im Zusammenhang mit der Abfallbehandlungshierarchie), hinsichtlich der zu behandelnde Abfallart, gibt (z.B. EAV).

Erreichter Nutzen für die Umwelt
Die Wahl einer geeigneten Behandlung für einen bestimmten Abfall ist unerlässlich, um zu gewährleisten, dass Emissionen in die Umwelt reduziert werden und der Abfall richtig behandelt wird.

Betriebsdaten
Häufig müssen zur richtigen Behandlung von Abfall verschiedene Verfahren eingesetzt werden. Die folgenden Verfahren, oder vielmehr die Kombinationen (Verfahrensarten, Abfolge ihrer Anwendung, durchgeführte Kontrollen usw.) werden üblicherweise durch die Koordination von Firmen/Anlagen spezifiziert. Bei solch einem Vorgehen haben die Laborergebnisse über die Zusammensetzung und über das Reaktionsverhalten des Abfalls einigen Einfluss auf die auszuwählende Abfallbehandlungsart.

Treibende Kraft für die Anwendung
Die Wahl der Behandlung ist nicht ausschließlich eine Funktion der Abfallart. Vielmehr stellen, auch andere Gesichtspunkte, wie etwa lokalen Bedingungen (z.B. Abfallstrategie), logistische Überlegungen und die verfügbaren Behandlungsarten in der Region, ebenso wichtige Punkte dar, die berücksichtigt werden müssen..

Mitunter und wo immer möglich, müssen Abfallstoffe einer chemischen, physikalischen oder biologischen Behandlung unterzogen werden, wenn sie inakzeptable Mengen von umweltgefährdenden Substanzen oder Verbindungen enthalten, die abgetrennt, umgewandelt oder immobilisiert und folglich weniger schädlich gemacht werden können.

Beispielanlagen
In allen Abfallbehandlungsanlagen angewendete Methode.

Literatur
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [131, UBA, 2003], [150, TWG, 2004]

4.1.2.2 Gewärleistung der Zufuhr von Abfällen

Beschreibung
Abfall kann als das "Roh"-Material von Abfallbehandlungsanlagen betrachtet werden. In manchen Fällen kann Abfall als Reaktionsmittel zur Behandlung anderer Abfälle eingesetzt werden. In jedem Fall ist es wichtig, die Gewährleistung zu besitzen, dass die Abfälle/Materialien zur richtigen Zeit für einen kontinuierlichen und richtigen Betrieb der Anlage zur Verfügung stehen.

Erreichter Nutzen für die Umwelt
Wenn der Abfall als Reaktionsmittel in einem Behandlungsverfahren verwendet werden soll, kann der Behandlungsprozess für die zu behandelnde Abfallart verzögert werden, wenn ein solcher Abfall nicht zur Verfügung steht. Diese Verzögerung kann Umweltprobleme mit sich bringen.

Anwendbarkeit
Zum Beispiel ist die Gewährleistung eines langfristigen Betriebs bei anaeroben Behandlungsverfahren eine wesentliche Voraussetzung für ihre ökonomische Machbarkeit (siehe Abschnitt 0)

Beispielanlagen
Ein Hauptinteresse bei der Vergärung liegt in der Gewährleistung eines langfristigen Betriebs der Anlage, welches der Schlüssel der ökonomischen Machbarkeit ist. Dieses Risiko kann durch technische Entwicklungen gesenkt werden, doch die damit verbundenen Kosten können die Wirtschaftlichkeit kurzfristig beeinflussen. Ein anderes Beispiel ist die Gewährleistung einer ausreichenden Zufuhr von Abfalllaugen in chemisch-physikalischen Anlagen, um saure Materialien zu neutralisieren, falls diese für Neutralisationsprozesse genutzt werden.

Bunker oder Einrichtungen, mit denen Abfälle in den Prozess aufgegeben werden, sollten eine kontinuierliche Aufgabe ermöglichen, um Überlastungen von Maschinen zu vermeiden.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [126, Pretz, et al., 2003]

4.1.2.3 Techniken zur Verbesserung der Verfolgbarkeit von Abfall

Beschreibung
Jedes einzuführende Nachverfolgungs- oder Verfolgbarkeitssystem muss in der Lage sein, über alle folgenden Punkte Auskunft zu geben:

- Absolute Menge des sich auf dem Betriebsgelände befindlichen Abfalls, zu jeder Zeit, in angemessenen Einheiten, zum Beispiel 205 Liter-Fass-Äquivalente
- Aufschlüsselung der gelagerten Abfallmengen, die auf eine Behandlung auf dem Gelände warten, gegliedert nach Behandlungsweg
- Aufschlüsselung der Abfallmengen, die sich nur zur Lagerung auf dem Gelände befinden, und auf die Weiterbeförderung warten
- Aufschlüsselung der Abfallmengen nach Gefährlichkeitseinstufung
- Anzeigen auf einem Lageplan des Betriebs, wo auf dem Gelände sich der Abfall befindet
- Vergleich der Abfallmenge auf dem Gelände mit der maximal genehmigten Menge
- Vergleich der Zeit, die der Abfall sich bereits auf dem Gelände befindet, mit der maximal genehmigten Zeitdauer.

Einige Techniken die angewand werden können, um die Rückverfolgbarkeit von Abfallströmen in einer Abfallbehandlungsanlage zu verbessern, sind:

a. Aufzeichnung und Bezugnahme der Informationen über Abfalleigenschaften und Herkunft des Abfalls, so dass sie jederzeit verfügbar sind. Dem Abfall muss eine Referenznummer zugeordnet wreden, auf die der Betreiber zu jedem Zeitpunkt im Verfahren Zugriff haben muss, um zu ermitteln, wo in der Anlage sich ein bestimmter Abfall befindet, wie lange er sich dort bereits befindet und welcher der vorgesehene oder tatsächliche Behandlungsweg ist. Dies ist eine wichtige Komponente des Anlagenmanagements.
b. Regelmäßige Überprüfung und Aktualisierung der Informationen über Abfallströme, d.h. Aktualisierung der Informationen bei jeder Veränderung
c. Einsatz von internen Rückverfolgungssysteme und Lagerkontrollverfahren für alle Abfälle, mit Querbezügen auf die eindeutige Referenznummer, die im Stadium der Voruntersuchungen vergeben wurde (siehe Abschnitt 4.1.1.2)
d. Anwendung eines Rückverfolgungssystems, welches alle Informationen der Voruntersuchungen, Annahme, Lagerung, Behandlung und/oder Entfernung von der Anlage, umfaßt. Aufzeichnungen können fortlaufend geführt und aktualisiert werden, um Anlieferungen, Behandlung auf dem Gelände und Auslieferungen widerzuspiegeln. Dokumentationen, die durch den Fahrer geliefert wurden, schriftliche Ergebnisse von Annahmeuntersuchungen und Details über Entladestellen oder Umladestationen müssen mit in die Dokumentation des Rückverfolgungssystems aufgenommen werden. Alle Aufzeichnungen der Vorüberprüfungen müssen in der Anlage aufbewahrt werden, um für Querverweise und der Überprüfung bei der Abfallannahme zur Verfügung zu stehen. In der Regel müssen Aufzeichnungen noch zwei bis sechs Monate aufbewahrt werden, nachdem der Abfall behandelt oder vom Betriebsgelände entfernt wurde.
e. Zuteilung einer eindeutigen Referenznummer für jeden Abfallstrom und “Verfolgung” des Abfalls während seiner Annahme, Lagerung, Behandlung oder Entfernung von der Anlage. Handelt es sich hierbei um einen regelmäßig anfallenden Abfall, sollte das Dokument eindeutig für die Abfallcharge vorliegen.
f. Anwendung eines Dokumentationsverfahrens oder einer computerbasierten Datenbank/Datenreihe, die regelmäßig gesichert wird. Das Rückverfolgungssystem arbeitet als Abfallinventar-/Lagerkontrollsystem und umfasst: Datum der Ankunft auf der Anlage, Details zum Abfallerzeuger, Details über alle vorherigen Besitzer, eindeutige Identifizierungszeichen, Analyseergebnisse der Vor- und Annahmeuntersuchungen, Verpackungsart und –größe, beabsichtigter Behandlungs-/Beseitigungsweg, eine präzise Aufzeichnung von Art und Menge aller Abfälle auf dem Betriebsgelände, einschließlich aller Gefahren, den Ort, an dem sich der Abfall befindet in Bezug auf den Lageplan, an welchem Punkt des vorgesehenen Beseitigungswegs sich der Abfall derzeit befindet usw.
g. Aufbewahrung des Belegs für die Behandlungs- oder Beseitigungsmethode, der eine bestimmte Abfallart unterzogen wird
h. Führung von Aufzeichnungen, die sicherstellen, dass ausreichendes Wissen darüber zur Verfügung steht, welche Abfälle sich in bestimmten Behältern/Tanks befinden. Sobald, zum Beispiel, ein Abfall erst ein Großmengenlager oder ein Behandlungsverfahren erreicht hat, sind einzelne Abfälle nicht mehr rückverfolgbar. Dennoch können Rückstände/Verbindungen, die sich in den Behälter zwischen Entschlammungsvorgängen ansammeln, rückverfolgt werden, um Inkompatibilitäten mit neu hinzukommenden Abfällen zu vermeiden.

i. Für flüssige Massenabfälle, müssen Aufzeichnungen des Lagerkontrollsystems hinsichtlich des Weges durch das Verfahren geführt werden; wohingegen bei der Kontrolle von in Fässern verpackten Abfällen die Beschriftungen jedes einzelnen Fasseses genutzt werden, um Ort und Dauer der Lagerung aufzuzeichnen
j. Anwendung eines qualitativ hochwertigen Verpackungs- und Beschriftungsverfahrens für ankommende Behälter.

Erreichter Nutzen für die Umwelt
Das System liefert dokumentierte Nachweise hinsichtlich der Behandlung eines bestimmten Abfalls, detaillierte Angaben, wann der Abfall auf das Betriebsgelände gelangt ist, wo er hergekommen ist, mit welchen anderen Verbindungen er vermischt und gelagert wurde und wohin und wann er versandt wurde. Dieses Techniken versetzen den Betreiber der Abfallbehandlungsanlage in die Lage:

- Vorteile aus Synergieeffekten zwischen Abfällen zu ziehen
- unerwünschte oder unerwartete Reaktionen zu vermeiden
- sicher zu stellen, dass Emissionen entweder vermieden oder vermindert werden
- die Abfalldurchsätze zu handhaben

Medienübergreifende Auswirkungen
Nicht bekannt.

Betriebsdaten
In der Regel sind computerbasierte Datenbanken erforderlich. Für die Einführung eines effektiven Systems wird zusätzliche Verwaltungsarbeit benötigt. Rückverfolgungssysteme müssen hinterfragen, was genau zu welchem Zeitpunkt rückverfolgt werden soll.

Anwendbarkeit
Weit verbreitet im Abfallbehandlungssektor. Im Fall kleiner Abfallbehandlungsanlagen kann die Adaption von Rückverfolgungssystemen (z.B. Papier zu Computer basierend) schwierig sein.

Die Anwendung mancher der oben erwähnten Techniken kann vielleicht nicht möglich sein, wenn Anlagen kontinuierlich oder halbkontinuierlich betrieben werden. Beispiele sind, flüssige Abfälle aus verschiedenen Chargen, die zusammen in einen Lagertank gegeben werden, oder wenn feste Abfälle in den Bunker gegeben und mit anderem Abfall gemischt werden oder wenn die physikalisch-chemischen Eigenschaften des Abfalls sich ändern. Rückverfolgungssysteme für kleine Volumen oder Mengen sind schwieriger anzuwenden.

Treibende Kraft für die Anwendung
Hilft dem Betreiber beim Management der Anlage.

Üblicherweise verlangen Abfallbehörden eine Berichterstattung vom Abfallerzeuger, aus der hervorgeht, dass der Abfall gemäß allen relevanten gesetzlichen und technischen Regelungen behandelt wurde. Dieses System hilft ebenso der Verfolgung, wo und wann die Behandlung durchgeführt wurde.

Beispielanlagen
Weit verbreitet in Abfallbehandlungsanlagen. Von grundlegender Bedeutung für Abfallumladestationen.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.1.2.4 Effizienzsteigerung der Abfallbehandlung

Beschreibung
Die Effizienz der Abfallbehandlung bezieht sich in diesem Abschnitt auf eine Verbesserung der Nützlichkeit der Outputs, des Verbrauchs von Rohmaterialien und der Materialflussanalyse. Techniken zur Energieeffizienz sind in Abschnitt 4.1.3.4. aufgeführt. Einige Techniken, die angewendet werden können, um die Effizienz der Abfallbehandlung zu steigern, sind:

a. Erstellen einer Bewertung der Effizienz des Behandlungsverfahrens im Hinblick auf Schadstoffe, d. h. unter dem Gesichtspunkt der Entfernung oder Abtrennung von Substanzen innerhalb des Verfahrens, zum Beispiel:
   - Fällung von Metallen aus Lösungen mit dem Ziel der Abtrennung mit dem Filterkuchen
   - Grad des Transfers vom eingehenden Abfall zu Emissionen (in Luft, festen Abfällen in Boden und Abwasser in die Kanalisation, zum Beispiel bei Pestiziden oder Lösemitteln)
   - der Nutzung von heißem Dampf zum Vorwärmen von Altöl
b. Analyse von Effizienzparametern unter Verwendung folgender Schritte:
   - Prozessanalayse – Ermittlung der Pfade der spezifischen Substanz/Substanzen innerhalb des Verfahrens
   - Massenbilanz
c. Analyse der Auswirkungen, die Schwankungen in der Abfallzusammensetzung auf den Betrieb der Abfallbehandlungseinheiten haben können
d. Überwachung der Effizienz. Betriebliches Effizienz-Monitoring kann mit Hilfe von Instrumenten, direkter Überwachung durch den Betreiber und chemischen Analysen durchgeführt werden. Jedes Monitoringprogramm umfasst in der Regel ausführliche Dokumentation unter Nutzung einer Kombination aus Computern, Messgeräten und von Hand ausgefüllten Papierprotokollen
e. Vorhandensein von Verfahren für die Trennung von Abfallmaterialien, die so beschaffen sind, dass die Verwertbarkeit der getrennten Materialien nicht nachteilig beeinflusst wird.

Einige dieser Techniken sind manchmal Bestandteil von ISO 9000 und ISO 14001.

Erreichter Nutzen für die Umwelt
Eine Anlage muss Betriebsabläufe sorgfältig überwachen, um sicherzustellen, dass die Arbeitsleistung die erwünschten Ergebnisse erzielt. Optimierungen von Abfallbehandlungsanlagen tragen in der Regel dazu bei, niedrigere Emissionen und geringere Verbräuche zu erzielen.

Betriebsdaten
Es ist bekannt, dass Abfallbehandlungsanlagen verschiedene Abfallströme behandeln müssen um wirtschaftlich sein zu können, allerdings ist es nicht immer wünschenswert oder effektiv, die Planung und Betriebsführung eines Abfallbehandlungsverfahrens zu sehr zu komplizieren, indem versucht wird, jede Komponente an die wechselnden Abfallströme anzupassen. Daher kann die Überwachung des Abfalls und die Anwendung geeigneter Trennungsverfahren dazu beitragen, eine höhere Effizienz und Wirtschaftlichkeit der Betriebsführung zu erreichen.
Manche Abfallbehandlungsanlagen müssen mit einem breiten Spektrum unterschiedlicher Abfälle umgehen. Dies erfordert eine vielseitige Anlage und Ausrüstung für eine Vielzahl von Abfällen. Dies steht im Gegensatz zu Abfallbehandlungstechniken, die bei betriebsinterner Behandlung von Abfällen beim Abfallerzeuger genutzt werden. Hier sind die Abfallströme in ihrer Anzahl begrenzt und gut charakterisiert. Diese Eigenschaften der betriebsinternen Behandlung können zur Entwicklung von zweckbestimmte Behandlungstechniken für Einzelströme beitragen.

Anwendbarkeit
Auch wenn alle Input- sowie Output- Abfallströme und Produkte der Anlage gewogen werden, ist es nicht immer einfach, eine sinnvolle Massenbilanz der Anlage durchzuführen. Massenbilanzen und Materialflussanalysen für jede einzelne Materialfraktionen oder jedes einzelne Bestandteil sind schwierig zu erstellen, und manchmal im Ergebnisse fragwürdig. Der Hauptgrund dafür ist die von Natur aus vorliegende Schwankung des Abfall-IN.

Beispiele recycelbarer Materialien in C-P-Anlagen sind hauptsächlich Öle, Fette, organische Lösemittel, Metalle und Metallsalze.

Treibende Kraft für die Anwendung
In der Regel werden die Maßnahmen zur Effizienssteigerung schon deswegen durchgeführt, um Betriebskosten der Einrichtung oder die Beseitigungskosten für den Abfall zu senken.

Beispielanlagen
Es gibt immer noch eine große Anzahl von Anlagen, die keine Waage besitzen oder in der nicht jede Ladung gewogen wird.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [153, TWG, 2005]

4.1.2.5 Managementtechniken

Beschreibung
Zu den Techniken gehören:

a. Betriebskontrolle des Behandlungsverfahrens
b. Bereitstellung und Aufrechterhaltung geeigneter Infrastruktur (gute Betriebsführung)
c. Abwassermanagement (entwickelt in Abschnitt 4.7.1)
d. Überwachung der Anlage auf Grundlage von Laboranalysen, welche auch die Behandlungen, die erforderlichen Kontrollen und die erforderliche Dokumentation festlegen.
e. Führung des Betriebes durch ausschließlich spezialisierte Experten (z.B. auf Managementebene: mit Universitätsausbildung, entsprechendem Abschluss und/oder einschlägiger Berufserfahrung, auf operative Ebene: Facharbeiter, Laboranten). Die Qualifikation des Personals kann mittels einer Mischung von relevanten Ausbildungszeiten und fortlaufenden Weiterbildungen gewährleistet werden. Das erforderliche Spezialwissen des technischen Personals muss im Rahmen der Anlagenzertifizierung festgelegt und überprüft werden. Dies steht in Zusammenhang mit Techniken, die in Abschnitt 4.1.2.10 beschrieben werden.
f. Vorhandensein aller notwendigen dezentralen Strukturen, die für ein korrekt funktionierendes Unternehmen erforderlich sind. Dies schließt zum Beispiel die Einzäunung des Standorts, Wegweiser zu Parkplätzen und Lagereinrichtungen, Beleuchtungen, Wiegevorrichtungen, Arbeitsräume usw. ein.

Erreichter Nutzen für die Umwelt
Allgemeine Verbesserung des Umweltbewusstseins in der Anlage.

Anwendbarkeit
Regelmäßige Schulungen sind im Abfallbehandlungssektor üblich.

Literatur
[50, Scori, 2002], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.1.2.6 Ermittlung von ökonomischen Größeneffekten und Synergien

Beschreibung
Wenn eine Anzahl separater Anlagen vorhanden sind (insbesondere bei verschiedenen Betrieben), besteht ggf. die Möglichkeit Problemstellungen und Möglichkeiten zu ermitteln, die den Gesamtstandort betreffen und wo, durch Interaktionen zwischen den Anlagen, die Gesamtleistung jeder Anlage erhöht werden kann. Insbesondere handelt es sich dabei um die Mitbenutzung oder das Kombinieren von Informationen oder Tätigkeiten und verbesserte Kooperation. Beispiele hierfür sind:

a. Verbesserung der Kommunikationsverfahren zwischen den verschiedenen Besitzern von Genehmigungen – besonders für diejenigen, die benötigt werden um sicherzustellen, dass das Risiko für umweltschädigende Geschehnisse minimiert wird
b. Nutzung von größenbedingten ökonomischen Vorteilen um eine gemeinsamen Kraft-Wärme-Kopplungs--Anlage zu rechtfertigen (siehe die Abschnitte über Energie im Abschnitt 4.1.3)
c. Zusammenführen brennbarer Abfälle, wodurch eine gemeinsame energetische Nutzung der Abfälle gerechtfertigt wird (siehe Abschnitte über Energie in Abschnitt 4.1.3)
d. Nutzung eines Abfalls aus einer Tätigkeit als Einsatzstoff für eine andere Behandlungsstufe
e. Nutzung von behandeltem Abwasser aus einer Tätigkeit als Rohwassereingabe für eine andere Tätigkeit, falls es von geeigneter Qualität ist
f. Zusammenführung von Abwässern, wodurch eine gemeinsame oder aufgerüstete Abwasserbehandlungsanlage gerechtfertigt ist
g. Verhütung von Unfällen, die schädliche Nebenwirkungen auf eine benachbarte Tätigkeit haben können
h. Vermeidung von Bodenkontaminationen oder einer Tätigkeit die andere beeinflusst – oder von möglichen Problemen, die dadurch entstehen, dass ein Betreiber das Grundstück besitzt, auf dem der andere seinen Betriebssitz hat.

Erreichter Nutzen für die Umwelt
Kann die Energieeffizienz erhöhen, sowie die Menge des erzeugten Abfalls, den Wasserverbrauch und die Abwasseremissionen des gesamten Komplexes reduzieren.

Medienübergreifende Auswirkungen
Einige der notwendigen Diskussionen sind schwierig zu führen, vor allem wenn es um wettbewerbsrelevante rechtliche Probleme geht.

Anwendbarkeit
Anwendbar, wo Synergien festgestellt wurden und wo mehr als eine Tätigkeit ausgeführt wird.

Wirtschaftlichkeit
Senkt in der Regel die Gesamtkosten der Abfallbehandlung.

Treibende Kraft für die Anwendung
Erhöht in der Regel die ökonomische Realisierbarkeit von Abfallbehandlungsanlagen.

Beispielanlagen
Es existieren viele Beispiele in diesem Bereich.

Literatur
[55, UK EA, 2001], [86, TWG, 2003]

4.1.2.7 Bereitstellung vollständiger Angaben über die auszuführenden Tätigkeiten

Beschreibung

Die Bereitstellung angemessener Verfahrensbeschreibungen der Aktivitäten und angewandter Minderungs- und Kontrollausrüstungen ist wichtig, um die Überwachungsbehörde in die Lage zu versetzen, ein gutes Verständnis des angewendeten Verfahrens zu gewinnen. Geeignete Punkte, die dazu beitragen, ein gutes Bild der Anlage zu bekommen, umfassen:

a. eine Beschreibung der in der Anlage durchgeführten Abfallbehandlungsmethoden und –verfahren
b. Bereitstellung von Rohrleitungs- und Flussdiagrammen zur Instrumentierung der Anlage (z.B. R/I-Fließbilder)
c. Diagramme der wichtigsten Anlagenteile mit Umweltrelevanz, und zusätzlich Prozessflussdiagramme (schematisch). Zum Beispiel Diagramme der Anlagenauslegung für Lagerung, Tanks, Behandlungs- und Minderungseinrichtungen, obwohl diese einzeln in der Regel nicht für eine richtige Bewertung der Umweltauswirkungen ausreichen
d. Details zu chemischen Reaktionen sowie deren Reaktionskinetik/Energiebilanz
e. Bestandsaufnahme der Ausstattung, detaillierte Anlagenart und Auslegungsparameter, wie zum Beispiel zu Flammpunkten
f. Details über die Abfallarten, die behandelt werden sollen
g. Philosophie des Kontrollsystems und wie das Kontrollsystem Informationen aus dem Umweltmonitoring einbezieht
h. Lüftungsdetails und Notfallmaßnahmen
i. Betriebs- und Wartungsprozeduren
j. Details über Schutzvorkehrungen bei außergewöhnlichen Betriebsbedingungen, wie etwa bei kurzfristigen Betriebsstopps und beim An- und Abfahren.

Des Weiteren sind im Hinblick auf Informationen für den Betreiber wichtig:

k. Zugang zu allen notwendigen Vorschriften in Bezug auf Betriebssicherheit und -ablauf sowie zu einer Betriebsordnung, bevor die Anlage in Betrieb genommen wird
l. Vorhandensein eines Betriebshandbuchs. Das Betriebshandbuch enthält alle notwendigen Maßnahmen, um eine geeignete und sichere Beseitigung entstandener Abfalle im Normalbetrieb, während Wartungsarbeiten und während Betriebsstörungen, zu gewährleisten. Alle Prozesse sollten mit Alarm- und Notfallplänen abgestimmt werden. Das Betriebshandbuch beschreibt auch detailliert Pflichten und Verantwortlichkeiten des Bedienungspersonals, die Arbeitsanweisungen, die Vereinbarungen zur Wartung und Inspektion, ebenso wie zur Berichterstattung, Dokumentation und Aufbewahrung. Dieses Handbuch muss, wenn notwendig, aktualisiert werden und sollte vor Inbetriebnahme der Anlage verfügbar sein.
m. die Führung eines Betriebstagebuchs, um Betriebsbedingungen detailliert aufzuzeichnen und als Nachweis für die angemessene Betriebsführung der Anlage. Das Betriebstagebuch wird alle relevanten Informationen aus dem täglichen Betrieb der Abfallbehandlungsanlage enthalten und soll insbesondere:
    - alle in der Anlage behandelten Abfälle, sowie alle anderen Materialien, die außerhalb der Anlage auf andere Art und Weise recycelt oder beseitigt werden, aufzeichnen
    - als Register der angenommenen Abfälle dienen
    - als Register aller Materialien dienen, die außerhalb der Anlage auf eine andere Art und Weise recycelt oder beseitigt werden
    - bei Streitfragen dokumentierte Nachweise liefern, z.B. in Fällen, in denen die angelieferten Abfälle nicht mit den Details der dokumentierten Voruntersuchungen übereinstimmen. In diesem Fall listet das Tagebuch alle getroffenen Maßnahmen detailliert auf
    - besondere Zwischenfälle festhalten, insbesondere Einzelheiten zu jeglicher Betriebsstörung, einschließlich Details über mögliche Ursachen und der getroffenen Gegenmaßnahmen
    - Betriebszeiten und Stillstandszeiten der Anlage aufzeichnen
    - Ergebnisse von Untersuchungen und von Messungen im Rahmen der Selbstüberwachung aufzeichnen
    - Art und Umfang aller Wartungsmaßnahmen aufzeichnen
    - Ergebnisse von Funktionsüberprüfungen aufzeichnen.

n. das Betriebstagebuch ist auf dem neuesten Stand zu halten. Alle von der zuständigen Behörde angeforderten zusätzlichen Bestätigungen müssen auch im Betriebstagebuch dokumentiert werden. Mittels eines Ordnersystems können im Betriebstagebuch auch einzelne Blätter gesammelt werden, die von Personen aus ver-

schiedenen Anlagenbereichen ausgefüllt wurden. Das Betriebstagebuch kann auch mittels elektronischer Datenverarbeitung geführt werden. Unabhängig davon, ob es in elektronischer oder in Papierform geführt wird, sollte es immer in sicherer Verwahrung gehalten und vor nicht autorisiertem Zugriff geschützt werden

o. das Betriebstagebuch ist über eine Zeitspanne von fünf Jahren aufzubewahren
p. alle Zwischenfälle, die zu einer bedeutenden Abweichung vom Normalbetrieb führen, sofort der zuständigen Behörde zu melden, insbesondere diejenigen, die einen Stillstand der Anlage verursachen
q. eines Jahresüberblick zu den durchgeführten Aktivitäten und der behandelten Abfälle anzufertigen. Der Jahresüberblick kann auch eine Vierteljahresbilanz der Abfall- und Reststoffströme einschließlich der benutzten Hilfsstoffe für jeden Standort enthalten. Der Jahresüberblick sollte der zuständigen Behörde innerhalb von drei Monaten nach Jahresende übermittelt werden.

Erreichter Nutzen für die Umwelt
Trägt dazu bei, die Vorschläge von Betreibern und insbesondere die Möglichkeiten für weitere Verbesserungen zu bewerten.

Medienübergreifende Auswirkungen
Nicht bekannt.

Betriebsdaten
Gehört zum Management.

Anwendbarkeit
Vollständig anwendbar in allen Abfallbehandlungsanlagen. Dennoch wird die Anwendung von Technik d (siehe obige Beschreibung) für einige Anlagen manchmal als schwierig betrachtet, weil es sich bei manchen Abfällen um komplexe Mischungen handelt sowie ihre Zusammensetzung stark schwankt.

Treibende Kraft für die Anwendung
Dies ist in der Regel Bestandteil des Genehmigungsverfahrens.

Beispielanlagen
Übliche Technik.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [131, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.2.8 Werkzeuge des Umweltmanagements

Beschreibung
Die beste Umweltleistung wird üblicherweise durch die Ausstattung der besten Technologie und deren effektivsten und effizientesten Betrieb erzielt. Dies wird von der IVU-Richtlinie durch deren Definition von "Techniken" als *"sowohl die angewandte Technologie, als auch die Art und Weise, wie die Anlage geplant, gebaut, gewartet, betrieben und stillgelegt wird"* anerkannt.

Für IVU-Anlagen stellt ein Umweltmanagementsystem (UMS) ein Werkzeug dar, mit dem der Betreiber Planung, Bauart, Wartung, Betrieb und Stilllegung auf systematische und nachweisbare Art und Weise angehen kann. Ein UMS umfasst die Organisationsstruktur, Verantwortlichkeiten, Verhaltensweisen, Vorgehensweisen, Verfahren und Mittel zur Entwicklung, Einführung, Aufrechterhaltung, Überprüfung und Überwachung von Umweltpolitiken. Umweltmanagementsysteme sind dort am effektivsten und effizientesten, wo sie einen inhärenten Bestandteil des gesamten Managements und der gesamten Betriebsführung der Anlage darstellen.

Innerhalb der Europäischen Union haben sich viele Organisationen auf freiwilliger Basis dafür entschieden, Umweltmanagementsysteme auf Grundlage von EN ISO 14001:1996 oder nach dem EU Umweltmanagement- und Umweltbetriebsprüfungsplan EMAS einzuführen. EMAS beinhaltet die Anforderungen an das Managementsystem von EN ISO 14001, legt aber zusätzlichen Nachdruck auf die Einhaltung von Rechtsvorschriften, die Umweltleistung und die Einbeziehung der Arbeitnehmer. Es fordert auch eine externe Überprüfung des Managementsystems und Gültigkeitsprüfung einer öffentlichen Umwelterklärung (in EN ISO 14001 ist die Eigenerklärung eine Alternative zur externen Überprüfung). Es gibt auch viele Organisationen, die entschieden haben, nicht-standardisierte Umweltmanagementsysteme einzuführen.

Während sich sowohl standardisierte Systeme (EN ISO 14001:1996 und EMAS) sowie nicht standardisierte ('kundenspezifischen') Systeme grundsätzlich auf die *Organisation* als Einheit beziehen, hat dieses Dokument eine engere Herangehensweise. Es bezieht nicht alle Tätigkeiten der Organisation ein, – z.B. im Hinblick auf ihre Produkte und Dienstleistungen – da die von der IVU-Richtlinie geregelte Einheit die *Anlage* selbst ist (wie in Artikel 2 definiert).

Ein Umweltmanagementsystem (UMS) für eine IVU-Anlage kann folgende Komponenten umfassen:

- Definition einer Umweltpolitik
- Planung und Festlegung von Zielsetzungen und Einzelzielen
- Einführung und Durchführung von Prozeduren
- Nachprüfung und Korrekturmaßnahmen
- Qualitätsmanagementbewertung
- Vorbereitung einer regelmäßigen Umwelterklärung
- Überprüfung durch Zertifizierungsstelle oder externen Umweltgutachter
- Aufbau von Überlegungen für die endgültige Stilllegung der Anlage
- Entwicklung sauberer Technologien
- Benchmark-Bewertungen.

Diese Merkmale werden weiter unten etwas detaillierter erklärt. Für ausführliche Informationen zu den Komponenten (a) bis (g), die alle in EMAS enthalten sind, wird der Leser auf die unten angeführte Referenzliteratur verwiesen.

a. Festlegung einer Umweltpolitik
   Die Betriebsführungsebene ist verantwortlich für die Festlegung einer Umweltpolitik für eine Anlage und für die Sicherstellung, dass sie:
   - angemessen ist in Art, Ausmaß und Umweltauswirkungen der Tätigkeiten
   - eine Verpflichtung zur Vermeidung und Kontrolle der Umweltverschmutzung enthält
   - eine Verpflichtung zur Einhaltung aller relevanten Umweltgesetze und –vorschriften sowie anderer Forderungen, denen sich die Organisation verpflichtet, enthält
   - einen Rahmen für die Festlegung und Bewertung der umweltbezogenen Zielsetzungen und Einzelziele bildet
   - dokumentiert und allen Mitarbeitern bekannt gemacht wird
   - der Öffentlichkeit und allen interessierten Kreisen zugänglich ist
b. Planung, d.h.:
   - Prozeduren zur Bestimmung von Umweltaspekten der Anlage, um jene Tätigkeiten zu ermitteln, die bedeutende Auswirkungen auf die Umwelt haben oder haben können und diese Informationen auf dem neuesten Stand zu halten
   - Prozeduren, um gesetzliche und andere Anforderungen zu ermitteln und zugänglich zu machen, zu deren Einhaltung sich die Organisation verpflichtet und die geeignet für die Umweltaspekte ihrer Tätigkeiten sind
   - Festlegung und Bewertung dokumentierter Zielsetzungen und Einzelziele, unter Berücksichtigung der gesetzlichen und anderen Forderungen und der Standpunkte interessierter Kreise
   - Einführung und regelmäßige Aktualisierung eines Umweltmanagementprogramms, einschließlich einer Festlegung der Verantwortlichkeit für die Verwirklichung der Zielsetzungen und Einzelziele für jede relevante Funktion und Ebene, ebenso wie die Mittel und den Zeitraum für ihre Zielerreichung

c. Implementierung und Durchführung von Prozeduren
Es ist wichtig, Systeme vorzuhalten, die gewährleisten, dass die Prozeduren bekannt sind, verstanden und eingehalten werden. Deshalb umfasst ein effektives Umweltmanagement:

- Organisationsstruktur und Verantwortlichkeit
  - Festlegung, der Dokumentation sowie Rollen des Informationsflusses, Verantwortlichkeiten und Kompetenzen, was die Bestellung eines spezifischen Beauftragten des Managements beinhaltet
  - Bereitstellung der für die Implementierung und Überwachung des Umweltmanagements benötigten Mittel, darunter auch das erforderliche qualifizierte Personal, Technologie und Finanzmittel
- Schulung, Bewusstsein und Kompetenz
  - Ermittlung des Schulungsbedarfs zur Sicherstellung, dass alle Beschäftigten, deren Arbeit einen signifikanten Einfluss auf Umweltauswirkungen haben können, entsprechende Schulung erhalten.
- Kommunikation
  - Einführung und Aufrechterhaltung von Prozeduren für die interne Kommunikation zwischen den verschiedenen Ebenen und Funktionen der Anlage sowie Prozeduren, die einen Dialog mit externen interessierten Kreisen fördern und Prozeduren für die Entgegennahme, Dokumentation und – wo es sinnvoll ist – Beantwortung relevanter Mitteilungen von externen interessierten Kreisen.
- Einbeziehung der Arbeitnehmer
  - Einbeziehung der Arbeitnehmer in den Prozess zur Erreichung einer hohen Umweltleistung durch Anwendung geeigneter Formen der Beteiligung, wie z.B. des Vorschlagswesens oder projektbezogener Gruppenarbeit oder Umweltausschüsse.
- Dokumentation
  - Einführung und Pflege von Informationen auf dem neuesten Stand, auf Papier oder in elektronischer Form. Dies geschieht, um wesentliche Elemente des Managementsystems und ihre Wechselwirkungen beschreiben zu können, und um Hinweise zu zugehöriger Dokumentation zu geben.
- Wirksame Prozesskontrolle
  - Angemessene Kontrolle von Prozessen in allen Betriebszuständen, d.h. Vorbereitung, Anfahren, Regelbetrieb, Abfahren und unnormale Betriebsbedingungen
  - Festlegung der wichtigsten Leistungsindikatoren und Methoden, um diese Parameter zu messen und zu überwachen (z.B. Durchfluss, Druck, Temperatur, Zusammensetzung und Menge)
  - Dokumentation und Analyse ungewöhnlicher Betriebsbedingungen zur Identifizierung der Ursachen und anschließender Besprechung, um sicherzustellen, dass solche Ereignisse sich nicht wiederholen (das kann erleichtert werden indem eine Kultur des „nicht Tadelns“ eingeführt wird, in der die Identifikation von Ursachen wichtiger ist als Zuweisung von Schuld an Einzelpersonen)
- Wartungsprogramm
  - Einführung eines strukturierten Wartungsprogramms, das auf technischen Beschreibungen der Ausrüstungen, Normen etc. und auch auf jeglichen Fehlfunktionen und deren Konsequenzen basiert
  - Unterstützung des Wartungsprogramms durch angemessene Dokumentationssysteme und Diagnosetests
  - Klare Zuweisung der Verantwortlichkeiten für Planung und Ausführung der Wartung.
- Notfallbereitschaft und –reaktionen
  - Einführung und Aufrechterhaltung von Verfahren, um das Potenzial für und Reaktionen auf mögliche Unfälle und Notfallsituationen zu ermitteln und Umweltauswirkungen, die damit verbunden sein könnten, zu verhindern und zu begrenzen

d. Kontroll- und Korrekturmaßnahmen, d.h.:
   - Überwachungen und Messungen
     - Einführung und Aufrechterhaltung dokumentierter Verfahren, um maßgebliche Betriebsparameter und Tätigkeiten, die eine signifikante Auswirkung auf die Umwelt haben können, regelmäßig zu überwachen und zu messen, einschließlich der Aufzeichnung von Informationen zu der Nachverfolgbarkeit der Leistung, den relevanten betrieblichen Kontrollen und der Konformität mit den umweltbezogenen Zielsetzungen und Einzelzielen (siehe auch das Referenzdokument zur Überwachung von Emissionen) [68, EIPPCB, 2003]
     - Einführung und Aufrechterhaltung einer dokumentierten Prozedur zur regelmäßigen Bewertung der Einhaltung von relevanten gesetzlichen Umweltvorschriften
   - Korrektur- und Vorsorgemaßnahmen
     - Einführung und Aufrechterhaltung von Verfahren, um die Verantwortlichkeit und Befugnis für die Handhabung und Untersuchung von Abweichungen von Genehmigungsauflagen, anderen gesetzlichen Vorschriften sowie von Zielsetzungen und Einzelzielen, zu bestimmen,
     - Maßnahmen zur Begrenzung etwaig verursachter Auswirkungen zu ergreifen und zur Initiierung und Vervollständigung von Korrektur- und Vorsorgemaßnahmen , die der Schwere des Problems Rechnung tragen und den Umweltauswirkungen angemessen sind.
   - Aufzeichnungen
     - Einführung und Aufrechterhaltung von Verfahren für die Kennzeichnung, Pflege und Verfügbarkeit von lesbaren, identifizier- und rückverfolgbaren umweltbezogenen Aufzeichnungen, einschließlich Aufzeichnungen über Schulungen und Ergebnisse von Umweltaudits und –bewertungen.
   - Audit
     - Einführung und Aufrechterhaltung eines (mehrerer) Programme(s) und Verfahren für die regelmäßige Auditierung des Umweltmanagementsystems, die Gespräche mit dem Personal, Inspektion der Betriebsbedingungen und der Ausstattung sowie Prüfung von Aufzeichnungen und Dokumentation beinhalten, die in einem schriftlichen Bericht zusammengefasst werden, der unparteiisch und objektiv entweder von Beschäftigten (interne Audits) oder von Externen (externe Audits) durchgeführt wird. Der Bericht umfasst Umfang, Häufigkeit und Methodik des Audits ebenso wie Verantwortlichkeiten und Anforderungen für die Durchführung von Audits und Berichterstattung der Ergebnisse, um festzulegen, ob das Umweltmanagementsystem mit den geplanten Abmachungen übereinstimmt oder nicht, und ob es richtig implementiert und aufrechterhalten wurde.
     - Absolvieren von Audits oder Auditszyklen, soweit angemessen, in Intervallen von nicht mehr als drei Jahren, abhängig von Art, Umfang und Komplexität der Tätigkeiten, der Bedeutung der damit verbundenen Umweltauswirkungen, der Wichtigkeit und Dringlichkeit der in früheren Audits aufgeführten Probleme sowie der Historie der Umweltprobleme – komplexere Tätigkeiten mit wesentlichen Umweltauswirkungen werden häufiger auditiert
     - Bereitstellung angemessener Mechanismen zur Sicherstellung, dass den Ergebnissen des Audits gefolgt wird
   - Regelmäßige Bewertung der Rechtskonformität
     - Prüfung der Einhaltung der geltenden Rechtsvorschriften und der Genehmigungsauflagen der Anlage
     - Dokumentation der Bewertung

e. Bewertung durch das Management, d. h.:
   - Bewertung des Umweltmanagementsystems, in festgelegten Abständen, durch die Betriebsleitung, um seine fortdauernde Eignung, Angemessenheit und Effektivität sicherzustellen
   - Gewährleistung, dass notwendige Informationen gesammelt werden, um dem Management eine Bewertung zu ermöglichen
   - Dokumentation dieser Bewertung

f. Erstellung einer regelmäßigen Umwelterklärung:
   - Erstellung einer Umwelterklärung, in der insbesondere auf erreichte Resultate der Anlage in Hinblick auf ihre Umweltzielsetzungen sowie Einzelziele eingegangen wird. Sie wird regelmäßig erstellt – von einmal im Jahr bis weniger häufig, abhängig von der Bedeutung der Emissionen, der Abfallerzeugung usw. Sie berücksichtigt den Informationsbedarf relevanter interessierter Kreise und ist öffentlich zugänglich (z.B. in elektronischen Veröffentlichungen, in Bibliotheken usw.)
   - Bei Erstellung der Umwelterklärung kann der Betreiber relevante vorhandene Indikatoren für die Umweltleistung nutzen, wobei er sicherstellt, dass die gewählten Indikatoren:
     - eine genaue Bestandsaufnahme der Umweltleistungen der Anlage geben
     - verständlich und eindeutig sind
     - einen Vergleich auf Jahresbasis ermöglichen, um die Entwicklung der Umweltleistung der Anlage zu beurteilen
     - wo angemessen, einen Vergleich zwischen verschiedenen branchenbezogenen, nationalen oder regionalen Benchmark-Bewertungen ermöglichen
     - wo angemessen, einen Vergeich mit rechtlichen Anforderungen ermöglichen

g. Prüfung durch Zertifizierungsstelle oder externen UMS-Gutachter:
   - Das Vorhandensein eines Managementsystems, Auditverfahrens und einer Umwelterklärung, die durch eine anerkannte Zertifizierungsstelle oder einen externen UMS-Gutachter untersucht und bestätigt werden, kann - wenn sie richtig durchgeführt werden - die Glaubwürdigkeit des Systems erhöhen.

h. Darstellung der Berücksichtigung der endgültigen Stilllegung der Anlage
   - Darstellen wie Umweltauswirkungen einer möglichen Stilllegung einer Einheit schon bei der Planung der neuen Anlage berücksichtigt werden, da die frühzeitige Beachtung, eine Stilllegung einfacher, sauberer und preiswerter macht
   - Stilllegungen stellen ein Umweltrisiko in Bezug auf Kontaminationen von Boden (und Grundwasser) dar und erzeugen große Mengen fester Abfälle. Vorsorgende Techniken sind prozessabhängig, doch allgemeine Überlegungen können enthalten:
     - Vermeidung von Untergrundbauten
     - Einbeziehung von Merkmalen, die die Demontage erleichtern
     - Wahl von Oberflächen, die leicht dekontaminiert werden können
     - Nutzung einer Konfiguration der Ausrüstung, das eingeschlossene Chemikalien minimiert und einen Ablauf oder Waschen ermöglicht
     - Planung flexibler, in sich abgeschlossener Einheiten, die eine stufenweise Schließung ermöglichen
     - Nutzung von Materialien die biologisch abbaubar und recycelbar sind, wo dies möglich ist

i. Entwicklung sauberer Technologien:
   - Umweltschutz sollte eine inhärentes Merkmal jeglicher vom Betreiber durchgeführter Prozessplanungstätigkeiten sein, denn Techniken, die im frühestmöglichen Stadium der Planung berücksichtigt werden, sind effektiver und preiswerter. Die Berücksichtigung der Entwicklung von sauberen Technologien kann zum Beispiel durch Forschungs- und Entwicklungsaktivitäten oder Studien erfolgen. Als Alternative zu internen Tätigkeiten, können Verabredungen getroffen werden, um mit anderen Betreibern oder Forschungseinrichtungen, die auf dem betreffenden Gebiet tätig sind, zu arbeiten oder – wo angemessen– von ihnen Auftragsarbeiten durchführen zu lassen.

j. Benchmark, d.h.:
   - Durchführung systematischer und regelmäßiger Vergleiche mit branchenbezogenen, nationalen oder regionalen Benchmarks, einschließlich Energieeffizienz und Energiesparaktivitäten, Wahl der Inputmaterialien, Emissionen in die Luft und Einleitungen ins Wasser (dabei kann zum Beipiel das Europäische Schadstoffemissionsregister EPER benutzt werden), Wasserverbrauch und Abfallerzeugung.

<u>Standardisierte und nicht standardisierte UMS</u>

Ein UMS kann die Form eines standardisierten oder eines nicht standardisierten („kundenorientierten“) System haben. Anwendung und Befolgung eines international akzeptierten standardisierten Systems wie EN ISO 14001:1996 kann dem UMS eine höhere Glaubwürdigkeit geben, insbesondere wenn es einer genau durchgeführten externen Überprüfung unterzogen wird. EMAS bringt zusätzliche Glaubwürdigkeit infolge der Wechselwirkung mit der Öffentlichkeit, durch die Umwelterklärung und den Mechanismus zur Sicherstellung der Einhaltung von geltenden Vorschriften des Umweltrechts. Dennoch können nicht standardisierte Systeme grundsätzlich ebenso wirksam sein, vorausgesetzt, dass sie richtig geplant und umgesetzt werden.

Erreichter Nutzen für die Umwelt
Die Implementierung und Anwendung eines Umweltmanagementsystems fokusiert die Aufmerksamkeit des Betreibers auf die Umweltleistung der Anlage. Insbesondere die Aufrechterhaltung und Einhaltung klarer Betriebsabläufe für normale und nicht geplante Situationen und der damit verbundenen Verantwortlichkeiten sollten gewährleisten, dass die Genehmigungsauflagen der Anlage sowie andere Umweltzielsetzungen und Einzelziele zu jeder Zeit eingehalten werden.

Umweltmanagementsysteme gewährleisten in der Regel die kontinuierliche Steigerung der Umweltleistung der Anlage. Je schlechter die Ausgangslage ist, desto bedeutendere kurzfristig erreichbare Verbesserungen können erwartet werden. Wenn die Anlage bereits eine gute Gesamtumweltleistung aufweist, hilft das System dem Betreiber, das hohe Leistungsniveau aufrechtzuerhalten.

Medienübergreifende Auswirkungen
Umweltmanagementmethoden sind so angelegt, dass sie die gesamten Umweltauswirkungen ansprechen, was dem integrierten Ansatz der IVU-Richtlinie entspricht.

Betriebsdaten
Es liegen keine speziellen Informationen vor.

Anwendbarkeit
Die oben beschriebenen Komponenten können in der Regel auf alle IVU-Anlagen angewendet werden. Der Umfang (z.B. Grad der Detaillierung) und die Art des Umweltmanagementsystems (z.B. standardisiert oder nicht standardisiert) stehen in der Regel in Bezug zu Art, Umfang und Komplexität der Anlage und dem Ausmaß ihrer möglichen Umweltauswirkungen.

Wirtschaftlichkeit
Die genaue Bestimmung der Kosten sowie des wirtschaftlichen Nutzens der Einführung und Aufrechterhaltung eines guten UMS ist schwierig. Einige Studien sind nachfolgend aufgeführt. Diese sind jedoch lediglich Beispiele, und die Ergebnisse nicht ganz koherent. Sie müssen nicht repräsentativ für alle Branchen innerhalb der EU sein und sollten deshalb mit Vorsicht behandelt werden.

Eine schwedische Studie aus dem Jahr 1999 befragte alle 360 ISO-zertifizierten und EMAS-registrierten Unternehmen in Schweden. Bei einer Rücklaufquote von 50 % kam sie unter anderem zu folgendem Ergebnis:

- die Ausgaben zur Einführung und Durchführung eines UMS sind hoch, aber nicht unverhältnismäßig, außer bei sehr kleinen Unternehmen. Die Kosten werden voraussichtlich in der Zukunft sinken
- ein höherer Grad an Koordination und Integration des UMS mit anderen Managementsystemen wird als möglicher Weg zur Kostenreduzierung angesehen
- die Hälfte aller Umweltzielsetzungen und Einzelziele amortisieren sich innerhalb eines Jahres durch Kostenersparnisse und/oder gesteigerte Einnahmen
- die höchsten Kosteneinsparungen wurden durch verringerte Ausgaben für Energie, Abfallbehandlung und Rohstoffe erzielt
- die meisten Unternehmen denken, dass ihre Marktposition durch das UMS gestärkt worden ist. Ein Drittel der Unternehmen berichtet, dass die Einnahmen durch das UMS gestiegen sind.

In manchen Mitgliedsstaaten werden ermäßigte Überwachungsgebühren erhoben, wenn die Anlage zertifiziert ist.

Mehrere Studien ([77, Klemisch and Holger, 2002], [78, Clausen, et al., 2002]) zeigen, dass ein umgekehrter Zusammenhang zwischen der Firmengröße und den Kosten zur Einführung eines UMS besteht. Ein ähnlicher umgekehrter Zusammenhang besteht für die Amortisationszeit des investierten Kapitals. Beide Ergebnisse zeigen, dass das Kosten-Nutzen-Verhältnis der Einführung eines UMS in KMU weniger günstig ist als in größeren Unternehmen.

Nach einer Schweizer Studie können die durchschnittlichen Kosten für Aufbau und Anwendung von ISO 14001 unterschiedlich sein:

- für ein Unternehmen mit 1 bis 49 Beschäftigten: (64000 CHF) 44000 EUR für den Aufbau des UMS und (16000 CHF) 11000 EUR pro Jahr für seine Anwendung
- für einen Industriestandort mit mehr als 250 Beschäftigten: (367000 CHF) 252000 EUR für den Aufbau des UMS und (155000 CHF) 106000 EUR pro Jahr für seineAnwendung.

Diese Durchschnittswerte repräsentieren nicht notwendigerweise die tatsächlichen Kosten für einen bestimmten Industriestandort, denn diese Kosten sind stark von der Anzahl relevanter Punkte (Schadstoffe, Energieverbrauch usw.) und von der Komplexität der zu untersuchenden Probleme abhängig.

Eine neuere deutsche Studie [69, Schaltegger and Wagner, 2002] zeigt die Kosten (siehe Tabelle 4.7) von EMAS für verschiedene Branchen. Es sei angemerkt, dass diese Zahlen viel kleiner als die der oben zitierten Schweizer Studie sind. Dies ist eine Bestätigung dafür, dass es schwierig ist, die Kosten eines UMS zu bestimmen.

Kosten für den Aufbau (EUR):	Kosten für Überprüfungen (EUR):
Bereich: 18750 - 75000 Durchschnitt: 50000	Bereich: 5000 – 12500 Durchschnitt: 6000

Tabelle 4.7: Kosten der Anwendung von EMAS

Eine Studie des deutschen Unternehmerinstitut/Arbeitsgemeinschaft. Selbständiger Unternehmer [70, UNI/-ASU,1997] liefert Informationen über die durchschnittlichen jährlichen Einsparungen durch EMAS und die durchschnittliche Amortisationszeit. Zum Beispiel wurden bei Implementierungskosten von 80000 EUR durchschnittliche Einsparungen von 50000 EUR pro Jahr ermittelt, was einer Amortisationszeit von 1 ½ Jahren entspricht.

Externe Kosten im Zusammenhang mit der Überprüfung des Systems können anhand eines Leitfadens des International Accreditation Forum [71, IAF, 2003] abgeschätzt werden.

Anreize zur Anwendung
Umweltmanagementsysteme können einige Vorteile bieten, zum Beispiel:

- verbesserte Einsicht in Umweltaspekte des Unternehmens
- verbesserte Grundlage für Entscheidungen
- höhere Motivation des Personals
- zusätzliche Möglichkeiten zur Senkung der Betriebskosten und Verbesserung der Produktqualität
- gesteigerte Umweltleistung
- verbessertes Firmenimage
- reduzierte Kosten bei der Haftung, Versicherungen und bei Nichteinhaltung der Vorgaben
- höhere Attraktivität für Beschäftigte, Kunden und Investoren
- größeres Vertrauen der Überwachungsbehörden, was zu verringerter Überwachung führen könnte
- besseres Verhältnis zu Umweltorganisationen.

Beispielanlagen
Die unter (a) bis (e) beschriebenen Punkte sind Bestandteile von EN ISO 14001:1996 und des EU-Gemeinschaftssystems für das Umweltmanagement und die Umweltbetriebsprüfung (EMAS), während die Punkte (f) und (g) EMAS-spezifisch sind. Es wurde berichtet, dass diese beiden standardisierten Methoden in sieben Abfallbehandlungsanlagen angewendet werden. Beispiele sind Anlagen für die Behandlung von Altöl, Lösemittelabfällen, Herstellung von Brennstoff aus gefährlichen Abfällen und nicht gefährlichen Abfällen.

Literatur
[66, TWG, 2003], [72, EC, 2001], [73, ISO, 1996], [150, TWG, 2004]

4.1.2.9 Förderung einer guten Zusammenarbeit zwischen Abfallerzeuger und –besitzer

Beschreibung
Grundsätzlich kann festgehalten werden, dass Maßnahmen, die zu Beginn der Kette getroffen werden, den höchsten Nutzen haben und die Vermeidung besser als die Behandlung ist. Folglich können Maßnahmen des Abfallerzeugers sowie –besitzers einen großen Einfluss auf den Abfall haben. Diese Methode legt somit den Schwerpunkt darauf, den Abfallerzeuger und –besitzer zu beeinflussen, und wenn Probleme existieren, die schlechten abfallwirtschaftlichen Gewohnheiten des Erzeugers und Besitzers zu ändern.

Erreichter Nutzen für die Umwelt
Abfallbehandlungsanlagen sind signifikant auf Verknüpfungen, mit der vorherigen Logistik, Maßnahmen und Firmen, angewiesen, insbesondere wenn dies zur Vermeidung kostspieliger Lösungen bei der Abfallbehandlung beiträgt.

Anwendbarkeit
Manchmal ist es sehr schwierig, Abfallerzeuger und –besitzer zur Änderung ihrer Gewohnheiten zu bewegen. Darüber hinaus wird die Kontrolle der Abfallerzeuger durch die zuständigen Behörden durchgeführt.

Wirtschaftlichkeit
Normalerweise verringert dies die Kosten der Abfallbehandlung.

Treibende Kraft für die Anwendung
Versuch, die Behandlungskosten zu senken. Diese Methode steht in Verbindung mit Artikel 3(c) zu Grundpflichten von Abfallerzeugern in Sektoren die unter die IVU-Richtlinie fallen und für Abfallerzeuger die nicht unter die IVU-Richtlinie fallen, Artikel 2 der Richtlinie über gefährliche Abfälle (91/689/EWG) .

Beispielanlagen
Chemisch-physikalische Behandlungsanlagen für Abwässer. Das bei der Abfallbehandlung in C-P-Anlagen anfallende Abwasser enthält unzulässig hohe Konzentrationen an organischen Stoffen, beschrieben als AOX. Technisch teure und zum Teil energieintensive Verfahren wie die Adsorption oder die Oxidation müssen eingesetzt werden, um diese organischen Stoffe aus dem Abwasser abzutrennen oder um sie in Abwasser umzuwandeln.

Eine verfahrensunabhängige Lösung dieser Aufgabe ist die getrennte Sammlung der organischen Materialien – beschrieben als AOX – direkt am Punkt der Entstehung, so dass sie in diesem Fall nicht mit dem zu behandelnden Abfall gemischt werden und das im Laufe der Abfallbehandlung anfallende Abwasser nicht verunreinigen können. Somit entfällt die Notwendigkeit, die oben genannten Verfahren anzuwenden, um den Anteil an organischen Materialien, beschrieben als AOX, zu verringern.

AOX kann nicht durch Adsorption an Aktivkohle abgetrennt werden. Es wird klar, dass eine getrennte Sammlung, der durch den AOX-Wert angezeigten Substanzen, sicherlich effektiver ist. In der Praxis werden diese Art Substanzen streng getrennt gehalten.

Ein Destillationsbetrieb sollte eine logistische Zusammenarbeit anstreben, um eine getrennte Sammlung der Materialien, die entsprechend der Destillationskriterien aufgearbeitet werden müssen, zu erreichen. Diese Kooperation wird in der Praxis angewendet und hat ihren Wert erwiesen.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.1.2.10 Einsatz von qualifiziertem Personal in der Anlage

Beschreibung
Einige Beispiele sind:

a. allgemeine Vorkehrungen: Zu allen Zeiten muss der Betreiber einer Abfallbehandlungsanlage genügend Personal mit den erforderlichen Qualifikation zur Verfügung und im Dienst haben. Das gesamte Personal muss sich speziellen Schulungen und Weiterbildungen unterziehen
b. Aufsichtsführendes Personal: Das aufsichtsführende Personal und alle Bereichsleiter der Abfallbehandlungsanlage müssen zuverlässig und technisch qualifiziert sein und angemessene praktische Erfahrungen vorweisen. Technische Qualifikationen können durch eine erfolgreich abgeschlossene Ausbildung an einer staatlichen oder staatlich anerkannten technischen Universität, Fachhochschule oder Ingenieursschule erworben worden sein. Technischer Sachverstand wird auch auf Basis vergleichbarer Ausbildung oder durch mehrjährige praktische Erfahrung anerkannt.
c. sonstiges Personal: Sonstiges Personal muss zuverlässig und technisch befähigt sein. Die technische Fähigkeit kann zum Beipiel auf anerkannte Ausbildungen in Ver- und Entsorgungsbetrieben der Kommunen oder in der Abfallbeseitigung, auf mehrjähriger praktischer Erfahrung oder auf vergleichbarer Ausbildung, beruhen.

Erreichter Nutzen für die Umwelt
Verbessert und erhält[7] die Umweltleistung der Einrichtung. Qualifiziertes Personal und qualifizierte Ausbildung sind für Abfallbehandlungen unentbehrlich, dies sowohl für die Abfallerzeuger (bei der Sortierung, Sammlung usw.), als auch für den Betreiber der Abfallbehandlungsanlage. Gesundheit, Sicherheit und Umweltschutz sind jeweils von einem guten Anlagenmanagement und von der Qualifikation der Arbeiter abhängig.

Medienübergreifende Auswirkungen
Nicht bekannt.

Betriebsdaten
Dies ist ein Managementinstrument.

Anwendbarkeit
Voll anwendbar in der gesamten Abfallbehandlungsbranche.

Wirtschaftlichkeit
Qualifizierte Arbeitskräfte sind in der Regel teurer. Die Durchführung von (entweder In-House- oder extern beauftragt) Schulungsprogrammen bringt zusätzliche Kosten für den Betreiber mit sich.

Beispielanlagen
In der Branche gibt es viele Beispiele. Es könnte passieren, dass angelieferte Abfälle Probleme verursachen, also ist es von Vorteil, dass das verantwortliche Personal aufmerksam gegenüber problematischen Abfällen ist. In jedem Fall sollten dem Personal alle Materialien bewusst sein, die Probleme während des Betriebs verursachen könnten. Abhängig von angewandten Maschinen könnten dies große sperrige Teile oder andere Bestandteile wie Metalle sein. Mit qualifiziertem Personal kann ein fast kontinuierlicher Betrieb mit geringen Qualitätsschwankungen garantiert werden.

Literatur
[126, Pretz, et al., 2003], [131, UBA, 2003], [150, TWG, 2004]

[7] Anm.d.Übers.: der Begriff „prevent“ des Originaltextes ist hier am ehesten als „erhalten“ zu verstehen.

4.1.3 Versorgungs- und Rohstoffmanagement

4.1.3.1 Bereitstellung einer Aufschlüsselung des Energieverbrauchs und der Energieerzeugung nach Quellen

Beschreibung
Zur Verbesserung des Energiesystem unter Umweltgesichtspunkten, muss das System gut verstanden und vollständig wiedergegeben sein. Unten sind einige Techniken angeführt, die dabei verwendet werden können:

a. Berichterstattung über den Energieverbrauch in Form der bezogenen Energie. Für Elektrizität kann dies unter Verwendung nationaler/regionaler Faktoren in den Primärenergieverbrauch umgerechnet werden (z.b. wird für Großbritannien in der Regel ein Umrechnungsfaktor von 2,6 für die öffentliche Elektrizitätsversorgung verwendet). Ein Beispielformat, in dem die Informationen dargestellt werden können, zeigt die folgende Tabelle 4.8:

Energiequelle	Energieverbrauch		
	Bezogen (MWh)	Primär (MWh)	% Anteil
Elektrizität *			
Gas			
Flüssige Brennstoffe			
Abfall			
Andere (vom Betreiber aufzuführen)			
* Quelle aufführen			

Tabelle 4.8: Energieverbrauchsberichterstattung
Basierend auf [55, UK EA, 2001]

b. Berichterstattung über die aus der Anlage abgegebene Energie
c. Bereitstellung von Informationen zu Energieflüssen (zum Beispiel Diagrammen oder Energiebilanzen), die zeigen, wie die Energie im Verlauf des Verfahrens eingesetzt wird. Diese Informationen können Betreibern die Bestimmung oder Berechnung des spezifischen Energieverbrauchs der Anlage ermöglichen.

Erreichter Nutzen für die Umwelt
Eine Bewertung der Verringerung der Emissionen des Energiesystems ist nur mittels richtiger Berechnung der tatsächlich erzeugten Emissionen möglich. Die Aufschlüsselung nach Erzeugung und Verbrauch kann dazu beitragen, die Übereinstimmung zwischen ihnen und folglich die Nutzung der Energie zu optimieren.

Medienübergreifende Auswirkungen
In manchen Fällen ist der Nutzen dieser Methode für die Umwelt begrenzt. Der Grund dafür ist, dass die Möglichkeit zur Senkung des Verbrauchs in einer existierenden Anlage sehr begrenzt sein kann, und mögliche Bemühungen zur Senkung des Verbrauchs gegen mögliche höhere Emissionen bei der Behandlung abgewogen werden müssen.

Anwendbarkeit
Voll anwendbar in der gesamten Abfallbehandlungsbranche. Dennoch kann es unter manchen Gegebenheiten (z.B. historische Entwicklung der Anlage/Standort, Management der Anlage), schwierig sein, Verbräuche jedem einzelnen Verfahrens-/Behandlungsschritt innerhalb des gesamten Verfahrens zuzuordnen. Diese Berichterstattung wird in der Regel jedes Jahr oder jedes halbe Jahr durchgeführt. Häufigere Frequenzen können im Fall starker Schwankungen der behandelten Abfallarten angewendet werden.

Wirtschaftlichkeit
Die Anforderungen sind einfach und mit geringen Kosten verbunden.

Anreize zur Anwendung
Verringerung der Energiekosten.

Literatur
[55, UK EA, 2001], [116, Irish EPA, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.3.2 Nutzung sauberer Brennstoffe

Beschreibung
Die Nutzung sauberer Brennstoffe hat eine direkte Auswirkung auf die Emissionen durch die Verbrennung dieser Brennstoffe. Brennstoffe mit weniger Kohlenstoff, Schwefel oder Partikeln pro Energieeinheit verursachen geringere Emissionen. So zum Beipiel Elektroautos oder mit Flüssiggas betriebene Fahrzeuge. Die Nutzung sauberer Brennstoffe kann im Konflikt mit der energetischen Nutzung der Abfälle stehen (z.B. mit der Nutzung von Abfall als Brennstoff im folgenden Abschnitt 4.1.3.3), denn letztere können unter bestimmten Umständen auch höhere Emissionen verursachen. Eine solche Fragestellung muss von Fall zu Fall untersucht werden.

Erreichter Nutzen für die Umwelt
Verringerung der Emissionen, vor allem von Kohlenstoff, Schwefel, Stickoxiden und Partikeln.

Wirtschaftlichkeit
In der Regel sind saubere Brennstoffe teurer.

Literatur
[86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004]

4.1.3.3 Nutzung von Abfall als Brennstoff

Beschreibung
Abfall kann in manchen Abfallbehandlungsanlagen als Brennstoff eingesetzt werden. Die meisten dieser Anlagen fallen unter die Abfallverbrennungs-Richtlinie und das BVT-Merkblatt zu Abfallverbrennungsanlagen und werden hier nicht aufgeführt. Allerdings wird die Nutzung brennbarer Gase aus Abfallbehandlungsanlagen (z.B. Deponie- und Biogas) sowie einiger Arten gefährlicher Abfälle (z.B. bestimmten Altölfraktionen) nicht von diesen Dokumenten abgedeckt. Bei der Nutzung derartiger Brennstoffe können folgende Techniken berücksichtigt werden:

a. Einsatz zertifizierter Brenner, d.h. eine Zertifizierung, dass sie das geforderte Verbrennungsniveau erreichen
b. Regeln über akzeptable Brennbedingungen könnten enthalten:
   - ordnungsgemäße Wartung und Betrieb von Brennern, um eine maximale Verbrennung sicherzustellen
   - Überprüfungen der Größe des Brenners und des verbrannten Ölvolumens
c. Einsatz einer Abgasreinigung, die den Brennern nachgeschaltet ist und Überwachung der Emissionen sowie der Aschebeseitigung (siehe Abschnitt 4.6).

Erreichter Nutzen für die Umwelt
Nutzung einer Ressource die in der Regel im Betrieb verfügbar ist. Infolge der hohen Anforderungen der Abfallverbrennungs-Richtlinie verursacht die Verbrennung von Abfall in der Regel geringe Emissionen.

Medienübergreifende Auswirkungen
In einigen Anlagen mit geringer Kontrolle kann die Verbrennung von Abfällen bei manchen Stoffen höhere Emissionen verursachen.

Wirtschaftlichkeit
In der Regel sind Brennstoffe aus Abfall preiswerter als konventionelle Brennstoffe. Zum Beipiel würde die voraussichtliche Kontrolle kleiner Altölbrenner eine spezifische maximale Schadstoffemission aus den Brennern ergeben. Dies würde von denjenigen, die Altöl verbrennen, verlangen, ihre Emissionen in die Luft zu überprüfen, um sicherzustellen, dass sie die benannten Werte nicht überschreiten. Dies ist wahrscheinlich weniger effektiv und teurer als die Einführung von Inputkontrollen. In dem Fall, dass kleine Mengen Altöl als Brennstoffe genutzt werden, ist die Überprüfung der Emissionen in die Luft schwieriger und teurer als die Überprüfung des Öl-Inputs, und wenn Emissionen festgelegte Werte überschreiten, kann schon ein Schaden eingetreten sein, bevor der Brenner abgeschaltet werden kann. Für kleinere Brenner würden wahrscheinlich die Kosten der Abluftkontrollen den finanziellen Vorteil der Altölverbrennung gegenüber der Verbrennung anderer Brennstoffe zunichte machen. Outputkontrollen zur Beseitigung der Asche würden ausfindig machen, wie und möglicherweise wo die Asche sicher beseitigt werden könnte.

Treibende Kraft für die Anwendung
Die Abfallverbrennung wird in der Richtlinie 2000/76/EG behandelt.

Beispielanlagen
Zum Beispiel nutzen Altölraffinerien die Leichtfraktion aus der Altöldestillation als Brennstoff. Die Abgaswäsche des Verbrennungsgases kann den Einsatz von Natronlauge erforderlich machen, um Emissionen saurer Gase aus einer Altölbehandlungsanlage zu reduzieren. Anschließend wird das Prozesswasser gestrippt, um das H_2S zu entfernen. Die Abgase werden den Prozess-Heizaggregaten für eine thermischen Zerstörung zugeführt und danach über den Abgaswäscher in die Luft abgeleitet.

Für Brenner mit hohen Volumendurchsätzen jeglicher Brennstoffe sind Abgasreinigungseinrichtungen Pflicht und für viele ist auch die Überwachung der Emissionen vorgeschrieben, da mögliche Auswirkungen als hoch eingeschätzt werden, falls Fehler auftreten.

Literatur
[14, Ministry for the Environment, 2000], [42, UK, 1995], [116, Irish EPA, 2003], [150, TWG, 2004]

4.1.3.4 Maßnahmen zur Steigerung der Energieeffizienz

Beschreibung
Einige Methoden die zur Steigerung der Energieeffizienz von Abfallbehandlungsanlagen anwendbar sind:

a. Entwicklung eines Energieeffizienzplans, der Kosten und Nutzen verschiedener Energieoptionen abschätzt
b. Einbeziehung von Energiemanagement-Techniken als Teil des gesamten Umweltmanagementsystem (UMS) einschließlich der Überwachung von Energieflüssen und Festlegung von Bereichen in denen der Energieverbrauch reduziert werden soll
c. Nutzung der Kraft-Wärme-Kopplung (KWK)
d. Durchführung von Betriebs-, Wartungs- und Haushaltungsmaßnahmen bei den relevantesten Installationen, in denen Energie verbraucht wird, wie:
   - Klimaanlagen, Prozesskühlungen sowie Kühlsysteme (Leckagen, Abdichtungen, Temperaturkontrolle, Wartung von Verdunstern und Kondensatoren)
   - Betrieb von Motoren und Antrieben (z. B. hocheffiziente Motoren)
   - Druckgassysteme (Leckagen, Verfahrensabläufe für die Nutzung)
   - Dampfverteilsysteme (Leckagen, Kondensatabscheider, Isolierung)
   - Raumheizung und Heißwassersysteme
   - Schmierung zur Vermeidung von hohen Reibungsverlusten (z.B. Nebelschmierung)
   - Wartung von Kesseln, z. B. Optimierung des Luftüberschusses
   - sonstige für die Aktivitäten in der Anlage relevante Wartungsarbeiten
   - regelmäßige Überprüfung der Geräteanforderungen
   - Minimierung von Verschüttungen und Leckagen durch die Nutzung von Tropfwannen. Die meisten verschütteten Brennstoffe werden zu den Hauptabscheidern des Standorts geleitet.

e. Anwendung von Techniken, die den Energieverbrauch senken und dadurch sowohl die direkten Emissionen (am Standort erzeugte Wärme und Emissionen) als auch die indirekten Emissionen (von einem entfernten Kraftwerk) reduzieren. Zu diesen Techniken gehören zum Beispiel:
   - die Wärmeisolation der Gebäude
   - die Anwendung energieeffizienter Beleuchtung auf der Anlage
   - die Wartung von Fahrzeugen
   - die effiziente Auslegung der Anlage, um Pumpstrecken zu verkürzen
   - die Phasenoptimierung von elektronischen Motoren
   - die Wärmeverwertung
   - sicherstellen, dass Geräte ausgeschaltet werden, wenn sie nicht benutzt werden und die Sicherheit nicht beeinträchtigt wird
   - sicherstellen, dass auf dem Betriebsgelände die Fahrzeugbewegungen auf ein Minimum beschränkt werden und Motoren ausgeschaltet werden, wenn sie nicht benutzt werden

f. Anwendung von einfachen, preiswerten physikalischen Techniken um große Ineffizienzen zu vermeiden; dazu gehören Wärmeisolierung, Eindämmungsmethoden (zum Beispiel Abdichtungen und selbstschließende Türen) und die Vermeidung von unnötigen Ableitungen von heißem Wasser oder von Luft (zum Beispiel durch Ausstattung mit einfachen Kontrollsystemen)
g. Anwendung von Energiespartechniken in der Gebäudetechnik
h. Betrieb von energieintensiven Geräten außerhalb der Spitzenverbrauchszeiten
i. Bestimmung und Berechnung des spezifischen Energieverbrauchs der Tätigkeit(en) anhand von Leistungsindikatoren auf jährlicher Basis (z.B. MWh/Mg verarbeiteten Abfalls). Diese können z.B. auf Primärenergieverbräuchen der Produkte oder dem Rohstoffinput basieren, welche möglichst weitgehend mit dem Hauptzweck oder der Produktionskapazität der Anlage übereinstimmen.
j. Emissionsminderung bei Dieselmotoren
k. Nutzung von Deponiegas zur Erzeugung von Elektrizität und Wärme
l. Anfertigung eines Energiegutachtens zur Identifizierung der Möglichkeiten weiterer Energieeinsparungen
m. Nutzung der Wärme aus Öfen und Motoren für Verdampfungs-, Trocknungs- und Vorheizprozesse
n. Auswahl der Abfälle, die zur Behandlung in der Anlage geeignet sind. In der Regel verbrauchen Anlagen, die nicht für die Behandlung eines bestimmten Abfalls ausgelegt sind, mehr Energie, wenn sie einen solchen Abfall behandeln.

Erreichter Nutzen für die Umwelt

Ein Energieeffizienzplan könnte in einem Format zusammengefasst werden, das dem unteren[8] Beispiel in Tabelle 4.8 ähnelt, zusammen mit unterstützenden Informationen aus durchgeführten Abschätzungen. Der Plan muss sicherstellen, dass der Betreiber alle relevanten Techniken berücksichtigt hat.

Möglichkeit effizienter Energienutzung	**CO_2-Einsparung (Mg)**	
	Jährlich	*Lebensdauer*
7MW KWK-Anlage	13500	135000
Hocheffizienter Motor	2	14
Druckluft	5	n.v.[9]

Tabelle 4.9: CO_2–Einsparungen durch die Integration verschiedener Techniken zur Erhöhung der Energieeffizienz [55, UK EA, 2001]

Die Nutzung eines Energieeffizienzplans und Umstellung auf saubere Brennstoffe kann den Energieverbrauch sowie Emissionen aus der Energienutzung reduzieren. Eine Erhöhung der Energieeffizienz des Kessels und der Heizaggregate reduziert VOC-Emissionen infolge einer vollständigeren Verbrennung und Minimierung der Brennstoffverluste.

Betriebsdaten

Der Ort innerhalb der Abfallbehandlungsanlage, an dem Verbesserungen durchgeführt werden können, hängt in der Regel von der Anlage selbst ab.

[8] Anm.d.Übers.: Wahrscheinlich ist hier „oben“ und nicht unten gemeint, da ein Verweis auf vorige Tabelle.
[9] Anm.d.Übers.: n.v. = nicht verfügbar.

Anwendbarkeit
Voll anwendbar. Auf Grund des typischerweise integrierten Ansatzes, das bei dem Energiesystem genutzt wird, wird allerdings in Anlagen, in denen mehrere Aktivitäten durchgeführt werden, die Zuordnung des Energieverbrauchs für jede einzelne Tätigkeit schwierig.

Diese Techniken werden in größerem Maße bei großen Energieverbrauchern angewendet. In energieintensiven Branchen mag die Anwendung von Energiespartechniken in der Gebäudetechnik nur geringe Auswirkungen haben, dies sollte aber, mit Blick auf die große Energiefrage, nicht von Anstrengungen abhalten. Sie können gleichwohl einen Platz im Programm zur Verbesserung des Energieverbrauchs finden, insbesondere dann, wenn sie mehr als 5% des Gesamtenergieverbrauchs ausmachen.

Wirtschaftlichkeit
In der Regel haben energieeffiziente Systeme höhere Investitionskosten. Allerdings sind die Betriebskosten in der Regel niedriger (oder die Einkünfte höher). In der Regel sind die Kosten für existierende Anlagen höher als für Neuanlagen. Einige Beispiele zeigt die Tabelle 4.10.

Möglichkeit effizienter Energienutzung	**Barwert EUR'000**	**Barwert/CO_2-Einsparung EUR/Mg**
7MW KWK-Anlage	2058	15
Hocheffizienter Motor	0,75	52,5
Druckluft	n.v.	n.v.
Nur Anhaltspunkt, basiert auf Kosten-Nutzen-Bewertung .		

Tabelle 4.10: Wirtschaftliche Daten für die Integration verschiedener Techniken zur Erhöhung der Energieeffizienz [55, UK EA, 2001]

Die Erhöhung der Energieeffizienz muss mit den verbundenen Kosten abgewogen werden. Abfallbehandlungsanlagen verbrauchen unterschiedliche Arten an Energie (Elektrizität, Dampf usw.), und die Möglichkeiten zur Senkung des Verbrauchs in einer existierenden Anlage können in manchen Fällen ziemlich begrenzt sein. In solchen Fällen sind die erforderlichen Anstrengungen möglicherweise ökonomisch oder ökologisch nicht gerechtfertigt.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [116, Irish EPA, 2003], [132, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.3.5 Wahl der Rohmaterialien

Beschreibung
Dieser Abschnitt befasst sich mit Auswahl und Ersatz der eingesetzten Rohstoffe. Einige Techniken sind:

a. Ermittlung der Roh- und Hilfsstoffe, weiterer Stoffe und des Wassers, die für den Einsatz vorgesehen sind. Dazu gehört die Zusammenstellung einer Liste aller eingesetzter Materialien (einschließlich, z.B. allgemeine Informationen über die Materialien; dabei ist zu beachten, dass es normalerweise angemessen ist, ähnliche Materialien zusammenzufassen, anstatt jede auf dem Markt befindliche Alternative aufzulisten), die ein Potenzial für signifikante Umweltauswirkungen haben können, einschließlich:
   - der chemischen Zusammensetzung der Materialien, soweit es von Bedeutung ist
   - der verwendeten Mengen
   - des Verbleibs der Materialien (das heißt, ungefährere Anteile je Medium und Produkt)
   - der Umweltauswirkungen, soweit bekannt (zum Beispiel Abbaubarkeit, Potenzial für Bioakkumulation, Giftigkeit für bedeutende Arten)
   - aller sinnvoll einsetzbaren alternativen Rohmaterialien, die geringere Umweltauswirkungen haben (d.h. Anwendung des Substitutionsprinzips)
b. Rechtfertigung (zum Beispiel auf der Grundlage von Emissionen, Produktqualität und Wirtschaftlichkeit) der weiteren Nutzung aller Stoffe, für die eine ungefährlichere Alternative vorhanden ist
c. Führung eines ausführlichen Inventars der am Standort eingesetzten Rohmaterialien
d. Einführung von Prozeduren zur regelmäßigen Überprüfung neuer Entwicklungen bei den Rohstoffen und regelmäßige Einführung geeigneter Materialien die weniger gefährlich sind
e. Qualitätssicherungsmaßnahmen zur Überprüfung der Inhaltsstoffe von Rohmaterialien
f. Wiederverwendung des Kalkabfalls aus der Kalkeindüsung zur Minimierung der sauren Bestandteile im Abgas von Verbrennungsanlagen
g. Wiederverwendung von starken Säuren in Verfahren, wo Säure benötigt wird.

Erreichter Nutzen für die Umwelt
Diese Maßnahmen können:

- den Einsatz von Chemikalien und anderen Materialien reduzieren
- die Substitution von weniger schädlichen Materialien fördern, auch solchen, die einfach gemindert werden können und wenn sie gemindert werden, zu Stoffen führen, die einfach zu behandeln sind
- helfen, ein Verständnis über Verbleib von Nebenprodukten und Kontaminationen sowie ihre Umweltauswirkungen zu entwickeln
- als präferierte Option für einige saure Abfälle gesehen werden, dies hängt jedoch von Volumen und Schadstoffgehalt des Abfalls ab.

Medienübergreifende Auswirkungen
Sind möglich, zum Beipiel sollte bei der Wiederverwendung von Kalkabfällen auf mögliche Konzentrationen von Metall- und Organik-Verunreinigungen geachtet werden.

Betriebsdaten
Auf Grund der besonderen Natur von Abfallbehandlungsverfahren wird der Verbrauch der Rohmaterialien durch Schwankungen des Abfall-IN beeinflusst. Darüber hinaus gibt es Fälle, wo ein Ersatz von Rohmaterialien durch Abfallstoffe nicht möglich ist. Zum Beispiel ist Rohkalk alkalischer als Kalkabfall, folglich werden bei Verwendung von Kalkabfällen größere Mengen benötigt. Dies stellt eine Begrenzung im Hinblick auf die Größe des Reaktionsbehälters dar. Dies erfordert eine entsprechende Vergrößerung der Mischbehälter zur Produktion der Kalklösung.

Anwendbarkeit
Der Handlungsspielraum der Minimierung der potentiellen Umweltauswirkungen durch die Nutzung von Rohstoffen ist manchmal limitiert, wie etwa für die eingesetzten Quantitäten (Abfallminimierung) oder der Qualität (zum Beipiel Vorhandensein von Verunreinigungen, Einsatz von weniger schädlichen Alternativen).

Treibende Kraft für die Anwendung
Ökonomische und ökologische Gründe. Für konzentrierte Säuren (>70 Gew.-%) besteht ein Markt für gemischte oder wieder aufkonzentrierte Säuren. Es ist praktikabel geworden, Säuren einer Konzentration von 50 Gew.-% zu verwenden, obwohl dies einen höheren Energieeinsatz erfordert. Es wird erwartet, dass der Markt sich auf den Bereich von 20- bis 30-prozentigen Säuren ausweiten wird.

Anhang IV der IVU-Richtlinie legt fest, dass bei der Ermittlung der besten verfügbaren Techniken im Allgemeinen wie auch in Einzelfällen der Einsatz abfallarmer Technologie und weniger gefährlicher Stoffe, das Recycling der erzeugten Stoffe und der Abfälle zu berücksichtigen sind, sofern dies angemessen ist.

Beispielanlagen
Die folgenden Substitutionen von Rohmaterialien werden in GB in Betracht gezogen:

Rohmaterial	Möglicher Ersatzstoff
Natriumhydroxid	Nur "quecksilberfreies" NaOH sollte verwendet werden[1]
Demulgatoren	Nur vollständig biologisch abbaubare Produkte mit bekannten, sicheren Abbauprodukten sollten verwendet werden
[1] Industrielle Hersteller von NaOH meinen, dass quecksilberfreies NaOH weniger als 50 µg/kg enthalten sollte.	

Tabelle 4.11: Beispiele für die Substitution von Rohmaterialien
[55, UK EA, 2001], [86, TWG, 2003]

C-P-Anlagen werden so geplant, dass eine größtmögliche Menge verwertbarer Materialien abgetrennt werden kann, und nur ein Minimum an Hilfsstoffen eingesetzt werden muss. Der Verbrauch an Hilfsstoffen wird soweit wie möglich minimiert, wenn Abfälle genutzt werden können (z.B. Behandlung von Abfall mit Abfällen) anstelle von hergestellten Materialien.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.1.3.6 Techniken zum Wassersparen und Vermeidung der Wasserverschmutzung

Beschreibung
Der Wasserverbrauch sollte im Rahmen der BVT-Kriterien zur Vermeidung oder Reduzierung der Emissionen minimiert werden und sollte im Einklang mit einer sorgfältigen Nutzung von Wasser als natürlicher Ressource stehen. Einige allgemeine Informationen zu diesen Punkten sind im BVT-Merkblatt „Abwasser- und Abgasbehandlung" dagelegt worden. Einige zu berücksichtigende Techniken für den Abfallbehandlungssektor sind:

a. Durchführung regelmäßiger Wasseraudits mit dem Ziel der Senkung des Wasserverbrauchs und der Vermeidung von Wasserverschmutzung. Ein gutes Wasseraudit erfordert Folgendes:
   - die Erstellung von Flussdiagrammen und Wasser-Massenbilanzen für alle Tätigkeiten, bei denen Wasser verwendet wird
   - die Aufstellung von Wassereffiezienzzielen durch den Vergleich mit Richtlinien für den Sektor oder, wo solche nicht vorliegen, mit nationalen Benchmarks
   - die Verwendung von Wasser-Pinch-Analysen[10] oder anderer Wasseroptimierungstechniken
   - die Nutzung der o.g. Informationen zur Ermittlung und Bewertung von Möglichkeiten zur Verringerung des Wasserverbrauchs und zur Erstellung eines Aktionsplans zur Einführung von Verbesserungen innerhalb einer festgelegten Zeitskala
b. Verwendung wassereffizienter Techniken an der Quelle

[10] Anm.d.Übers.: Pinch Analyse: Analyse und Optimierung der energetischen Kopplung mehrerer Prozesse auf Grundlage thermodynamischer Kriterien. Der Begriff wird im Originaltext nicht erklärt.

c. Verfahrensinternes Wasserrecycling. Mögliche Optionen bei denen es möglich sein kann, sind:
   - Erneute Nutzung von Wasser innerhalb des Verfahrens, aus dem es kommt, indem es bei Bedarf zunächst behandelt wird. Wo dies nicht praktikabel ist, kann es in einem anderen Teil des Verfahrens genutzt werden, in dem geringere Anforderungen an die Wasserqualität bestehen
   - Ermittlung der Möglichkeit, in dem Frischwasser aus aufbereiteten Wasser substituiert werden kann, Ermittlung der Anforderungen an die Wasserqualität, die mit jeder Nutzung verbunden sind. Gering kontaminierte Wasserströme, wie etwa Kühlwässer, müssen getrennt gehalten werden, wenn die Möglichkeit der Wiederverwendung, möglicherweise auch nach einer Aufbereitung, besteht.

d. getrennte Einleitung von nicht verunreinigtem Wasser von Dächern und Oberflächen, welches nicht genutzt werden kann

e. schließlich die Behandlung des Abwassers. Allerdings erzeugt die beste konventionelle Abwasserbehandlung in vielen Fällen Wasser von guter Qualität, welches direkt oder nach Mischung mit Frischwasser im Verfahren verwendet werden kann. Obwohl die Qualität des behandelten Abwassers schwankt, kann es wahlweise bei geeigneter Qualität aufbereitet werden, oder zum Abwasser eingeleitet werden, wenn die Qualität unter die Toleranzwerte des Systems fällt. Der Betreiber der Abfallbehandlungsanlage kann identifizieren, wo behandeltes Wasser aus der Abwasserbehandlungsanlage genutzt werden kann und rechtfertigen, wo dies nicht der Fall ist. Besonders die Kosten von Membrantechnologie sinken kontinuierlich, so dass sie nun bei Abwasserströmen einzelner Verfahren oder auf das letztendliche Abwasser aus der Abwasserbehandlunganlage angewendet werden kann

f. Ersatz der Abwasserbehandlungsanlage und hierdurch ein wesentlich geringeres Abwasservolumen. Dennoch wird ein aufkonzentrierter Abwasserstrom verbleiben, allerdings kann, falls dieser klein genug ist und insbesondere wo Abwärme zur weiteren Behandlung durch Eindampfungen vorhanden ist, eine abwasserfreies System erreicht werden

g. Minimierung des Wasserverbrauchs, der zu Reinigungs- sowie Waschzwecken (unter Berücksichtigung der Auswirkungen auf Staubemissionen) verwendet wird durch:
   - Saugen, Kratzen oder Schrubben anstatt Abwaschen mit dem Schlauch
   - Bewertung des Umfangs, in dem Waschwasser wiederverwendet werden kann
   - Verwendung von Durchflußsteuerungen an allen Schläuchen, Handlanzen und Waschgeräten

h. Ableitung von Regenwasser zu Abscheidern

i. Überdachung von Teilen des Standortes, um eine Verunreinigung des Regenwassers zu vermeiden (z.B. der Hauptabfallbehandlungsanlage)

j. Schutz von Vorkehrungen, um eine direkte Einleitung von flüssigen und festen verschütteten Stoffen in Wasserläufe oder Abwasserkanäle zu vermeiden

k. Ermittlung und, wenn möglich, Quantifizierung von signifikanten diffusen Emissionen aus allen relevanten Quellen in das Wasser, einschließlich einer Schätzung des Anteils an den gesamten diffusen Emissionen für jeden einzelnen Stoff

l. Anwendung folgender Techniken auf unterirdische Bauten
   - Bestandaufnahme und Aufzeichnung des Verlaufs aller Entwässerungen und unterirdischer Leitungen
   - Ausweisung aller unterirdischer Gruben und Lagerbehälter
   - Verwendung ingenieurtechnischer Systeme zur Sicherstellung, dass Leckagen (z.B. aus Rohren) minimiert werden und, falls sie entstehen, sogleich erkannt werden, dies insbesondere dort, wo gefährliche Stoffe beteiligt sind
   - insbesondere die Bereitstellung von sekundären Auffangvorrichtung und/oder von Leckagemeldesysteme für unterirdische Rohrleitungen, Gruben und Lagerbehälter
   - Einführen eines Inspektions- und Wartungsprogramms für alle unterirdischen Bauteilen, zum Beispiel Druck- und Dichtigkeitsprüfungen und Überprüfung der Materialdicke

m. Anwendung der folgenden Techniken auf oberirdische Bauwerke:
   - detaillierte Beschreibung der Planung (relevante Informationen können, soweit diese angemessen sind, enthalten: Kapazität, Dicke, Abmessungen, Material, Durchlässigkeit, Stärke/Verstärkung, Resistenz gegenüber Chemikalien, Inspektions- und Wartungsvorgänge, Qualitätssicherungsverfahren beim Bau) und des Zustands der Oberflächen aller Betriebsflächen.
   - Inspektions- und Wartungsprogramm für undurchlässige Oberflächen und Eindämmungsvorrichtungen
   - Begründung der Fälle, wo Betriebsflächen nicht mit
     - einer undurchlässigen Oberfläche
     - Leckage-Rückhaltevorrichtungen
     - Abgedichteten Konstruktionsfugen
     - einer Verbindung zu einem abgedichteten Entwässerungssystem

   ausgestattet worden sind.
n. Anwendung der Techniken für Dichtungsmaßnahmen aus Abschnitt 4.1.4.4

Erreichter Nutzen für die Umwelt
Die Verringerung des Wasserverbrauchs kann ein eigenständiges ökologisches (oder ökonomisches) Ziel sein. Zusätzlich wird, unter dem Gesichtspunkt der Reduzierung von Schadstoffemissionen, Wasser das einen industriellen Prozess durchläuft durch die Zufuhr von Schadstoffen verunreinigt, deshalb kann durch Senkung des Wasserverbrauchs ein eindeutiger Nutzen gezogen werden, insbesondere:

- Wenn ein damit verbundener verfahrensinterner Vorteil besteht, wie etwa eine Senkung des Energiebedarfs zum Heizen und Pumpen des Wassers
- Wenn die Senkung des Wasserverbrauchs dazu führt, dass weniger Schadstoffe im Wasser gelöst werden, was wiederum eine Verringerung der Schlammbildung in der Abwasserbehandlungsanlage zur Folge hat
- Eine Berechnung der Massenbilanz für das Wasser kann in der Regel aufdecken, wo Verbräuche reduziert werden können.

Anwendbarkeit
In der Regel ist dies Teil eines integrierten Umweltmanagementsystems (Abschnitt 4.1.2.8) in der Anlage. Einige dieser Techniken werden nur in komplexen Abfallbehandlungsanlagen angewendet, um Möglichkeiten einer maximalen Wiederverwendung zu identifizieren und den Wasserverbrauch auf ein Minimum zu reduzieren.

Die oben erwähnten Techniken können Anwendungsbeschränkungen unterliegen, abhängig von der Art der Wasserabgabe, die kontinuierlich oder chargenweise erfolgen kann, sowie der Lage der Abwasserbehandlungsanlage, die off-site oder on-site sein kann.

Wirtschaftlichkeit
Wirtschaftliche Anreize zur Anwendung dieser Technik können sein:

- Verringerung der notwendigen Größe einer (neuen) Abwasserbehandlungsanlage
- Verringerung von Kosten, indem Wasser betriebsintern wiederverwendet oder von Dritten abgenommen oder beseitigt wird.

Treibende Kraft für die Anwendung
Ökonomische Anreize zur Senkung des Abwasseraufkommens und des Wasserverbrauchs. In manchen EU-Ländern bestehen Anreizsysteme, die zum Ziel haben, die Senkung des Wasserverbrauchs zu fördern.

Beispielanlagen
Flussdiagramme und Wasser-Massenbilanzen werden allgemein verwendet. Einige Standorte besitzen unterirdische Abscheider, Lagertanks, Mischtanks und Rohrleitungen, wobei es schwierig zu sein scheint, deren Unversehrtheit festzustellen. Aus allen dieser Anlagen können Emissionen in den darunterliegenden Boden auftreten, die normalerweise als meldepflichtige Freisetzungen zu behandeln wären. Einige Anlagen haben berichtet, dass es möglich ist, den Wasserverbrauch um bis zu 90 % zu senken.

Literatur
[54, Vrancken, et al., 2001], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.1.4 Lagerung und Handhabung

Dieser Abschnitt enthält bei der Festlegung der BVT zu berücksichtigende Techniken bei Lagerungs- und Handhabungsvorgängen in einer Abfallbehandlungsanlage. Dennoch muss darauf hingewiesen werden, dass ein horizontales BVT-Merkblatt mit dem Titel „Emissionen aus Lagerung“ erhältlich ist, und weitere Informationen zum Thema bereitstellt.

4.1.4.1 Allgemeine bei der Abfalllagerung angewendete Techniken

Beschreibung
Einige allgemeine Techniken sind:

a. Festlegung von Lagerabläufen für Fälle, in denen Fahrzeuge, die Abfälle befördern, über Nacht oder an Feiertagen auf dem Betriebsgelände geparkt werden müssen, wenn das Betriebsgelände nicht überwacht wird
b. Platzierung von Lagerflächen fern von Wasserläufen und sensiblen Bereichen und in einer Art und Weise, dass eine doppelte Behandlung von Abfällen in der Anlage vermieden oder auf ein Minimum reduziert wird
c. klare Markierung und Ausschilderung von Lagerbereichen im Hinblick auf Quantität und gefährlicher Eigenschaften zu darin gelagerten Abfällen
d. klare und eindeutige schriftliche Festlegung der gesamten maximalen Lagerkapazität der Anlage zusammen mit Einzelheiten zur Methode, die zur Berechnung der gelagerten Volumen im Vergleich zur maximalen Kapazität verwendet wird. Die festgelegte maximale Kapazität der Lagerbereiche sollte nicht überschritten werden
e. Gewährleistung, dass die Entwässerungs-Infrastruktur des Lagerbereichs den gesamten möglichen kontaminierten Ablauf fassen kann und dass Abflüsse unverträglicher Abfälle nicht miteinander in Kontakt kommen können
f. Freihaltung der Verkehrswege (zum Beispiel für Gabelstapler und Fußgänger) des gesamten Lagerbereichs, so dass der Umschlag von Behältern nicht von der Entfernung anderer abhängt, die eventuell den Zugang blockieren, außer von Fässern in derselben Reihe
g. Nutzung eines speziell ausgewiesenen Bereichs/Lagers für die Sortierung und Wiederverpackung von Laborabfallkleinmengen. Sobald die Abfälle nach ihrer Gefahreneinstufung, unter Berücksichtigung aller möglichen Inkompatibilitäten, sortiert und wiederverpackt worden sind, sollen diese Behälter nicht innerhalb des ausgewiesenen Bereichs für Laborabfall-Kleinmengen gelagert werden, sondern können und müssen zum geeigneten Lagerbereich abtransportiert werden.
h. Sorgfältige, den Umständen entsprechende, optimale Auslegung der Tanks und Behälter, in allen Fällen unter Beachtung der Art des Abfalls, Lagerzeit, des Gesamtdesigns der Tanks und der Mischverfahren, um eine Anhäufung von Schlamm zu vermeiden und die Entschlammung zu vereinfachen. Lagerungs- und Behandlungsbehälter müssen regelmäßig entschlammt werden
i. Gewährleistung, dass alle Verbindungen zwischen Behältern durch geeignete Ventile geschlossen werden können. Überlaufrohre müssen zu einem Auffangdrainagesystem führen, welches ein ausreichend eingedämmter Bereich oder ein anderer Behälter sein kann, vorausgesetzt, dass geeignete Kontrollmaßnahmen bestehen
j. Ausrüstung von Tanks und Behältern mit geeigneten Sicherungssystemen, zusammen mit Füllstandsmessern mit hörbarem und sichtbarem Alarm bei zu hohen Füllständen. Diese Systeme müssen robust genug sein und regelmäßig gewartet werden, um Schaumbildung und Schlammaufbau, die die Zuverlässigkeit der Füllstandsmesser beeinträchtigen, zu vermeiden
k. Gewährleistung, dass Lagerbehälter, die entzündliche oder leicht entzündliche Abfälle enthalten, speziellen Anforderungen genügen
l. Vorrangig oberirdische Verlegung von Leitungen, bei unterirdischer Verlegung müssen die Leitungen von geeigneten Inspektionskanälen umschlossen sein
m. Ersatz von unterirdischen oder teilweise unterirdischen Behältern ohne sekundäre Auffangvorrichtungen, zum Beispiel doppelwandige Behälter mit Leckagedetektion, durch oberirdische Konstruktionen
n. Ausrüstung von Silos mit Sicherheitssystemen, Füllstandsüberwachung und Alarm bei hohem Füllstand
o. Gewährleistung, dass in geschlossenen Lagerbunkern Entlüftungssysteme für Partikel oder eine Sprühbefeuchtung eingebaut sind

p. Behälter zur Lagerung großer Mengen müssen auf einer undurchlässigen Oberfläche, die gegenüber dem gelagerten Material resistent ist, errichtet werden. Die Behälter müssen abgedichtete Fugen und einen eingedämmten Bereich, mit ausreichender Kapazität, besitzen. Einige Beispiele für die angewendeten Volumenkapazitäten sind: Mindestens 110 % (andere 100 %) des größten Behälters oder 25 % (andere 50 %) des gesamten Tankvolumens innerhalb des eingedämmten Bereichs
q. Gewährleistung, dass die zu den Behälter gehörenden Konstruktionen, Leitungen, Schläuche und Verbindungen resistent gegenüber den gelagerten Stoffen (und Stoffgemischen) sind
r. keine Verwendung von Behältern über die festgelegte Lebensdauer hinweg, mit Ausnahme, wenn die Gefäße in regelmäßigen Intervallen überwacht werden und schriftlich festgehalten wird, dass sie weiterhin für ihren Zweck geeignet sind und ihr Wandstärken ausreichend bemessen sind
s. Dort, wo Öl in Vorbehandlungsverfahren innerhalb einer chemischen Behandlungsanlage behandelt wird, Verbinden des Gasraums oberhalb des Ölabsetztanks mit der Abgasreinigungsanlage des gesamten Standorts. Einige Standorte haben lokale Absaugentlüftungssysteme, um den Luftaustausch beim Laden und Entladen von Tankfahrzeugen auszugleichen
t. Lagerung von flüssigen organischen Abfällen (z.B. mit einem Flammpunkt von weniger als 21 °C) unter Stickstoffatmosphäre, um sie inert zu halten. Jeder Lagertank befindet sich in einem wasserundurchlässigen Rückhaltebereich und ist mit einem Füllstandsanzeiger ausgerüstet. Abgase aus Zwischenfällen werden erfasst und behandelt.
u. Verwendung von Kunststoffbahnen zur Abdeckung von offen gelagerten Feststoffen, bei denen Stäube entstehen können
v. Vorhalten einer angemessenen Anzahl von Behältnissen für die verschiedenen Arten von eingehenden und ausgehenden Abfallströmen
w. Ausrüstung einiger oder aller Behälter mit Auslässen auf verschiedenen Höhen, um in der Lage zu sein, bestimmte Schichten des Inhalts zu entnehmen
x. getrennte Behandlung von VOC-haltigen Abfallströmen und Nutzung von Anlagen, die für diese Abfallströme bestimmt sind
y. Vorhandensein von Messeinrichtungen, mit denen ein Schlammaufbau oberhalb eines bestimmten Levels und das Entstehen von Schaum vermieden wird, da sie Messungen in Behältern mit Flüssigkeiten beeinträchtigen können, z.B. durch regelmäßige Kontrolle der Behälter, Ablassen der Schlämme für eine geeignete weitere Behandlung und Verwendung von Entschäumern
z. Ausstattung von Tanks und Behältern mit geeigneten Sicherheitssystemen, falls flüchtige Emissionen entstehen können, zusammen mit Füllstandsmessern und Alarmeinrichtungen. Diese Verfahren müssen entsprechend robust sein (z.B. arbeitsfähig bei Anwesenheit von Schlamm und Schaum) und regelmäßig gewartet werden.

Einige allgemeine Techniken zur Geruchsreduzierung im Zusammenhang mit der Lagerung sind:

aa. Optimierung der Kontrollzeitdauer und Temperatur bei Absetzprozessen
bb. Kontrollieren der Dekantierung abgesetzter Schichten mittels visueller Bewertung von Proben aus verschiedenen Höhen
cc. Umgang mit geruchsintensiven Verbindungen in vollständig eingekapselten Behältern
dd. Lagerung von Fässern und Behältern mit geruchsintensiven Materialien in geschlossenen Gebäuden
ee. Lagerung von sauren und alkalischen Abfällen, die zur Geruchsbehandlung eingesetzt werden können, in einer Reihe von Silos und anschließendes erstellen eines optimalen Säure-Base-Gleichgewichts in großen Behältern (oder kleineren Einheiten).

Erreichter Nutzen für die Umwelt
Die angemessene und sichere Lagerung von Abfällen trägt zur Reduzierung von diffusen Emissionen (z.B. VOC, Gerüchen, Staub) und zur Senkung des Risikos von Leckagen bei. Eine getrennte Lagerung ist notwendig, um Zwischenfälle aus der Reaktion unverträglicher Stoffe zu vermeiden und um einer Eskalation im Falle eines solchen Zwischenfalls vorzubeugen.

Die Begründung für Technik p (siehe oben), in der ein Volumen von 110%, vorgesehen wird, berücksichtigt die Ansammlung von Regenwasser innerhalb der eingedämmten Auffangvorichtung.

Beispielanlagen

Anlagen, in denen organische Abfälle mit Lösemittel lagern, neigen zum Einsatz von Kohlefiltersytemen um Freisetzungen in die Luft zu kontrollieren, sowie zum Monitoring des Abgases. Einige VOCs können mittels Nachreinigung wie wässriger Gaswäsche oder Öl-Wäscher in Lösung zurückgeführt werden, während andere VOCs mittels Aktivkohlefilter zurückgehalten werden können. Geschlossene Behälter sind bei der Lagerung von Materialien, die Stoffe mit hohem Dampfdruck enthalten, üblich. Eine besondere Ausstattung ist bei der Lagerung leicht entzündlicher Produkte erforderlich. Besondere Sorgfalt wird in der Regel angewendet, um Lecks und Verschüttungen zu vermeiden, die den Boden und das Grundwasser verunreinigen oder Materialien ermöglichen würden, ins Oberflächenwasser zu gelangen. Einige Standorte besitzen Gaspendelsysteme (mit Stickstoff), um den Luftaustausch bei der Befüllung der Tanks zu reduzieren. In allen Re-Raffinationsprozessen verwendeten Lagerbehälter werden Inertgas- sowie Gaspendelsysteme angewandt. Eine Minimierung des Luftaustauschs während des Umfüllens von Inhalten findet in manchen Fällen mittels direkt verbundener Entlüftungsleitungen statt. Die folgende Abbildung 4.1 zeigt ein Beispiel dafür.

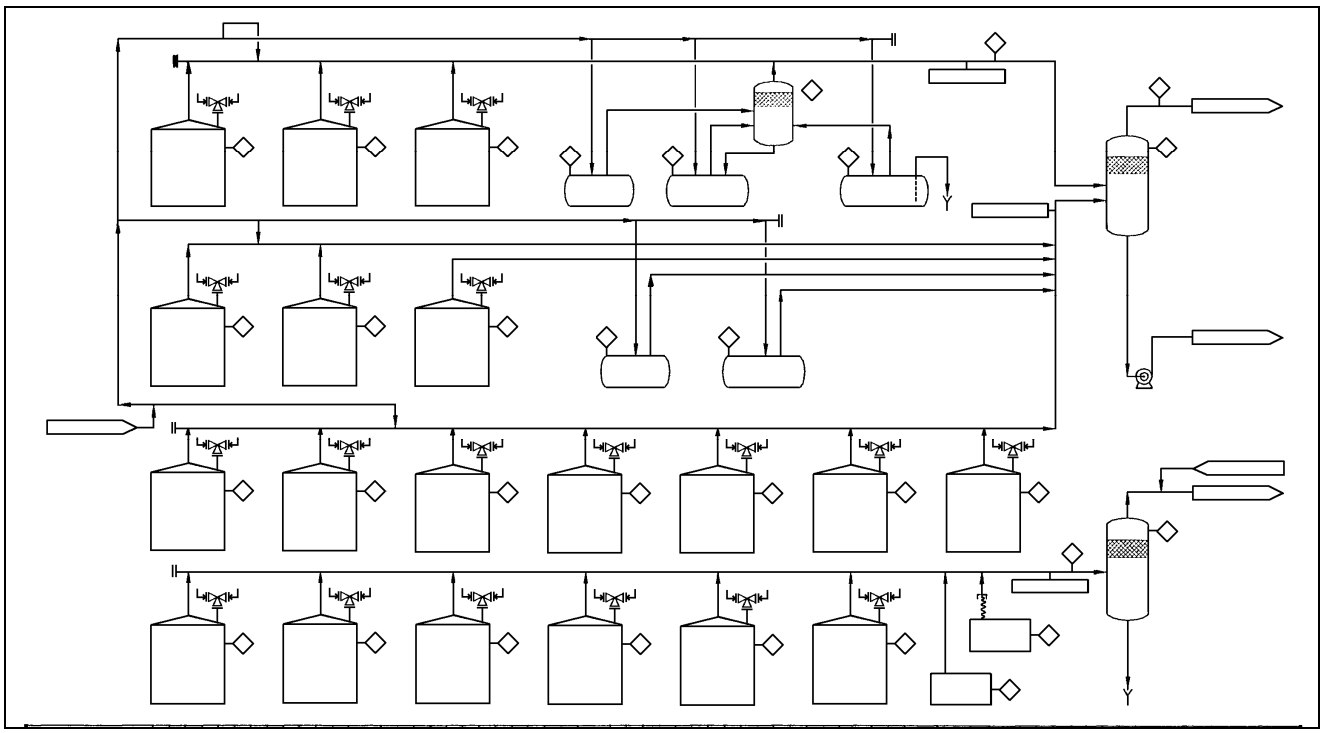


Abbildung 4.1: Schutzgassystem in einem in einer Altölreraffinationsanlage verwendeten Lagersystem [36, Viscolube, 2002]

Eine Anlage in der EU hat alle Lagertanks für den Input sowie die Zwischenprodukte des Verfahrens mit Inertgas ausgestattet. Die einzigen Behälter die nicht so ausgestattet sind, sind die für Gasöl (unterschiedliche Arten) und Wasser. Eine andere Anlage in der EU hat alle Lagertanks der End- und Zwischenprodukte des Verfahrens mit Inertgas ausgestattet. Rückhalteeinrichtungen für VOCs und Gerüche sind in Lagertanks vieler Altölraffinerien üblich. Diese Art Installationen sind auch bei der Erzeugung von Brennstoff aus flüssigen organischen Abfällen üblich.

Literatur

[30, Eklund, et al., 1997], [36, Viscolube, 2002], [50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [128, Ribi, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.4.2 Techniken zur Lagerung von Fässern und Abfällen in anderen geschlossenen Behältern

Beschreibung
Einige Techniken sind:

a. Lagerung von Abfällen in Behältern unter Überdachungen. Dies kann auch auf alle Behälter angewendet werden, die vor der Probenahme und Entleerung gelagert werden. Überdachte Bereiche müssen über geeignete Vorrichtungen zur Entlüftung verfügen. Die Abluft wird vor der Freisetzung, in Abhängigkeit von der Art der vorhandenen Verunreinigung, behandelt. (siehe Abschnitt 4.6)
b. Lagerung von Behältern mit gut passenden Deckeln, Kappen und/oder mit sicheren, sich am richtigen Platz befindenden Ventilen
c. Vorhalten von Lagerbereichen und freien Zugang für Behälter, die Stoffe enthalten, die bekanntermaßen hitze- und lichtempfindlich sind, sie müssen abgedeckt und geschützt vor Hitze und direkter Sonneneinstrahlung sein
d. strikte Befolgung von Vorschriften in Bezug auf Lagerbereiche für Behälter, die entzündliche oder leicht entzündliche Abfälle enthalten, weil für diese Bereiche umfangreiche Vorschriften bestehen
e. Bearbeitung von Behältern nur anhand schriftlicher Anweisungen. Diese Anweisungen müssen enthalten, welche Charge bearbeitet werden soll und welche Art von Behälter erforderlich ist, um jegliche Reststoffe aufzunehmen
f. Anwendung einer aktiven Belüftung oder den Lagerbereich unter Unterdruck halten
g. Verwendung von überdachten Bereichen mit offenen Seiten
h. Verwendung von brandsicherer Beleuchtung
i. Keine Lagerung von mehr als zwei Fässern übereinander und Sicherstellung, dass jederzeit der Zugang für Inspektionen, von allen Seiten, gesichert ist. Das heißt, vier 205-Liter-Fässer auf einer Palette, dürfen nicht höher gestapelt werden als zwei 205-Liter-Fässer in Reihen
j. Lagerung von Behältern in einer Art und Weise, dass Lecks, Überläufe und Verschüttungen nicht über Eindämmungen oder über die Kante des versiegelten Entwässerungsbereichs entweichen können
k. Vorhandensein einer kleinen Schütteinheit, die so ausgelegt ist, dass Laborabfallkleinmengen in einen Kalkschlamm in 205-Liter-Fässer, vor ihrer Beseitigung in der Behandlungsanlage, umgefüllt werden können. Hierfür wird eine Abzugshaube benötigt, die über dem Fass angebracht und mit einem Entlüftungssystem und einem Aktivkohlefilter verbunden ist. Das System ist nicht hermetisch verschlossen, da der Anwender in der Lage sein muss, die Flaschen in den Behälter zu entleeren. Allerdings könnte es als ein einfaches kostengünstiges System zur Abschätzung der Freisetzungen in die Luft während der Umschüttung von Lösemitteln eingesetzt werden,.
l. Erstellung und Befolgung von schriftlich festgelegten Arbeitsabläufen zur Sortierung und Verpackung von Laborabfallkleinmengen
m. Vermeidung der Lagerung unverträglicher Substanzen innerhalb desselben geschlossenen Behälters (z.B. Laborabfallkleinmengen)
n. Verwendung eines ausgewiesenen Bereichs/Lagers zur Sortierung und Wiederverpackung von Laborabfallkleinmengen
o. Sobald die Abfälle erst einmal nach ihrer Gefahreneinstufung unter Berücksichtigung aller möglichen Inkompatibilitätsprobleme sortiert und wiederverpackt worden sind, ist zu gewährleisten, dass diese Behälter nicht innerhalb des ausgewiesenen Bereichs für Laborabfallkleinmengen gelagert, sondern zum geeigneten Lagerbereich abtransportiert werden
p. Wenn Laborabfallkleinmengen in größere Behälter umgefüllt werden, muss dies in einem geschlossenen Gebäude mit Entlüftung, Abluftbehandlung und Auffangsystemen ohne Drainage durchgeführt werden
q. Lagerung von Fässern und Behältern, die gefährliche Abfälle enthalten, in undurchlässigen, doppelwandigen Becken
r. Lagerung von vollständig geschlossenen Behältern wie IBC und größeren, die außerhalb von Hallen gelagert werden dürfen, auf einem untergrundgeschützten Bereich.

Erreichter Nutzen für die Umwelt
Die überdachte Lagerung von Abfällen in Fässern hat den Vorteil, die Menge an potenziell verunreinigtem Wasser zu senken, was im Falle jedlicher Verschüttung entstehen kann, und die Nutzungsdauer des Behälters zu verlängern. Einige der vorgestellten Techniken vermeiden auch Emissionen, die durch die Zusammenlagerung unverträglicher Substanzen im Falle einer Reaktion entstehen könnten. Andere Vorteile stehen im Zusammenhang mit der Vermeidung von Bodenkontamination.

Medienübergreifende Auswirkungen
Im Zusammenhang mit Technik a (siehe obige Beschreibung) wird die Ventilation durch Wand- oder Dachentlüftungen oder durch die Bauweise des Bereiches, zum Beispiel als offene Halle, als Verdünnung der Luftemissionen angesehen.

Betriebsdaten
Der Umschlag ist normalerweise in überdachten Bereichen komplizierter als in nicht überdachten. Es kann physikalisch unmöglich sein, manche großen Behälter überdacht zu lagern. Überdachte Einrichtungen müssen Anforderungen an die Zugänglichkeit für die Brandbekämpfung berücksichtigen.

Anwendbarkeit
Im Zusammenhang mit Technik a ist es nicht notwendig, alle Abfälle in Behältern überdacht zu lagern. In der Regel sind diejenigen Abfälle und Behälter, die nicht empfindlich gegenüber Licht, Hitze, extremen Umgebungstemperaturen oder dem Eindringen von Wasser sind, nicht betroffen. Unter solchen Bedingungen genügen in der Regel geeignete Auffangvorrichtungen für die Lagerbereiche und die Rückhaltung/Behandlung des Wasserablaufs, um einen wirksamen Umweltschutz zu gewährleisten.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.1.4.3 Techniken zur Verbesserung der Wartung bei der Lagerung

Beschreibung
Einige Techniken sind:

a. Einführung von Arbeitsabläufen zur regelmäßigen Inspektion und Wartung der Lagerbereiche, einschließlich der Fässer, Behälter, Böden und Auffangvorrichtungen. Bei Inspektionen muss besondere Aufmerksamkeit auf alle Zeichen von Schäden, Verschlechterungen und Leckagen gerichtet werden. Die getroffenen Maßnahmen müssen detailliert aufgezeichnet werden. Mängel sollten so bald wie möglich repariert werden. Wenn die Rückhaltekapazität oder die Tauglichkeit einer Auffangvorrichtung, einer Grube oder des Bodens beeinträchtigt ist, muss der Abfall bis zur Beendigung der Reparatur entfernt werden
b. Durchführung täglicher Überprüfungen hinsichtlich des Zustandes der Behälter und Paletten und Aufbewahrung der schriftlichen Aufzeichnung der Inspektion. Wenn sich herausstellt, dass ein Behälter beschädigt ist, leckt oder sich in einem Stadium des Verfalls befindet, müssen Vorkehrungen getroffen werden, indem entweder ein Überbehälter benutzt oder die Inhalte in einen anderen Behälter überführt werden. Paletten, die in dem Maße beschädigt sind, dass die Stabilität der Behälter beeinträchtigt ist oder wird, müssen ersetzt werden. „Kunststoffschrumpffolie“ darf nur verwendet werden, um der Lagerung in Fässern/Behältern zusätzliche Stabilität zu geben, zusätzlich zur Nutzung von Paletten die einen geeigneten Zustand besitzen
c. Aufstellung und Befolgung eines Routineprogramms für die Inspektion von Tanks, Misch- und Reaktionsbehältern, einschließlich einer regelmäßigen Überprüfung der Wandstärke. Im Falle einer entdeckten Beschädigung oder Verschlechterung müssen die Inhalte einer geeigneten anderen Lagerung zugeführt werden. Diese Inspektionen müssen vorzugsweise durch unabhängige Experten ausgeführt werden, und schriftliche Aufzeichnungen der Inspektion und aller getroffenen Sanierungsmaßnahmen müssen festgehalten werden.

Erreichter Nutzen für die Umwelt
Verringerung von Lagerproblemen und Vermeidung von diffusen Emissionen.

Beipielanlagen
Im Sektor gibt es viele Beipiele.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

4.1.4.4 Auffangvorrichtungen für die Lagerung von Flüssigkeiten

Beschreibung
Für alle Behälter, die Flüssigkeiten enthalten, deren Verschüttung der Umwelt schaden könnte, müssen Auffangvorrichtungen vorhanden sein. Einige Punkte, die bei diesen Auffangvorrichtungen berücksichtigt werden müssen, sind:

a. Sie müssen undurchlässig und resistent gegenüber den gelagerten Materialien sein
b. Sie dürfen keinen Auslass haben (das heißt, keine Abläufe oder Hähne), sondern sollen zu einem Sammelpunkt zur Behandlung entleert werden
c. Leitungen müssen innerhalb von eingedämmten Bereichen verlegt sein und dürfen nicht in versiegelte Oberflächen eindringen
d. Sie müssen so ausgelegt sein, dass sie Leckagen aus Tanks oder Armaturen auffangen
e. Sie müssen eine geeignete Auffangkapazität vorhalten. Siehe Punkt p in Abschnitt 4.1.4.1
f. Sie müssen regelmäßigen visuellen Inspektionen unterzogen werden, und alle Inhaltsstoffe, die ausgepumpt oder anderweitig unter manueller Kontrolle entfernt werden, sollten zuerst auf Verunreinigungen getestet werden. Auffangvorrichtungen, die nicht häufig überwacht werden, sollten mit einer Füllstandssonde und soweit angemessen mit einem Alarmsystem ausgestattet sein. Ein Routineprogramm für die Inspektion von Auffangvorrichtungen ist erforderlich (normalerweise in Form einer visuellen Inspektion, jedoch ausgeweitet auf Wasseruntersuchungen, wo Zweifel über die Unversehrtheit bestehen)
g. Vorhandensein von Abfüllstellen innerhalb der Auffangvorrichtung

Zu beachten ist, dass für die Arbeitsbereiche zum Umfüllen von Flüssigkeiten und die Lagerbereiche getrennte Auffangvorrichtungen vorhanden sein müssen.

Erreichter Nutzen für die Umwelt
Verringerung der Bodenkontamination und Wasserverunreinigung aus größeren Verschüttungen oder Zwischenfällen, die zur Folge haben, dass Inhalte verloren gehen

Anwendbarkeit
Lagerung von Flüssigkeiten

Treibende Kraft für die Einführung
Diese Punkte werden normalerweise in den verschiedenen EU-Ländern geregelt.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.1.4.5 Einschränkung der Verwendung von offenen Tanks, Behältern oder Bunkern

Beschreibung
Einige Techniken sind:

a. eine direkte Entlüftung oder Freisetzungen in die Luft nicht zuzulassen, indem alle Entlüftungen mit geeigneten Abluftreinigungsanlagen verbunden werden
b. den Abfall oder die Rohmaterialien mit einer wasserdichten Verpackung abzudecken.

Erreichter Nutzen für die Umwelt
Reduzierung von diffusen Emissionen (z.B. von VOC, Partikel) und Verschüttungen.

Betriebsdaten
Bei Unfällen können Freisetzungen in die Luft gestattet werden, um schwerwiegendere Schäden zu vermeiden.

Anwendbarkeit
In der Regel angewendet auf die Lagerung von Abfall, der diffuse Emissionen verursachen kann (z.B. VOC, Partikel).

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.1.4.6 Allgemein angewandte Techniken der Handhabung von Abfall

Beschreibung
Einige allgemeine Techniken sind:

a. Vorhalten von Verfahren und Prozeduren, die sicherstellen, dass Abfälle sicher zur geeigneten Lagerung transportiert werden
b. Weiterführung des Abfallrückverfolgungssystems, das im Stadium der Voruntersuchungen begann, auch unter Beachtung der Abfallannahme, für die Dauer in der sich der Abfall am Standort befindet (siehe Abschnitt 4.1.2.3)
c. Vorhalten eines Managementsystems für das Be- und Entladen von Abfall auf der Anlage unter Berücksichtigung sämtlicher Risiken, die diese Tätigkeiten mit sich bringen können (z.B. beim Umfüllen großer Mengen flüssiger Abfälle von Tankfahrzeugen in Lagerbehälter). Dazu könnte gehören:
    - Einsatz von Verfahren zur Verhinderung eines "Wegrollens" von Tankfahrzeugen, d.h. ein Fahrzeug, das wegrollt, während es noch angeschlossen ist
    - Sicherstellung, dass diese Arbeiten nur durch hierfür geschulte Kräfte und in einem angemessenen Zeitrahmen durchgeführt werden, so dass kein Druck verursacht wird, schneller als zulässig zu arbeiten
    - Maßnahmen zur Gewährleistung, dass Kupplungen richtig passen; dies wird verhinden, dass sich Kupplungen lockern oder ablösen, dies sind:
        - eine Einrichtung, in der Schläuche bereitgestellt sowie gewartet werden. Dies kann dazu beitragen, die Unversehrtheit und Tauglichkeit der Kupplungen zu gewährleisten
        - Sicherstellung, dass man besonders darauf Acht gibt, dass die Kupplung dem maximalen Druck der Pumpe bei geschlossenem Ventil standhalten kann, andernfalls könnte sich ein ernsthafter Zwischenfall ereignen
        - Ein Schutz des Umfüllschlauchs muss nicht notwendig sein, wenn eine Fallstromförderanlage vorhanden ist. Dennoch wird es noch wichtig sein, eine intakte Kupplung an jedem Ende des Umfüllschlauchs vorzuhalten
        - Kontrolle potenzieller Leckagen von Kupplungsteilen durch einfache Systeme wie Tropfwannen oder durch ausgewiesene Bereiche innerhalb der Auffangvorrichtung. Regenwasser, das auf den restlichen eingedämmten Auffangbereich fällt, wird in eine Grube gesammelt und kann, falls es nicht verunreinigt ist, zum Abscheider des Standorts und zu den Einleitungsstellen gepumpt werden. Die eingedämmten Auffangbereiche werden überwacht, gewartet und gereinigt. Eine Verschmutzung des eingeleiteten Wassers kann vorkommen, wird aber durch Planung und Management auf ein Minimum reduziert
        - Praktiken guter Betriebsführung erfordern eine permanente Aufmerksamkeit sowie regelmäßige Reinigung
    - Routine-Wartungsarbeiten, die dazu führen, dass keine akute Unfallsituation aufgrund des Ausfalls der Anlage oder von Geräten entsteht. Dazu kann der Ausfall einer Pumpenabdichtung oder die Blockierung eines Filtertopfes gehören, die üblicherweise an Umfüllstellen verwendet werden
    - Notfalllager für Fahrzeuge mit Leckagen, um die Folgen eines akuten Zwischenfalls, der mit dem Ausfall einer Dichtung des Tankfahrzeugs verbunden ist, auf ein Minimum zu reduzieren,
    - Rückführung der Dämpfe bei der Beladung von Tankfahrzeugen
    - Maßnahmen zur Gewährleistung, dass der richtige Abfall am richtigen Umschlagpunkt abgeladen wird und dass der Abfall zum richtigen Lagerplatz transportiert wird. Um unautorisierte Abladungen zu vermeiden, muss ein verschließbares Absperrventil an der Beladeverbindung angebracht werden. Dieses muss während der Zeiten verschlossen gehalten werden, in denen die Entladestellen nicht überwacht werden
d. Eintragungen in das Betriebstagebuch auch bei kleinen Verschüttungen während des Umfüllens. Die Verschüttungen müssen innerhalb des eingedämmten Auffangbereichs zurückgehalten werden und mit Hilfe von Adsorbentien gesammelt werden. Erfolgt dies nicht, kann die verschüttete Flüssigkeit das Betriebsgelände durch die Regenwassersammelsysteme verlassen oder eventuell Emissionen (z.B. von VOC) verursachen.
e. Vorhandensein eines qualifizierten Chemikers/Mitarbeiters, der auf dem Betriebsgelände des Abfallerzeugers/besitzers, Laborabfallkleinmengen überprüft, Substanzen entsprechend einstuft und die Behälter in spezielle Sammelbehälter verpackt. In manchen Fällen werden die Verpackungen im Sammelbehälter durch die Verwendung von Vermikulit vor mechanischer Beschädigung geschützt. Manche Betreiber behandeln Laborabfallkleinmengen nur dann, wenn die Kunden ihren Verpackungsservice nutzen

f. Behälter mit Chemikalien werden in getrennte Fässer anhand ihrer Gefahreneinstufung verpackt. Unverträgliche Chemikalien (z.B. Oxidationsmittel und entzündliche Flüssigkeiten) sollten nicht im selben Fass gelagert werden
g. Verfahren zur Gewährleistung, dass der richtige Abladeplatz oder Lagerbereich benutzt wird. Einige Möglichkeiten dafür sind die Einführung eines Ticketsystems, Aufsicht durch Anlagenpersonal, Benutzung von Symbolen oder Farbcodes für Anschlüsse/Schläuche oder Armaturen in bestimmten Größen
h. Verwendung einer undurchlässigen Oberfläche mit unabhängiger Entwässerung, um zu verhindern, dass Verschüttungen in die Lagersysteme gelangen oder an den Entlade- und Zwischenlagern vom Betriebsgelände entweichen
i. Sicherstellung, dass keine beschädigten Schläuche, Ventile und Verbindungen verwendet werden. Schläuche, Ventile und Verbindungen müssen so ausgelegt und gewartet werden, dass sie sicher für ihren Verwendungzweck geeignet sind und dass sie chemisch stabil gegenüber den Stoffen sind, für die sie bestimmt sind
j. Verwendung von Kreiselpumpen, die mit einem Druckkontrollsystem und Sicherheitsventil ausgestattet sind
k. Erfassung des Abgases aus Behältern und Tanks beim Umfüllen von flüssigen Abfällen, die flüchtige Emissionen verursachen können
l. Wahl des geeigneten Verpackungsmaterials unter Berücksichtigung, welches Material/ Abfall als Inhalt vorgesehen ist (z.B. gefährliche Stoffe)
m. Verfahren und Prozeduren, die gewährleisten, dass der umzuschlagende Abfall so verpackt und transportiert wird, dass er im Einklang mit der Gesetzgebung zur sicheren Beförderung von Gefahrgut steht.

Erreichter Nutzen für die Umwelt
Eine angemessene und sichere Lagerung von Abfällen trägt dazu bei, diffuse Emissionen und das Risiko von Leckagen zu reduzieren und Unfälle zu vermeiden. Eine getrennte Lagerung ist notwendig, um Zwischenfälle aufgrund von unverträglichen Substanzen zu vermeiden und um einer Eskalation vorzubeugen, wenn es zu einem Zwischenfall kommt. Ein Transport beschädigter Paletten kann zur Lagerung weiterer Paletten auf ihnen führen, was zu weiteren Schäden und möglicherweise zu einem Zusammenbruch des Stapels führt.

Anwendbarkeit
Gängige Reinhaltungssysteme können mit den Entlüftungssystemen für Tanks verbunden werden, um Lösemittelverluste in die Luft, durch Verdrängungsvorgänge, bei der Befüllung von Behältern und Tankfahrzeugen zu senken. Standorte, an denen staubige Abfälle umgeschlagen werden, können spezielle Abzugshauben, Filter und Entlüftungssysteme haben.

Die meisten Standorte haben einen Betonboden, der zu betriebsinternen Entwässerungssystemen abfällt, diese führen wiederum zu Lagertanks oder Abscheidern, die Regenwasser und Verschüttungen sammeln. Abscheider mit Überläufen zu Abwasserkanälen haben normalerweise automatische Überwachungssysteme, wie eine pH-Wert Messung, mit denen ein Überlauf geschlossen werden kann.

Treibende Kraft für die Anwendung
Gesetzgebung zum sicheren Transport von Gefahrgut.

Beispielanlagen
Die größeren Lösemittelumschlagstationen reduzieren die Gasaustauschverluste aus dem Be- und Entladen von Tankfahrzeugen und Fässern mit Gaspendel- oder VOC-Verwertungsverfahren. Viele chemische Behandlungsanlagen und Standorte zur Lösemittellagerung besitzen Reinhaltungstechniken zur Minderung von sauren und VOC- Emissionen.

Standorte, an denen organische Abfälle mit Lösemittelgehalt gelagert werden, verwenden meist Kohlefiltersyteme, um Freisetzungen in die Luft aus der Abluft zu kontrollieren und zu überwachen. Viele der Abfallumladestationen, die größere Mengen von VOC lagern und pumpen, haben Vorrichtungen zur Abluftreinigung oder verwenden das Gaspendelverfahren, um Verluste in die Luft aufgrund des Gasaustauschs oder thermischer Effekte zu minimieren.

Literatur
[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.1.4.7 Handhabung von festen Abfällen

Beschreibung
Einige Techniken sind:

a. Gewährleistung, dass verschiedene Chargen nur nach dem Kompatibilitätstest zusammengeschüttet werden
b. Keine Hinzufügung von flüssigen zu festen Abfällen, außer in Reaktionsbehältern, die für diesen Zweck geplant und gebaut wurden und nur nach einem angemessenen Kompatibilitätstest
c. Verwendung lokaler Absaugentlüftung zur Überwachung von Gerüchen und Staub
d. Entladen von Feststoffen und Schlamm in einem geschlossenen, unter Unterdruck stehenden Gebäude
e. Ausgleich der Luft zwischen Behältern und anderen Bereichen
f. Pumpen von Schlämmen statt offener Transport.

Ereichte Vorteile für die Umwelt
Vermeidung von Unfällen und diffusen Emissionen.

Medienübergreifende Auswirkungen
Wenn Schlämme oder Flüssigkeiten von einem Behälter in einen anderen gepumpt werden, können wegen des Gasaustauschs Emissionen in dem Bereich erzeugt werden, in den das Material gepumpt wird.

Anwendbarkeit
Die mit c) und d) bezeichneten Techniken sind in der Regel für Abfälle anwendbar, die diffuse Emissionen erzeugen können.

Beispielanlagen
Erzeugung von Brennstoff aus Abfall

Literatur
[29, UK Environment Agency, 1996], [55, UK EA, 2001], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.1.4.8 Handhabungstätigkeiten im Zusammenhang mit dem Umfüllen in oder aus Fässern und Containern

Beschreibung
Dieser Abschnitt beschreibt das Umfüllen von Fässern, Behältern, Tankfahrzeugen oder kleinen Containern in oder aus Fässer/n. Einige Techniken sind:

a. Sicherstellen, dass das Zusammenschütten/Mischen fester und flüssiger Abfälle nur unter der Anweisung und direkten Aufsicht eines geeigneten Managers/Chemikers und unter lokaler Absaugentlüftung, falls angemessen, stattfindet
b. Zusammenschütten von geruchsintensiven Materialien nur unter kontrollierten Bedingungen (z.B. nicht im Freien) zur Vermeidung von Geruchsemissionen
c. den Container/Behälter so weit wie möglich verschlossen halten
d. Umfüllen von Abfällen aus Behältern in Lagerbehälter unter Verwendung eines Tauchrohrs
e. während des Schüttens in Tankfahrzeuge, Nutzung von Gaspendelsystemen, die mit geeigneten Abgasreinigungsvorrichtungen verbunden sind
f. Gewährleistung, dass beim Umfüllen von einem Tankfahrzeug in ein Fass oder umgekehrt jederzeit mindestens zwei Arbeitskräfte zur Überprüfung der Leitungen und Ventile im Einsatz sind
g. Handhaben von Fässern mit mechanischen Mitteln, z.B. mit Gabelstaplern die eine sich drehende Halterung für Fässer besitzten
h. Gewährleistung, dass ein Umfüllen/Ableiten nur nach Abschluss von Kompatibilitätstests stattfindet (siehe Abschnitt 4.1.4.13), und auch dann nur mit Bewilligung einer geeigneten Führungskraft. Die Bewilligung sollte festlegen, welche Charge/Ladung des Materials umgefüllt werden soll; den aufnehmenden Lagerbehälter; die erforderliche Gerätschaft, einschließlich Überlaufkontrolle und Rückgewinnungstechniken; und alle speziellen Vorkehrungen, die für diese Charge/Ladung von Bedeutung sind
i. Sicherstellung, dass Tankfahrzeuge nicht als Reaktionsbehälter benutzt werden, da das nicht ihr Zweck ist

j. Vermischung durch Zusammenschütten in Tanks darf nur stattfinden, wenn geeignete Überprüfungen und Kompatibilitätstests durchgeführt wurden
k. Umfüllen größerer Einzelcontainer in IBCs oder 205-Liter-Fässer auf Flächen mit Auffangvorrichtungen für diese Bereiche, um die Entwässerung des Standorts abzusichern
l. Treffen geeigneter Vorsichtsmaßnahmen gegen die Gefahren statischer Aufladungen beim Umgang mit entzündlichen Flüssigkeiten
m. Sicherung der Fässer durch Einschweißen mit Schrumpffolie
n. Schulung von Gabelstaplerfahrern im Umgang mit Gütern auf Paletten, um die Beschädigung von Fässern durch Gabelstapler auf ein Minimum zu reduzieren
o. Verwendung intakter und unbeschädigter Paletten
p. Ersatz aller beschädigter Paletten bei der Ankunft, kein Transport dieser Paletten ins Lager
q. Vorhalten angemessener Freiflächen in Lagerbereichen für Fässer
r. Bewegung von Fässern und anderen beweglichen Behältern zwischen verschiedenen Standorten (oder Beladung zur Entfernung vom Betriebsgelände) nur unter Anweisungen der geeigneten Führungskraft; und unter Gewährleistung, dass mittels Abfallrückverfolgungssystem die Veränderungen aufgezeichnet werden.

Erreichter Nutzen für die Umwelt
Vermeidung von diffusen Emissionen, z.B. durch Minimierung von Verspritzungen, Rauch und Gerüchen, Gesundheits- und Sicherheitsproblemen; Vorbeugung vor unerwarteten Freisetzungen oder Reaktionen.

Anwendbarkeit
Technik r (siehe obige Beschreibung) wird normalerweise für Standorte innerhalb der Anlage angewendet.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004], [153, TWG, 2005]

4.1.4.9 Automatisches Entladen von Fässern

Beschreibung
Die Entladestation enthält (von vorgeschaltet bis nachgeschaltet):

a. eine Fass-Anlieferungsstation, unter Anwendung von pneumatisch angetriebenen Motoren. Die Fässer werden durch einen Gabelstapler antransportiert und dann auf Förderbänder mit motorisierten Transportrollen gesetzt, über die die Behälter danach zu einer Greifstation transportiert werden
b. eine Greifstation für Fässer mit einer hydraulischen Halterung. Die hydraulische Halterung, die mit drei Greifern ausgestattet ist, die dem Umfang der Fässer entsprechen, erlaubt es die Fässer in einer verlagernden Bewegung zu verschiedenen Terminals der Station zu dirigieren
c. eine Station zum Zerschneiden, Abkratzen, Waschen und Entfernen des Fassbodens. Die Beseitigung des pastösen Abfalls wird durch zwei parallel angeordnete vertikale H-Schienen gewährleistet, wobei eine der scharfen Kanten gegen das Innere der Hülle des Fasses stößt und damit Reibung verursacht. Die Form des oberen Teils der Leiste ist so gestaltet, dass sie für das Durchdringen dicken Materials geeignet ist. Die Fässer werden nach dem Prinzip hoher Druck/geringer Durchfluss gewaschen, welches eine Senkung des Wasserverbrauchs, unter Verwendung von Düsen ermöglicht, die innerhalb von Metallhüllen angebracht sind.
d. eine Station zum Ableiten, Abkratzen und Hochdruckreinigen des Fassmantels. Nach Ableitung und Reinigung werden die Fässer durch zwei Kolben in Richtung ihrer größten Ausdehnung gepresst. Für geeignete Einhausungen ist zu sorgen, um die Spritzer und Umreifungen der Fässer zurückzuhalten. Die gepressten Fässer werden danach mittels Förderer zu einem Sammelbehälter transportiert
e. eine Station zum Pressen und Entfernen der gereinigten Fässer
f. eine Kontrollkabine.
g. Vermeidung von VOC-Emissionen. Die flüchtigen organischen Verbindungen, die von den Schneide-, Ableitungs- und Waschstationen emittiert werden, werden durch Abzugshauben mit einer Entlüftungseinrichtung verbunden und in einer Verbrennungsanlage behandelt.

Erreichter Nutzen für die Umwelt
Verkürzung der Zeitdauer, in der der aufbereitete Abfall auf dem Betriebsgelände verbleibt und Optimierung des Reinigungsprozesses für die Behälter. Zweck eines solchen Verfahrens ist das Entladen von Abfällen aus Fässern ohne menschlichen Eingriff und somit die Vermeidung von Unfällen.

Anwendbarkeit
Die Station ist darauf ausgelegt, Standardfässer mit Volumina von 120 und 200 Litern, die vollständig geöffnet oder geschlossen sein können, anzunehmen. Ihre Beseitigungskapazität liegt bei 250 Fässern pro Tag.

Treibende Kraft für die Anwendung
Die automatische Station zum Entladen von aufbereitetem Abfall soll das folgende Doppelziel erreichen:

- Verbesserung der Arbeitsbedingungen
- Verkürzung der Zeitdauer, in der der aufbereitete Abfall auf dem Betriebsgelände bleibt und Optimierung des Reinigungsprozesses der Behälter.

Beispielanlagen
Angewendet bei der Herstellung von Brennstoff aus gefährlichen Abfällen.

Literatur
[91, Syke, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

4.1.4.10 Techniken zur Verbesserung der Lagerkontrolle

Beschreibung
Einige zu berücksichtigende Themen sind:

a. Für flüssige Abfälle in großen Mengen, beinhaltet die Lagerkontrolle die Aufzeichnung des Wegs durch das gesamte Verfahren. Für Abfälle in Fässern muss die Kontrolle die individuelle Beschriftung jedes einzelnen Fasses verwenden, um Standort und Dauer der Lagerung aufzuzeichnen
b. Bereitstellung von Lagerkapazität für Notfälle. Dies wäre in einer Situation von Bedeutung, in der es notwendig wäre, einen Abfall wegen eines Defekts oder möglichen Fehlers der Sicherheitshülle eines Fahrzeugs, aus diesem umzulagern. Diese Zwischenfälle sind selten, wobei die verfügbare Kapazität innerhalb der Anlage ein limitierender Faktor sein kann.
c. Alle Behälter müssen klar mit dem Ankunftsdatum, den zutreffenden Gefahrencodes und einer eindeutigen Referenznummer oder einem eindeutigen Bezugscode beschriftet sein, um eine Identifikation durch die Lagerkontrolle zu ermöglichen und einen Bezug zu Aufzeichnungen aus den Voruntersuchungen und der Annahme herzustellen. Alle Beschriftungen müssen resistent genug sein, um während der gesamten Dauer der Lagerung in der Anlage befestigt und lesbar zu bleiben.
d. Verpacken in Überbehälter als Notfallmaßnahme. Alle notwendigen Informationen müssen bei der Beschriftung des neuen Behälters übertragen werden. Ein Transfer großer Mengen von Abfällen in Überbehältern muss vermieden werden, indem Abfälle neu wiederverpackt werden, sobald der Zwischenfall, der zum Verpacken in einen Überbehälter geführt hat, bewältigt wurde
e. automatische Überwachung der Füllstände der Lager- und Behandlungstanks mittels Tankfüllstandsmessern
f. die Kontrolle von Emissionen, z.B. mit existierenden Ausgleichssystemen oder einfachen Aktivkohlefiltern, aus Tanks, während des Rührens oder des Mischens als auch grundsätzlich für Tanks zur chemischen Behandlung oder zum Mischen von Schlamm
g. Begrenzung der Lagerdauer im Annahmelager auf ein Maximum von nur einer Woche (siehe Abschnitt 4.1.1.5)
h. Ergreifen von Maßnahmen (z.B. die Annahmeplanung, die Festlegung der maximalen Kapazitätsgrenze für einen bestimmten Abfall und die Gewährleistung, dass die Lagerkapazität nicht überschritten wird), zur Vermeidung von Problemen, die durch die Lagerung/Ansammlung von Abfällen entstehen können. Dies ist wichtig, da sich Abfalleigenschaften während der Lagerung/Ansammlung ändern können, z.B. können Abfälle verdichtet und verhärtet werden oder als Ergebnis von Mischungsreaktionen können Reaktionsprodukte sowie Abwässer entstehen. In einigen Fällen ist eine Homogenisierung des Abfalls nur mit Hilfe einer Erwärmung oder eines Zusatzes von Hilfsreagenzien usw., sowie auch der Voraussetzung von Kenntnissen über das Reaktionsverhalten des Abfalls, möglich. Die Anwendung einiger einfacher Vorsorgemaßnahmen kann in der Regel helfen, diese Nachteile abzumildern.

Erreichter Nutzen für die Umwelt
Verhinderung von Emissionen während der Lagerung.

Betriebsdaten
Ein Managementsystem ist erforderlich, da sich die obigen Techniken auf ein Qualitätsmanagementsystem (QMS) beziehen.

Beipielanlagen
In der Abfallbranche existieren viele Beispiele.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.1.4.11 Computergestützte Hochregallager für gefährliche Abfälle

Beschreibung
Das logistische Zentrum im Verbund verschiedener Behandlungsanlagen ist ein computerüberwachtes Hochregallager für gefährliche Abfälle. Hier werden alle Stoffe identifiziert, gewogen, fotografiert und beprobt, bevor sie gelagert werden.

Von besonderer Bedeutung ist das betriebsinterne Labor, wo Proben der einzelnen Abfallstoffe vor der Beseitigung oder Verwertung untersucht werden, um die genauen Stoffbestandteile zu bestimmen und das geeignete Behandlungsverfahren festzulegen. Das Labor erarbeitet auch Konzepte für die Aufbereitung in Zusammenarbeit mit den anderen Abteilungen.

Zur Brandvorbeugung im Hochregallagerbereich werden die Behälter einer Inertisierung mit Stickstoff unterzogen. Eine installierte Stickstoffanreicherungsanlage erzeugt Stickstoff mit einem Sauerstoff-Restgehalt von 2 %, der in die Behälter geleitet wird. Dieser Prozess wird kontinuierlich überwacht und aufgezeichnet. Zur Reduzierung von gasförmigen Emissionen wird das Inertgas aus den Behältern durch Lüfter im Kreislauf geführt und mittels Aktivkohle filtriert.

Erreichter Nutzen für die Umwelt
Verschiedene Arten gefährlicher Abfälle werden separiert und deren angemessene Behandlung gewährleistet.

Betriebsdaten
Vor Lagerung der Behälter im Hochregallager finden administrative und technische Kontrollen statt (z.B. Probenahme und fotografische Dokumentation). Die Lagerung der Behälter wird mit Hilfe eines programmierten Lagerkontrollsystems durchgeführt. Der Transport des Behälters innerhalb des Hochregalbereichs wird durch computergestützte Installationen durchgeführt, die einen Zugang zu den Regalen besitzen. Die Programmierung stellt sicher, dass alle Transportvorgänge des Behälters im Voraus geplant und folglich vordefiniert werden und dass alle damit zusammenhängenden Informationen (z.B. Dokumente und Probenahmeergebnisse) und durchgeführten Transportvorgänge des Behälters aufgezeichnet werden, was eine umfassende Kontrolle gestattet. Um die Annahme und Lagerung von Abfällen in unterschiedlichen Behältern zu ermöglichen, befindet sich jeder Behälter auf einer standardisierten Palette. Diese Palette ist als Wanne ausgelegt, die Überläufe, z. B. aus der Probenahme, auffängt.

Anwendbarkeit
Diese Technik ist für Abfallbehandlungsanlagen, die gefährliche Abfälle annehmen, anwendbar.

Beispielanlagen
Eine Beispiel-Abfallbeseitigungsanlage in Deutschland.

Literatur
[157, UBA, 2004]

4.1.4.12 Beschriftung der Behälter- und Prozessrohrleitungen

Beschreibung
Folgende Anforderungen sind bei der Beschriftung zu berücksichtigen:

a. Alle Behälter müssen im Hinblick auf ihre Inhalte und Kapazität klar beschriftet sein und eine eindeutige Kennzeichnung besitzen. Behälter müssen entsprechend ihrer Nutzung und ihrem Inhalt angemessen beschriftet sein, zum Beispiel:

Inhalt	Beispielbeschriftung
Lösemittel	Hochentzündlich
Abwasser	Abwasser

b. Die Beschriftung sollte zwischen Abwasser und Prozesswasser, brennbaren Flüssigkeiten und brennbaren Dämpfen unterscheiden und die Richtung des Durchlaufs anzeigen (d. h. Zulauf oder Ablauf)
c. Schriftliche Aufzeichnungen müssen für jeden Behälter geführt werden, mit eindeutiger Kennzeichnung, Kapazität, seiner Bauweise, einschließlich der Materialien, der Wartungspläne und Ergebnisse der Inspektionen, der Armaturen und der Abfallarten, die im Gefäß gelagert/behandelt werden dürfen, einschließlich der Grenzwerte für den Flammpunkt.
d. Verwendung eines geeigneten Codierungssystems für Rohrleitungen, zum Beispiel nach CEN Europäische Norm für Farbkennzeichnung, z.B.

Farbe	Codierung	Inhalt
Grün	6010	Wasser
Braun	8001	Brennbare Flüssigkeit/brennbarer Dampf
Rot	3001	Feuerlöschwasser
Blau	5012	Druckluft

e. Beschildern aller Ventile mit einer eindeutigen Kennzeichnung und deren Aufzeichnung in Prozess- und Gerätediagrammen
f. Richtige Dimensionierung aller Verbindungen und Aufrechterhaltung ihres unbeschädigten Zustands

Erreichter Nutzen für die Umwelt
Die Systeme erleichtern es dem Betreiber, eine gute Kenntnis des Gesamtverfahrens aufrechtzuerhalten und tragen zur Verringerung von Unfällen und zur Emissionskontrolle bei.

Anwendbarkeit
Die Auszeichnung aller Ventile mit einem Identifikationsschlüssel, der dann in den Prozess- und Gerätediagrammen verzeichnet wird, ist selbst in der chemischen Industrie keine übliche Praxis.

Literatur
[55, UK EA, 2001], [86, TWG, 2003]

4.1.4.13 Durchführung eines Kompatibilitätstests vor der Übernahme

Beschreibung
Ein guter Kompatibilitätstest sollte die folgenden Bestandteile enthalten:

a. Eine Probe aus dem Annahmebehälter/-gefäß/-container wird im proportionalen Verhältnis mit einer Probe des ankommenden Abfallstroms, der dem Behälter/Gefäß/Container hinzugefügt werden soll, gemischt
b. Die beiden Proben müssen ein “Worst-Case“ Szenario für wahrscheinliche Bestandteile abdecken
c. Alle entstehenden Gase und der Grund möglicher Gerüche müssen bestimmt werden
d. Wenn eine ungünstige Reaktion beobachtet wird, muss ein alternativer Einleitungs- oder Beseitigungsweg gefunden werden
e. Berücksichtigung der Folgen eines „up-scalings“ der Kompatibilitätstests im Labor auf den Umschlag in großen Mengen
f. Die spezifischen Parameter des Kompatibilitätstests werden in Abhängigkeit der Abfälle, die zusammengeschüttet werden sollen, festgelegt. Eine Minimalforderung ist die Aufzeichnung und Aufbewahrung der Tests, die alle Reaktionen einschließen, die einen Anstieg von Sicherheitsparametern (Temperaturanstieg, Entstehung von Gasen oder Anstieg des Drucks), Betriebsparametern (Änderungen der Viskosität, Abtrennung oder Ausfällung von Feststoffen) und anderen Parametern (z. B. Entstehung von Gerüchen) zur Folge haben.

Tabelle 4.12 Beispiel einer Verträglichkeitstabelle. Die Tabelle zeigt, dass die Lagerung von Chemikalien sorgfältig geplant werden muss, z.B. können “Säuren, Mineralien (Nicht-Oxidantien)“ (Nummer 1) Wärme und heftige Polymerisationsreaktionen verursachen, wenn sie mit „Aldehyden“ (Nummer 5) vermischt werden.

Nr.	Name der Reaktivitätsgruppe	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Säuren, anorganisch (Nicht-Oxidantien)																								
2	Säuren,anorganisch (Oxidantien)																								
3	Säuren, organisch		G H																						
4	Alkohole, Glykole	H	H F	H P																					
5	Aldehyde	H P	H F	H P																					
6	Amide	H	H GT																						
7	Amine (aliphatisch und aromatisch)	H	H GT	H		H																			
8	Azo- und Diazoverbindungen Hydrazine	H G	H GT	H G	H																				
9	Carbamate	H G	H GT						H G																
10	Basen	H	H	H		H				H G															
11	Cyanide	GT GF	GT GF	GT GF					G																
12	Dithiocarbamate	H GF F	H F	GF H GF GT		G F G T		U	H G																
13	Ester	H	H F						H G		H														
14	Ether	H	H F																						
15	Fluoride (anorganisch)	GT	GT	GT																					
16	Kohlenwasserstoffe (aromatisch)		H F																						
17	Halogenierte organische Stoffe	H GT	H F GT					H GT	H G		H GF	H													
18	Isocyanate	H G	H F GT	H G	H P			H P	H G		H P G	H G	U												
19	Ketone	H	H F						H G		H	H													
20	Mercaptane,andere organische Sulfide	GT GF	H F GT						H G										H	H	H				
21	Alkali- und Erdalkalimetalle, (elementare Metalle)	GF H F	GF H F	GF H F	GF H F	G F H F	GF H	GF H	GF H	G F H	GF H	GF H	GF GT H	GF H				H E	GF H	GF H	GF H				
22	Andere elementare Metalle und Legierungen als Pulver, Dämpfe oder Schwämme	GF H F	GF H F	GF					E F GT	U	GF H							H E	GF H		GF H F				
23	Andere elementare Metalle als Bleche, Stäbe, Tropfen, etc.	GF H F	GF H F						H F G									H F							
24	toxische Metalle und Metallverbindungen	S	S	S			S	S			S														

Nr.	Name der Reaktivitätsgruppe	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	101	102	103	104	105	106	107
25	Nitride	GF H F	H F E	H GF	GF H E	G F H			U	H G	U	GF H	GF H	GF H				GF H	U	GF H	GF H	E				25																
26	Nitrite	H GT F	H F GT						U													H P			S	GF H	26																
27	Nitroverbindungen (organisch)		H F GT			H			H E													H GF E				H GF E		27														
28	aliphatische ungesättigte Kohlenwasserstoffe	H	H F			H																	H E					28														
29	aliphatische gesättigte Kohlenwasserstoffe		H F																										29													
30	Peroxide und Hydroperoxide (organisch)	H G	H E		H F	H G		H GT	H E	H F G T		H E GT	H E GT					H E	H	E	H F GT	H E	P G		H G	H GF E	H P GT		H P		30										
31	Phenole und Kresole	H	H F						H G										H P			GF H				GF H					H	31									
32	Organophosphate, Phosphothioate, Phosphodithioate	H GT	H GT						U		H E											H									U		32								
33	Sulfide (anorganisch)	GT GF	HF GT	GT		H			E										H												H GT			33						
34	Epoxide	H P	H P	H P	H P	U		H P	H P		H P	H P	U								H P	H P	H P		H P	H P					H P	H P	U	H P	34					
101	Sonstige brennbare und entzündliche Materialien	H G	H F GT																			H G F				H GF F					H F GT				101					
102	Sprengstoffe	H E	H E	H E					H E		H E			H E								H E	H E	H E	E	E					H E	H E		H E	H E	H E	102			
103	Polymerisierbare Verbindungen	P H	P H	P H					P H		P H	P H	U									P H	P H	P H	P H	P H					P H	P H		P H			103			
104	Starke Oxidantien	H GT		H GT	H F	H F	H F GT	H F GT	H E	H G GT		H F GT	H F GT	H F	H F		H F	H GT	H F GT	H F	H F GT	H F E	H F E	H F		H F E	H F GT	H E	H F	H F	H G	H F	H F GT	H F GT	H F G	H F G	H E	H F GT	104		
105	Starke Reduktionsmittel	H GF	H F GT	H GF	H GF F	G F H F	GF H	H GF	H G				H GT	H F				H E	GF H	GF H	GF H						H GF	H E			H E	GF H	GT GF H		H	GF H	H E	H P GF	H F E	105		
106	Wasser und Wasser enthaltende Mischungen	H	H						G										H G			GF H	GF H		S	GF H								GT GF					GF GT	106	
107	Mit Wasser reagierende Stoffe	Extrem reaktionsfreudig! Mit keiner Chemikalie und keinem Abfall mischen!																																								107

Schlüssel: Reaktivitätscode (Großbuchstabe): Folgen des Mischens
H: Wärmeerzeugung F: Feuer G: Entstehung unschädlicher und nicht entzündlicher Gase GT: Entstehung giftiger Gase
GF: Entstehung entzündlicher Gase E: Explosion P: Heftige Polymerisation S: Giftige Substanzen gehen in Lösung U: Möglicherweise gefährlich, aber unbekannt

Tabelle 4.12: Beispiel einer Verträglichkeitstabelle für die Lagerung von Sonderabfällen [53, LaGrega, et al., 1994]

Erreichter Nutzen für die Umwelt
Verhinderung nachteiliger oder unerwarteter Reaktionen und Freisetzungen vor dem Umfüllen in Lagertanks.

Anwendbarkeit
Überprüfungen sind vor dem Umfüllen erforderlich. Diese umfassen:

- Entladungen von Tankfahrzeugen in Containerlager
- Umfüllungen von Tank zu Tank
- Umfüllungen von einem Container in einen Massentank
- Schüttungen in Fässer/IBCs
- Schüttungen festen Abfalls in Fässer oder Kübel.

Literatur
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [86, TWG, 2003]

4.1.4.14 Getrennte Lagerung

Beschreibung
Eine zentraler Aspekt für die Gewährleistung einer sicheren Lagerung ist die Kompatibilität. Dies beinhaltet zwei voneinander unabhängige Betrachtungen:

- die Kompatibilität des Abfalls mit dem Material, das für Konstruktionen von Behältern, Tanks oder Rohre, die in Kontakt mit dem Abfall stehen, verwendet wurde (z. B. sollten bestimmte Lösemittel nicht in Kunststoffbehältern gelagert werden)
- die Kompatibilität des Abfalls mit anderen Abfällen, mit denen er zusammen gelagert wird (z.B. Behälter mit Cyanidabfällen sollen nicht in der Nähe von sauren Abfällen gelagert werden).

Nachdem die Abfälle bei der Ankunft überprüft worden sind, werden sie auf der Basis der chemischen Inhaltsstoffe und der Behältergröße in verschiedene Gruppen aufgeteilt. Einige Techniken sind:

a. Berücksichtigung aller möglicher chemischer Inkompatibilitäten bei der Bestimmung der Getrennthaltungskriterien (z.B. Vermeidung der Unterbringung von Säuren zusammen mit Cyaniden). Die Seveso-Richtlinie und das Chemikalienrecht stellen Anleitungen für eine Getrennthaltung bereit. Das BVT-Merkblatt „Lagerung“ enthält hierzu ebenso einige Anleitungen
b. Altöle nicht mit Lösemittelabfällen mischen. Einige übliche Kfz-Produkte wie Entfetter sowie Brems- und Vergaserreiniger in Spraydosen können chlor-, brom- und jodhaltige Halogenverbindungen enthalten. Wenn sie mit Altöl gemischt werden, wird die Aufbereitung der gesamten Mischung erschwert
c. unterschiedliche Lagerung abhängig von der Gefährlichkeit des Abfalls (z. B. Flammpunktgrenze bei 55 °C)
d. Vorhandensein von Brandschutzwänden zwischen den Lagerbereichen oder eines Sicherheitsabstandes, der groß genug ist, um die Ausbreitung von Feuer zu vermeiden.

Erreichter Nutzen für die Umwelt
Eine getrennte Lagerung ist notwendig, um Zwischenfälle durch inkompatible Substanzen die miteinander reagieren, zu vermeiden und falls sich ein Zwischenfall ereignet, einer Eskalation vorzubeugen. Ein weiterer Vorteil ergibt sich aus der Tatsache, dass die Aufbereitung gemischter Abfälle generell schwieriger sein können.

Medienübergreifende Auswirkungen
In der Regel ist für eine getrennte Lagerung mehr Platz erforderlich.

Anwendbarkeit
Die Lagerung von Oxidationsmittel und entzündlichen Flüssigkeiten erfolgt getrennt, so dass sie Infolge einer Leckage nicht in Kontakt miteinander kommen können.

Treibende Kraft für die Anwendung

Vermeidung von Zwischenfällen infolge auftretender Inkompatibilitätsreaktionen. Hierzu stehen in einigen Mitgliedsstaaten (z.B. GB) einige Rechtsvorschriften und Richtlinien zur Verfügung.

Literatur

[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.1.5 Getrennthaltung und Kompatibilitätstests

Beschreibung
Ein erster Beitrag zur Verringerung von Abfällen am Entstehungsort, ist die Vermeidung der Mischung von Abfällen. Der Grundsatz hierbei ist, dass die Mischung einer kleinen Menge von gefährlichen Abfällen mit einer größeren Menge nicht gefährlicher Abfälle eine große Menge an Material erzeugt, welches dann als gefährlicher Abfall behandelt werden muss. Weitere Informationen befinden sich im Abschnitt 2.1.5. Folgende Methoden und Prinzipien sind zu berücksichtigen:

a. keine Verflüssigung trockener Abfälle
b. richtige Kennzeichnung aller Leitungen und Behälter. Dies erhöht die Wahrscheinlichkeit, dass das Anlagenpersonal Änderungen von Verfahren befolgen wird, deren Ziel eine gesteigerte Getrennthaltung von Abfällen ist
c. Das Mischen von verunreinigten Abfällen unterschiedlicher Stärken ist nur gestattet, wenn der gemischte Abfall gemäß den Vorschriften für den stärker verunreinigten Abfall behandelt wird
d. Getrennthaltung des Kühlwassers von Abfallströmen (z.B. Abwässern)
e. Erwägung und, wenn angebracht, Anwendung der Getrennthaltung bei der Lagerung von Materialien (siehe Abschnitt 4.1.4.14)
f. Vorhandensein von Regeln zur Einschränkung der Abfallarten, die miteinander gemischt werden dürfen. Zweck solcher Regeln sind die Senkung des Umweltrisikos, Sicherheitsgründe oder die Vermeidung von Verdünnungen.

Erreichter Nutzen für die Umwelt
Eine Getrennthaltung von Abfällen erleichtert jede erforderliche Behandlung. Einige Probleme könnten vermieden werden, wenn eine angemessene Separierung am Herkunftsort (am Ort der Erzeugung des Abfalls) durchgeführt werden würde. Ein Schlüssel ist die Getrennthaltung nicht kompatibler Abfälle, indem sie in getrennten Bereiche gehalten werden, die aus geeigneten Materialien bestehen. Wenn sie zusammen gelagert werden, könnten in einigen Fällen Zwischenfälle wie Leckagen zu einer Mischung nicht kompatibler Abfälle führen. Verschiedene chemische Reaktionen könnten stattfinden, wobei manche der Reaktionen hohen Druck und/oder Hitze erzeugen und folglich mit Feuer- und Explosionsgefahren verbunden sind. In anderen Fällen könnten giftige Dämpfe oder Gase entstehen.

Zum Beispiel haben nicht getrennt gehaltene Altöle in der Regel einen geringeren Wert als Heizöle. Verunreinigte Altöle sind potenzielle Emissionsquellen, wenn sie in Verbrennungsprozessen eingesetzt werden. Getrennt gehaltene gebrauchte Schmieröle können einen höheren Wert für die Verwertung als Brennstoff haben.

Die Art der Zuführung bei der Herstellung von festen Brennstoffen aus Siedlungsabfall ist sehr wichtig, da er einen großen Einfluss auf die Qualitäten des Abfall-OUT besitzt. Eine effektive Homogenisierung muss gewährleistet werden, stark verunreinigte Mengen sollten von der Verarbeitung zu festem Brennstoff aus Abfall ausgeschlossen werden, da sie die Produktqualität senken könnten.

Medienübergreifende Auswirkungen
In einigen Fällen kann das Mischen von Abfall (wegen der potenziellen chemischen Inkompatibilität mancher Inhaltsstoffe) ein höheres Risiko darstellen und kann zum Ausschluss der Möglichkeit eines Recyclings führen.

Anwendbarkeit
Einige Methoden, die im Abschnitt Beschreibung erwähnt werden, werden auf den Abfall-IN, andere auf den Abfall-OUT angewendet; weitere werden während des Betriebs der Anlage angewendet (z.B. bei Umschlag und Lagerung von Abfall). Große Hindernisse für Abfallgetrennthaltungsprogramme sind diejenigen Materialien, die in den Abfall gelangen, ohne das sie dort hin gehören. Erwähnenswerte Beispiele sind Laborproben, die als gefährliche Abfälle entsorgt werden müssten. Weitere Materialien sind Lösemittel und Pigmente, für die spezielle Behälter vorgehalten werden müssten.

Einige Anlagen haben getrennte Bunker für verschiedene Arten von Abfällen, z.B. Haushaltsabfälle, hausmüllähnliche Gewerbeabfälle und produktionsspezifische Gewerbeabfälle.

Methode a (siehe obige Beschreibung) wird in manchen Fällen aus Sicherheitsgründen für nicht anwendbar gehalten.

Die Anwendung der Grundprinzipien beim Mischen und Vermengen fester und flüssiger Abfälle, wie sie im Abschnitt 2.1.5 beschrieben werden (Risikovermeidung, minderwertge Aufbereitung und Vermeidung der diffusen Verbreitung) stellt sich für jeden Behandlungsweg anders dar. Abfälle können in verschiedenen Aufbereitungswegen behandelt werden und als Brennstoff, Baumaterial, Dünger, Tiernahrung, Grundstoff für neue Produkte usw. enden. Angesichts der stark variierenden zahlreichen Aufbereitungsverfahren wird diese Ausarbeitung zu verschiedenen Ergebnisse für jeden Behandlungsweg führen. Die Wahl der durchgeführten Behandlung beeinflusst die Möglichkeiten zur Mischung von Abfällen deutlich. In jedem Behandlungsweg sind Art und Konzentration von umweltgefährdenden Stoffen verschieden, weshalb auch die betrieblichen Kriterien zur Bewertung der Mischtätigkeit unterschiedlich sind.

Vor dem Mischen von Abfällen gilt die allgemeine Vermutung, dass einige Abfallarten auf keinen Fall geeignet zum Recycling oder zur Wiederverwertung geeignet sind. Dies kann Abfälle aus verschiedenen Reinigungsprozessen betreffen, zum Beispiel ARA-Rückstände, Flugasche, aushärtende Salze, Filterkuchen, die Metalle aus der Entgiftung-Neutralisation-Entwässerung enthalten, Hochofengasstaub usw. Das Mischen dieser Abfälle und Rückstände aus Reinigungsprozessen, die hoch aufkonzentrierte Gehalte an umweltgefährdenden Stoffen enthalten, ist auf keinem Aufbereitungsweg zur Verwertung zugelassen. Dieses sind Abfälle, die entsorgt werden müssen und deren Umweltrisiken vor der Beseitigung durch Immobilisierung oder Feststoffabtrennungstechniken unschädlich gemacht werden müssen. Punkte zur Wahl der Abfallbehandlung sind in Abschnitt 4.1.2.1. enthalten.

Wirtschaftlichkeit
Einige feste Abfallströme können durch kleine Änderungen des Anlagenequipments wirksam getrennt gehalten werden. In der Regel ist die Beseitigung eines gemischten Abfalls teurer als die Behandlung eines Stoffstroms, der aus einer einzigen Abfallart besteht.

Treibende Kraft für die Anwendung
Die Richtlinie über gefährliche Abfälle (91/689/EG) und die Abfallrahmenrichtlinie (75/442/EG) stellen die Rahmengesetzgebung der EU zur Vermengung und Vermischung von Abfällen dar. Einige Länder legen nationale Regeln fest (z.B. ist es in manchen Ländern absolut verboten, Schlacken/Rostasche von verschiedenen Herkünften zu mischen).

Regelungen auf Betriebsebene zur Vermengung und Vermischung sind im Genehmigungsbescheid und anderen (gesetzlichen und freiwilligen) Verpflichtungen enthalten und werden unter der Verantwortung des Betreibers der Abfallbehandlungsanlage niedergeschrieben und angewendet. Sie berücksichtigen Risiko- und Sicherheitsgesichtspunkte zur:

- Vermeidung von Unfällen, die Risiken für die menschliche Gesundheit und schädliche Wirkungen auf die Umwelt verursachen können
- Vermeidung technischer und mechanischer Zwischenfälle, die Anlageninstallationen beschädigen können.

So sind Vermengungs- und Vermischungsregeln auf Betriebsebene im Allgemeinen verbunden mit:

- Regelungen im Genehmigungsbescheid (nicht zugelassene Abfälle, Verpflichtungen zur Getrennthaltung von Abfällen)
- Regelungen in Bezug auf die Sicherheit
- betriebsinternen Prozeduren (zum Beispiel Qualitätskontrolle, Zertifizierung nach ISO 14000)
- Voruntersuchungen und Annahmeprozeduren
- vorgeschriebenen Kompatibilitätstests (während der Voruntersuchungen und der Annahmeprozeduren).

Beispielanlagen
Einige typische Beispiele für Kompatibilitätstests, die in der Abfallbranche angewendet werden, sind:

- Kompatibilitätstests für die Lagerung (siehe Abschnitt 4.1.1.14)
- Durchführung von Laborexperimenten zur Simulation von Neutralisationswirkungen
- Wahl und Dosierung der richtigen Fällungs- und Flockungsmittel müssen in jedem Fall durch Experimente bestimmt werden
- Experimentelle Laboruntersuchungen sind notwendig, um festzulegen, welche Chemikalien am besten für die Oxidation/Reduktion geeignet sind und welcher Art die Reaktion ist
- Labortests zur Bestimmung der notwendigen Menge Aktivkohle zur Reinigung des Abwassers. Die wichtigsten Ergebnisse sind der Beladungswert, z.B. g TOC/g Aktivkohle und die notwendige Kontaktzeit
- Weil der Zeitpunkt der Dosierung bei der Benutzung von Agenzien aus organischen Spaltmitteln besonders wichtig ist, sind Laborkontrollen während des Verfahrens erforderlich
- Prüfung der folgenden Parameter (siehe Tabelle 4.13), wenn Eindampfungs/Destillationsverfahren angewendet werden müssen.

Inhaltsstoffe	Bemerkungen	Eindampfertyp
Ungelöste Feststoffe	Bereits vorhanden oder aus Fällung	Eindampfer ohne Verkrustung und mit mechanischen Einrichtungen zur Entfernung von Feststoffen
Flüchtige Substanzen, die zu Verkrustung oder Verklebung führen	Während thermischem Aufschluss	Eindampfer mit kurzen Haltezeiten und/oder geringen Temperaturdifferenzen zwischen Aufheiz- und Kochphase
Wasserdampf-flüchtige Bestandteile	Mit hoher Konzentration in der Ausgangslösung	Eindampfer mit spezieller Dampfbehandlung
Grenzflächenaktive Stoffe	Schaumbildend	Eindampfer mit speziellem Trennungsdesign und/oder Zugabe von Entschäumern

Tabelle 4.13: Inhaltsstoffe, die die Eindampfung beeinflussen
[152, TWG, 2004]

Das Labor ist mit Geräten ausgestattet (z.B. Turbomischer, die nur kurz zur Mischung verwendet werden, langsame Mischer zur Flockenbildung), die grob die Anlagenbedingungen simulieren.

Die Getrennthaltung von Altölen, um ein hochwertigeres Material als Heizöl herzustellen, ist eine gängige Praxis.

Einige Beispiele für Vermengungs- und Vermischungsregeln, die auf bestimmte Verfahrens- und Abfallarten angewendet werden, werden unten beschrieben.

Thermische Verfahren
In den meisten Fällen ist es nicht zweckmäßig bestimmte Abfälle (siehe einige Beispiele dafür im obigen Abschnitt zur Anwendbarkeit) thermisch zu behandeln. Dennoch kann eine thermische Behandlung erforderlich sein, wenn der Organikgehalt im Ursprungsabfall höher als 10 % ist. Ein Kriterium zur Bewertung der Wirksamkeit der Verbrennung ist zum Beispiel die Messung des Glühverlusts nach der thermischen Behandlung. Wenn der Glühverlust weniger als 5 % des Trockengewichts des neu erzeugten Reststoffs beträgt, ist die Behandlung effektiv. Ein alternatives Kriterium für die Effektivität der Verbrennung ist eine Konzentration von unter 3 % des organischen Kohlenstoffs im Rückstand.

Behandlung von POP-verunreinigte Abfälle

Die Vermengung und Vermischung von Abfällen zum Zweck der Verwertung kann zulässig sein, wenn die POP-Konzentration nicht den niedrigsten POP-Gehalt überschreitet, wie er in den Verträgen von Basel und Stockholm festgeschrieben ist. Dies spiegelt sich in den technischen Richtlinien zur umweltgerechten Behandlung von Abfällen wider, die kürzlich durch die 7. Konferenz der Parteien der Baseler Konvention angenommen wurden. Dies umfasst Abfälle, die POPs und PCBs enthalten oder damit verunreinigt sind oder daraus bestehen. Tabelle 4.14 zeigt die niedrigen POP-Gehalte. Dennoch kann das Mischen von Abfällen für andere Behandlungswege, wie etwa die Bodensanierung, die Herstellung von Tierfutter und die Herstellung von Düngemitteln sogar dann verboten werden, wenn der niedrige POP-Gehalt nicht überschritten wird.

Verbindung	Niedriger POP-Gehalt
Dioxine/Furane	0,015 TEQ mg/kg
PCB	50 mg/kg
Andere POPs	50 mg/kg

Tabelle 4.14: Maximale zulässige Konzentrationen für gemischte Abfällen zur Verwertung [152, TWG, 2004]

Schwermetalle - Cadmium, Quecksilber, Thallium

Wenn die drei Grundlagen zum Mischen und Vermengen sowie ihre Ausarbeitung berücksichtigt werden, können die zuständigen Behörden die aufgeführten Maximalkonzentrationen in Abfällen für das Mischen von Abfällen zum Zweck der Mitverbrennung gestatten. Die maximalen Konzentrationen sind in Tabelle 4.15 dargestellt. Emissionen an Schwermetallen wie Hg, Cd und Tl, in die Luft, treten auf, wenn Abfall, der solche Inhaltsstoffe enthält, in Zementöfen und Kraftwerken eingesetzt wird. Jegliche Abweichungen oberhalb der Höchstkonzentrationen sind deshalb nicht erlaubt. Zuständige Behörden können von diesen Maximalkonzentrationen abweichen, indem sie in der Genehmigung zum Mischen und Vermengen von Abfällen eine niedrigere Konzentration vorschreiben, falls die Annahmekriterien der entsprechenden Anlage dies notwendig machen.

In diesem Zusammenhang ist es wichtig anzumerken, dass ein Unterschied zwischen Konzentrationen, die fürs Mischen gestattet werden und Konzentrationen zur Bestimmung der zulässigen Emissionsgrenzwerte für die Luft gemacht werden muss.

Metalle	Maximale Konzentration (mg/kg Trockensubstanz)
Quecksilber	10
Cadmium	100
Thallium	100

Tabelle 4.15: Maximal zulässige Konzentrationen für das Mischen zur Mitverbrennung [152, TWG, 2004]

Abfall, der andere als die oben erwähnten Schadstoffe enthält, darf gemischt werden, um die Annahmekriterien der verarbeitenden Anlage zu erfüllen. Dies gilt selbstverständlich nicht für die oben genannten Restsubstanzen sowie Rückstände aus der Verarbeitung, die hohe Schadstoffkonzentrationen enthalten.

Literatur

[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.1.6 Techniken zur Verbesserung der Auswirkungen anderer üblicher Techniken auf die Umwelt

4.1.6.1 Techniken zur Emissionsminderung beim Zerdrücken und Schreddern von Fässern

Beschreibung
Einige Techniken, die zur Emissionsminderung beim Zerdrücken und Schreddern von Fässern angewendet werden können, sind:

a. vollständige Einhausung der Quetsch- und Schredderanlage für Fässer und Ausstattung mit einer Absaugentlüftungsanlage, die mit Minderungstechnik, z.B. einem Ölwäscher und einem Aktivkohlefilter, verbunden ist. Die Minderungstechnik kann mit dem Anlagenbetrieb so verbunden sein, dass die Anlage nur dann arbeiten kann, wenn die Minderungstechnik eingeschaltet ist
b. Vorhalten von abdeckbaren Containern zur Lagerung von zerdrückten/geschnittenen Fässern
c. Verwendung von abgedichteten Systemen, z.B. Rinnen zur sicheren Zurückhaltung von Reststoffen
d. Nutzung einer abgedichteten Drainage
e. Vermeidung des Zerdrückens von Fässern, die entzündliche und hochentzündliche Abfälle oder flüchtige Substanzen enthalten (oder enthalten haben), bevor die Reststoffe entfernt worden sind und das Fass danach gereinigt worden ist.

In einer Schredderanlage können auch folgende Techniken angewendet werden:

f. Bereitstellen einer Halle zur Konditionierung von gefährlichen Abfällen vor ihrer Behandlung; die gesamte Behandlungshalle wird ständig über die Abgasbehandlungsanlage unter Unterdruck gehalten. Dadurch werden keine Emissionen freigesetzt
g. Lagerhaltung für Säuren, Basen, Fotochemikalien, Chemikalienabfälle aus Haushalten, Pestizide und Laborchemikalien
h. Lagerhaltung für entzündliche Flüssigkeiten wie Lösemittelabfälle mit einem Flammpunkt von <21 ºC
i. Zerlegung von Sprühdosen in folgende Bestandteile: Treibgase, flüssige Inhaltsstoffe, Metalle und Kunststoffe
j. Absaugung aller Emissionen; dabei kann die Abluftabsaugung für verschiedene Prozessverfahren automatisch überwacht werden und die Absaugung kann während Nicht-Betriebszeiten reduziert werden, um den Energieverbrauch zu reduzieren
k. Behandlung der Abluft mit einem Staubfilter und/oder einer regenerativen Nachverbrennung mit dem Ziel einer reststofffreien Verbrennung. Ein vorgeschalteter Precoat-Filter (Aktivkohle und Kalkmischung) zur Abscheidung von anhaftenden Inhaltsstoffen kann auch eingesetzt werden.

Bei der Behandlung von gefährlichen Abfällen in einer Schredderanlage können auch die folgenden Techniken eingesetzt werden:

l. Gegen Beschädigungen sicherer druckstoßfester Kanal von 12 m Höhe
m. Druckbeständigkeit der Anlage bis 10 bar
n. chargenweiser Betrieb des Schredders, um Belastungen zu minimieren
o. Einsatz von Feueralarmsystemen und Sprinkleranlagen; darüber hinaus sind Boxen mit einer Sprinkleranlage zur Staubbekämpfung ausgestattet
p. Standleitung zum Rettungsdienst; im Brandfall muss die Feuerwehr sofort benachrichtigt werden
q. Verwendung von explosionsgesicherten Schaltern, Aggregaten und Maschinen in der gesamten Halle
r. Nutzung von Überdruckkabinen mit Aktivkohlefiltern bei allen Maschinen zur Gewährleistung der Arbeitssicherheit
s. 50 m^3 Feuerlöschwasser in einem unterirdischen Becken
t. ständige Stickstoffbeflutung des Arbeitsraums innerhalb des Schredders, folglich finden unter Ausschluss von Sauerstoff keine Reaktionen statt (Anlage zur Stickstoffreinigung).

Schließlich können in einer Schredderanlage die folgenden Techniken zum Schutz des Bodens eingesetzt werden:

u. Nutzung eines durch Vakuum überwachten beschichteten Bodens zur Ermittlung von Leckagen; der Boden der Halle ist schalenförmig, so dass flüssiges Material nicht heraus fließen kann
v. Rückhaltebecken für 450 m^3 Feuerlöschwasser; dies wird ermöglicht durch den schalenförmigen Boden in Verbindung mit einem Pumpensumpf, um das Feuerlöschwasser zu pumpen.

Erreichter Nutzen für die Umwelt
Reduzierung von VOC-Emissionen in die Luft und Verringerung der Verunreinigung von Wasserströmen und Boden. So können Einheiten, in denen Fässer zerdrückt/geschreddert werden, direkt in die Luft entlüften. Eine Methode zur Reduzierung der VOC-Emissionen besteht darin, eine direkte Entlüftung in die Luft zu vermeiden, bevor die Emissionen/Abluft gewaschen und völlig von ihren früheren Inhaltsstoffen gereinigt worden sind. Einige Techniken, zum Beispiel Technik t (siehe obige Beschreibung) werden zur Vermeidung von Entzündungen eingesetzt.

Betriebsdaten
Inerte Atmosphären zur Vermeidung von Entzündungen können durch Inertgase, wie etwa Stickstoff oder Kohlendioxid, erzielt werden.

In einem Sprühdosenschredder werden 30000 m^3 Hallenluft pro Stunde abgesaugt und durch einen Staubfilter geleitet. Zwei separate Anlagen zur Ablufterfassung und –behandlung werden eingesetzt. Alternativ könnte eine kontrollierte Absaugung an der Quelle in Boxen, Schredder und Sprühdosenschredder, die auf einen maximalen Durchsatz von 12000 m^3/h ausgelegt ist, zum Einsatz kommen. Die Abluftverbrennungsanlage arbeitet bei über 800 ºC, um Schadstoffe vollständig zu zerstören.

Anwendbarkeit
Bei solchen Behandlungen können bei einigen Abfällen, die z.B. VOCs enthalten, brennbare Gemische entstehen, was ein Problem sein kann, da die Möglichkeit elektrostatischer Entladungen mit manchen Arten und Gemischen von Abfällen und Reagenzien besteht. In einigen besonderen Fällen können Fässer, die flüchtige Substanzen enthalten (siehe Technik e in obiger Beschreibung) zerdrückt werden, wenn der Brecher über Vorrichtungen zur Vermeidung von Entflammbarkeits- und Explosionsproblemen verfügt. Wenn die behandelten Abfälle keine Emissionen in die Luft (z. B. Gerüche, Staub, VOCs) erzeugen, werden in der Regel keine Absaugsysteme verwendet.

Wirtschaftlichkeit
z.B. eine Schredderanlage für Gebinde in Deutschland. Die Kapazität liegt bei 5000 Mg/a. Die Masse behandelter gefährlicher Abfälle liegt bei 1000 Mg/a. Die benötigte Investitionssumme für die Anlage beträgt 325 000 EUR.

z.B. eine Sprühdosenschredderanlage in Deutschland. Die Kapazität beträgt 500 Mg/a. Die benötigte Investitionssumme für die Anlage liegt bei 500 000 EUR.

Beispielanlagen
Eine Beispielanlage besteht aus einem geschlossenen Dunstabzug, welche oben auf einer erhöhten Plattform angebracht ist und einen hydraulisch betriebenen ferngesteuerten Brecherkopf besitzt. Rückstände die während des Zerdrückens der Fässer freigesetzt werden, werden über ein geschlossenes Rohr in ein Fass geleitet, das sich unterhalb der erhobenen Plattform befindet. Dämpfe werden über einen Ölwäscher und zwei Aktivkohlefilter, die in Serie geschaltet werden, abgesaugt und anschließend in die Luft abgeleitet. Verrigelungen verhindern den Betrieb des Brechers, wenn die Tür des Brechers offen ist oder die Minderungstechniken nicht in Betrieb sind.

Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.1.6.2 Techniken zur Emissionsminderung bei Waschprozessen

Beschreibung

Zu den Techniken gehören:

a. Bestimmung der Inhaltsstoffe, die in dem zu waschenden Gegenstand[11] vorhanden sein können (z.B. Lösemittel)
b. Transport der Abwässer[12] in ein geeignetes Lager und anschließende Behandlung dieser, in derselben Art wie der Abfall dem die Abwässer entstammen
c. Nutzung von behandeltem Abwasser aus der Abfallbehandlungsanlage; das entstehende Abwasser kann in die Abwasserbehandlungsanlage rückgeführt und behandelt oder im Fall von CP-Anlagen in die Anlage zurückgeführt werden. In letzterem Fall wird das Abwasser genauso behandelt wie der Abfall, der in dem inzwischen gereinigten Gefäß/Behälter/Container transportiert und angeliefert wurde.

Erreichter Nutzen für die Umwelt

Ermöglicht die Erkennung und Behandlung von Rückständen aus der Wäsche

Anwendbarkeit

Das Waschen von Fässern und IBCs wird normalerweise nur durchgeführt, wenn eine benachbarte Behandlungsanlage zur Annahme der Waschwässer vorhanden ist oder wenn andere Möglichkeiten zur Verfügung stehen, um das Waschwasser ordnungsgemäß zu behandeln.

Wasch- und Reinigungsvorgänge werden im Allgemeinen mit behandeltem Abwasser durchgeführt. Das entstehende Wasch- und Reinigungsabwasser wird in das Verfahren oder in die Abwasserbehandlungsanlage zur erneuten Behandlung rückgeführt. In einigen Fällen befindet sich die Abwasserbehandlungsanlage außerhalb der Abfallbehandlungsanlage.

Literatur

[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.1.7 Techniken zur Vermeidung von Unfällen sowie ihrer Folgen

Beschreibung

Die IVU-Richtlinie fordert als allgemeingültiges Prinzip, dass notwendige Maßnahmen zur Verhütung von Unfällen, die Umweltfolgen nach sich ziehen können, zu ergreifen und deren Folgen zu begrenzen sind. Zu den Techniken gehören:

a. Ausarbeitung eines strukturierten Unfallmanagementplans innerhalb eines bestimmten Zeitrahmens. Dazu gehört:
   - Bestimmung der durch die Anlage bedingten Gefahren für die Umwelt. Die besonderen zu berücksichtigenden Punkte können umfassen: die Abfallarten, Überfüllung von Behältern, Ausfall der Anlage und/oder von Geräten (zum Beispiel Überdruck in Behältern und Leitungen, blockierte Drainagen), Ausfall der Rückhaltesysteme (zum Beispiel der Auffangvorrichtung und/oder Überfüllung der Drainagegruben), nicht zurückgehaltenes Feuerlöschwasser, Erstellung falscher Verbindungen in Drainagen oder anderen Systemen, Vermeidung des Kontakts unverträglicher Substanzen, unerwünschte und/oder unkontrollierte Reaktionen, Einleitung von Abwasser bevor dieses angemessen auf seine Inhaltsstoffe überprüft wurde, Vandalismus/Brandstiftung, extreme Wetterbedingungen wie z. B. Überflutung, sehr starke Winde
   - Bewertung aller Risiken (Gefährlichkeit x Wahrscheinlichkeit) von Unfällen und ihrer möglichen Folgen. Nach Bestimmung der Gefahren kann der Prozess der Risikobewertung durchgeführt werden, indem sechs grundlegende Fragen zu stellen sind:
     - Wie hoch ist die geschätzte Wahrscheinlichkeit ihres Auftretens? (Ursache, Häufigkeit)
     - Was und wie viel kann emittiert werden? (Risikobewertung des Ereignisses)
     - Wohin gehen die Emissionen? (Vorhersagen für die Emission – welche sind die Pfade und Rezeptoren?)
     - Was sind die Folgen? (Folgenbewertung – Auswirkungen auf die Rezeptoren)
     - Was sind die Gesamtrisiken? (Bestimmung des Gesamtrisikos und seiner Bedeutung für die Umwelt)
     - Was kann zur Vermeidung oder Senkung des Risikos getan werden? (Risikomanagement – Maßnahmen zur Verhinderung von Unfällen und/oder zur Verringerung ihrer Umweltauswirkungen)

[11] Anm.d.Übers.: Hierbei handelt es sich um Behälter, wie im weiteren Textverlauf deutlich wird.
[12] Anm.d.Übers.: Im Originaltext steht hier „washed waste“.

Die Tiefe sowie Art der Bewertung hängt von den Eigenschaften der Anlage und ihrer örtlichen Lage ab. Die Hauptfaktoren, die berücksichtigt werden sollten, sind:

- Ausmaß und Art der durch die Anlage und ihre Tätigkeiten bedingten Unfallgefahr
- Risiken für bewohnte Gebiete und Umwelt (Rezeptoren)
- Art der Anlage und Komplexität oder andererseits der Tätigkeiten und der relativen Schwierigkeit der Entscheidung und Rechtfertigung einer angemessenen Risikokontrolltechnik

b. dokumentiertes Verfahren zur Bestimmung, Bewertung und Minimierung der Umweltrisiken und der Gefahren durch Unfälle und ihre Folgen
c. Sicherstellung, dass das Abfallannahmeverfahren, bestehend aus Probenahme und Untersuchung im Rahmen der Voruntersuchungen und anschließender Überprüfung bei der Ankunft an der Anlage eine entscheidende Rolle bei der Unfallverhütung spielt (siehe Abschnitt 4.1.1)
d. Führen eines Inventars von vorhandenen oder wahrscheinlich vorhandenen Stoffen, die im Fall ihrer Freisetzung Auswirkungen auf die Umwelt haben könnten. Dabei sollte nicht vergessen werden, dass viele scheinbar unschädliche Stoffe umweltschädigend sein können, falls sie freigesetzt werden (zum Beispiel kann Milch aus einem Tankfahrzeug, wenn sie in einen Wasserlauf verschüttet wird, sein Ökosystem zerstören). (Das Inventar steht auch in Beziehung mit der Rückverfolgbarkeit, siehe Abschnitt 4.1.2.3)
e. Vorgehensweisen zur Überprüfung von Rohstoffen und Abfällen, um die Verträglichkeit mit anderen Stoffen sicherzustellen, mit denen sie versehentlich in Kontakt kommen können (siehe Verträglichkeit, Abschnitt 4.1.4.13)
f. Getrennthaltung unverträglicher Abfälle und Stoffe abhängig von ihrem Gefahrenpotenzial. Unverträgliche Abfallarten müssen in voneinander getrennten Kammern oder in zweckbestimmten Gebäuden gelagert werden. Die Mindestanforderung umfassen eine begrenzende Umfassung sowie getrennte Entwässerung. Es müssen auch Maßnahmen getroffen werden, die verhindern, dass Behälter in andere Lagerbereiche hineinfallen können
g. Vorhalten geeigneter Lagereinrichtungen für Rohstoffe, Produkte und Abfälle
h. Verwendung eines automatischen, durch Mikroprozessoren überwachten Verfahrens, das über eine Ventilkontrolle oder Füllstandablesung von Tanks hinausgeht. Beispiele dafür sind: Ultraschall-Messungen, Füllstandwarnungen bei hohen Pegeln und Prozesssperren.
i. Sicherstellung, dass in Notfallsituationen die Kontrolle aufrechterhalten wird, unter Beachtung der Nutzung von Prozessalarmsystemen, Zweihandbedienungen und anderen Kontrollgesichtspunkten, z.B. automatischen Verfahren basierend auf einer Mikroprozessorkontrolle, die über eine Ventilkontrolle oder Füllstandsablesungen hinausgeht, wie Ultraschallmessungen, Füllstandwarnungen bei hohem Pegel, Prozesssperren und Prozessparameter
j. Dokumentation der vorhandenen Kontrollmaßnahmen, einschließlich der Evaluierung der Maßnahmen und der Entscheidung hinsichtlich ihrer Eignung
k. Einsetzung geeigneter Kontrolltechniken, um die Folgen eines Unfalls zu begrenzen, wie etwa Einrichtungen für den Fall von Ölverschüttungen, Abriegelung von Drainagen, Alarmierung der betroffenen Behörden und Evakuierungsmaßnahmen
l. Ggf. Anwendung von Vorsorgetechniken, wie etwa geeigneter Sperren, um Schaden an der Betriebseinrichtung durch den Verkehr zu vermeiden (siehe Abschnitt 4.1.4.6)
m. Vorhalten geeigneter Rückhaltevorrichtungen, z.B. Dämme und Auffanggefäße, Gebäude-Eindämmung (siehe Abschnitt 4.1.4.4)
n. Einführung von Techniken und Vorgehensweisen zur Vermeidung der Überfüllung von Lagertanks (flüssig oder pulverförmig), z.B. Füllstandsmessungen, unabhängige Alarmsysteme bei hohem Füllstand, Abschaltung bei hohem Füllstand und einer Chargendosierung (siehe Abschnitt 4.1.4.1)
o. Führung eines aktuellen Tagebuch zur Aufzeichnung aller Zwischenfälle, BeinaheZwischenfälle, Änderungen von Arbeitsabläufen, ungewöhnlicher Vorfälle und Ergebnisse von Wartungsinspektionen. Leckagen, Verschüttungen und Unfälle können im Betriebstagebuch aufgezeichnet werden. Der Zwischenfall und die darauf eingeleiteten Reaktionen stehen so zur Verfügung, um die meldepflichtige Freisetzungen für den Jahresbericht abzuschätzen
p. Einführung von Arbeitsabläufen, um Zwischenfälle zu erkennen, auf sie zu reagieren und aus ihnen zu lernen
q. Bestimmung der Rollen und Verantwortlichkeiten des am Unfallmanagement beteiligten Personals. Zusätzlich muss eine klare Anleitung zur Verfügung stehen, wie mit jedem Unfallszenario umzugehen ist, zum Beispiel Rückhaltung oder Verdünnung, Feuer löschen oder brennen lassen
r. Einführung von Arbeitsabläufen zur Vermeidung von Zwischenfällen, die als Folge schlechter Kommunikation des Betriebspersonals während des Schichtwechsels auftreten sowie der Verfolgung von Wartungs- oder anderen Konstruktionsarbeiten

s. Ermittlung des erforderlichen Schulungsbedarfs für das Personal und dessen Durchführung
t. Systeme, die bereits zur Vermeidung von flüchtigen Emissionen eingesetzt werden, sind im Allgemeinen auch für Drainagesysteme von Bedeutung (siehe auch Abschnitt 4.1.3.6):
   - Es müssen Arbeitsabläufe vorhanden sein, um sicherzustellen, dass die Inhalte von Auffangbecken, oder Gruben, die mit einem Drainagesystem verbundenen sind, vor der Behandlung oder Beseitigung auf ihre Zusammensetzung überprüft werden
   - Drainagegruben müssen mit einem Alarm oder einem Sensor bei hohem Füllstand und einer Pumpe ausgestattet sein, die das Abwasser in diesem Fall zu einer geeigneten Lagerung (nicht zur Einleitung) transportiert;
   - Es muss ein Verfahren vorhanden sein, das gewährleistet, dass die Füllstände der Gruben in der Regel auf ein Minimum beschränkt werden
   - Alarmvorrichtungen bei hohem Füllstand usw. sollten nicht routinemäßig als die vorrangige Methode zur Füllstandskontrolle eingesetzt werden
u. Sicherstellung, dass Prozesswasser, Wasser der Anlagendrainage, bei Notfällen Feuerlöschwasser, chemisch verunreinigtes Wasser und Verschüttungen von Chemikalien, wo angemessen, zurückgehalten werden und wo notwendig, zum Abwassersystem geleitet werden, mit einer Vorkehrung, das Hoch- und Regenwasser zurückhält, und behandelt wird, bevor Emissionen in überwachte Gewässer oder Abwasserkanäle gelangen. Es muss eine ausreichende Lagerkapazität vorhanden sein, um sicherzustellen, dass dies erreicht werden kann. Ebenso müssen Verfahren für den Fall von Verschüttungen eingesetzt werden, um das Risiko von unfallbedingten Emissionen der Rohstoffe, Produkte und Abfallstoffe zu minimieren und ihren Eintrag in das Wasser zu verhindern. Jegliche Sammelsysteme in denen in Notfällen Löschwasser aufgenommen wird müssen Flüsse von zusätzlichem Feuerlöschwasser oder von zusätzlichen Feuerlöschschäumen berücksichtigen. Im Notfall können Teiche als Speicher notwendig sein, um zu verhindern, dass verunreinigtes Feuerlöschwasser in überwachte Gewässer gelangen (siehe auch Abschnitt 4.1.3.6)
v. Durchführung der Wartung und Überprüfung unter denselben Standards wie in der Hauptanlage oder den Notfallanlagen
w. Erwägung, und falls angemessen, Planung der Möglichkeit eines Rückhalte- oder Minderungssystems für unfallbedingte Emissionen aus Entlüftungen und Sicherheitsventilen/gebrochenen Scheiben. Wo dies aus Sicherheitsgründen nicht ratsam ist, muss die Aufmerksamkeit auf die Reduzierung der Wahrscheinlichkeit von Emissionen im Vordergrund stehen
x. Einsatz geeigneter Prozeduren und Vorrichtungen, z.B. für die Lagerung bestimmter Arten von gefährlichen Abfällen, die einen automatischen Alarm und möglicherweise Sprinkleranlagen erfordern. Die Anlage muss einer geeigneten Wasserversorgung zum Löschen von Feuer und zudem der Möglichkeit der Sammlung und Lagerung des Feuerlöschwasser-Abflusses verfügen. Die Lagerung oder Behandlung von Abfällen, die mit Wasser reagieren, macht ein alternatives Feuerlöschverfahren erforderlich
y. Aufstellung sicherer Arbeitsabläufe für das Abfahren der Anlage
z. Aufbau von Kommunikationswegen mit zuständigen Behörden und Notfalldiensten bereits vor und im Falle eines Unfalls. Prozeduren nach einem Unfall müssen eine Bewertung des Schadens beinhalten der eintreten kann und es müssen Maßnahmen entwickelt werden, um den Schaden zu beheben
aa. ausreichende Sicherheitsmaßnahmen, einschließlich des Einsatzes von Personal, um Vandalismus und versehentliche Eindringlinge zu verhindern, da sie durch Kontakt mit dem Abfall Schaden nehmen können, und um eine Beschädigung der Betriebseinrichtungen oder illegale Deponierungen zu verhindern. Die meisten Einrichtungen nutzen eine Kombination aus Wachleuten, völliger Einfriedung (normalerweise mit Zäunen), kontrollierten Eingangsstellen, angemessener Beleuchtung, ordnungsgemäßen Warnschildern und 24-Stunden-Überwachung. In der Regel betreiben die Wachleute auch das Pförtnerhaus, wo sie das Eintreffen nicht erwarteter Lastwagen verhindern sowie den Eintritt von Besuchern überwachen
bb. Vorhandensein und Befolgen eines Inspektionsverfahrens, welches eine Liste von zu inspizierenden Punkten, einen Zeitplan und typische Probleme, die auftreten können, enthält. Mittels der Inspektion sollten Gerätschaften, Lagerbereiche, Notfalleinrichtungen, Überwachungseinrichtungen und Sicherheitseinrichtungen überprüft werden. Grundsätzlich sollte die Inspektion nach Defekten an Gerätschaften, Strukturverschlechterungen, Betriebsfehlern und Ableitungen suchen, die zur Freisetzung von Inhaltsstoffen gefährlicher Abfälle führen könnten.
cc. Ernennung eines Angestellten der Anlage zum Unfallbeauftragten, der leitende Verantwortung für die Umsetzung des Plans trägt. Es ist wichtig, dass die Anlage ihren Angestellten Schulungen anbietet, damit diese ihre Pflichten wirksam und sicher erfüllen können, so dass das Personal ein Fachwissen besitzt um auf Unfälle zu reagieren.
dd. Vorhandensein eines Feuer- und Explosionsschutzsystems, zu dem Vorsorge-, Melde- und Löschgeräte gehören.

Erreichter Nutzen für die Umwelt
Die bedeutendsten Umweltrisiken im Zusammenhang mit Abfallbehandlungstätigkeiten entstammen der Lagerung von gefährlichen Abfällen, von Emissionen aus Reaktionen von Abfällen im Fall von Leckagen oder Verschüttungen, oder von Behandlungsverfahren, die außer Kontrolle geraten.

Kombinationen aus ungeeigneten Gerätschaften und schlechten Inspektions- und Wartungsarbeiten können auch die Unfallrisiken vergrößern, zum Beispiel, wenn Tanks überfüllt werden, wenn die Füllstandsmesser nicht funktionieren oder nicht richtig kalibriert worden sind.

Leckagen, Verschüttungen und Unfälle werden an jedem Standort vorkommen. Ein Betreiber einer Umladeanlage weist darauf hin, dass pro Vierteljahr ein Fass unfallbedingt zerbricht. Technik o (siehe obige Beschreibung) hilft Betreibern, Probleme der Betriebsführung zu verstehen, so dass sie Maßnahmen ergreifen können, um das Auftreten solcher Fälle in der Zukunft zu vermeiden oder zu minimieren.

Medienübergreifende Auswirkungen
Nicht bekannt.

Betriebsdaten
Technik o (siehe obige Beschreibung) ist in der Regel ein computergestütztes System.

Anwendbarkeit
Einige der Techniken sind spezifisch für den Abfallbehandlungssektor, andere jedoch sehr allgemein. Einige sind nur für Behandlungen von gefährlichen Abfällen von Bedeutung.

Treibende Kraft für die Anwendung
Hauptsächlich Gesundheits- und Sicherheitsgründe (Verringerung der Unfallhäufigkeit). Technik bb) in der obigen Beschreibung ist eine grundlegende Anforderung von Artikel 9 der EU-Richtlinie 75/442.

Beispielanlagen
Diese Techniken sind Standardverfahren, die in allen Arten von Abfallbehandlungsanlagen eingesetzt werden. Dennoch verwenden Abfallbehandlungsanlagen in der Regel hierfür manuell betriebene Systeme.

Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.1.8 Techniken zum Lärm- und Vibrationsschutz

Beschreibung
Ein Lärmminderungsplan ist in der Regel ein Teil des Umweltmanagementsystems (UMS in Abschnitt 4.1.2.8). Solch ein Plan enthält normalerweise:

a. eine Beschreibung der Hauptquellen von Lärm und Vibrationen (einschließlich seltener Quellen) und der nächsten lärmempfindlichen Standorte. Diese Beschreibung enthält die folgenden Informationen für jede wichtige Quelle von Lärm und Vibrationen innerhalb der Anlage:
   - die Quelle und ihre Lage auf einem maßstabsgetreuen Plan des Standorts
   - ob der Lärm oder die Vibration kontinuierlich/diskontinuierlich auftritt, ob sie stationär oder mobil ist
   - die Betriebszeiten
   - eine Beschreibung des Lärms oder der Vibration, z.B. Klappern, Jaulen, Zischen, Kreischen, Summen, Knallen, Klicken, Bumsen oder Tonal
   - ihr Beitrag zur Gesamt-Lärmemission des Standorts, z.B. Einstufung als hoch, mittel oder niedrig, falls keine unterstützenden Daten zur Verfügung stehen
b. beinhaltet die oben genannten Informationen auch für den Betrieb seltener Lärm- und Vibrationsquellen (wie etwa selten durchgeführte/saisonbedingte Tätigkeiten, Reinigungs-/Wartungstätigkeiten, Anlieferungen/Sammel- und Transportvorgänge auf dem Betriebsgelände oder zu unüblichen Arbeitszeiten, Notstromaggregaten oder Notfallpumpen und Probealarm)
c. eine detaillierte Auflistung der angemessenen Lärmbegutachtung, -messungen, -ermittlungen (was detaillierte Bewertungen der Schallleistungspegel für einzelne Anlagenteile beinhalten kann) oder es könnte eine Modellierung für neue sowie für bestehende Anlagen erforderlich sein, dies unter Berücksichtigung der potenziellen Lärmprobleme.

Sich an den "Lärm- und Vibrationsplan" zu halten, ermutigt Betreiber:

d. alle Teile der Anlage oder der Gerätschaft sachgemäß zu warten, deren Zustandsverschlechterung eine Erhöhung der Geräuschemissionen mit sich bringen kann (z. B. Wartung von Lagern, der Lüftungsanlage und der Bausubstanz, wie auch spezielle Lärmminderungsmaßnahmen, die mit der Anlage, der Gerätschaft oder den Maschinen verbunden sind)
e. laute Bereiche/Tätigkeiten einzuhausen

Erreichter Nutzen für die Umwelt
Senkt den erzeugten Geräuschpegel der Anlage.

Anwendbarkeit
Bei der Bestimmung, welche Quellen mit berücksichtigt werden sollen, ist eine Methode zu wählen, die diejenigen Quellen berücksichtigt, die eine Umweltbeeinträchtigung verursachen können. So kann z.B. eine kleine Einheit in einem abgeschlossenen Bereich arbeitsbedingten Lärm erzeugen, jedoch unwahrscheinlich eine Umweltbeeinträchtigung verursachen. Im Gegensatz dazu könnte zum Beispiel eine große Einheit oder eine Anzahl kleinerer Einheiten innerhalb eines geschlossenen Gebäudes eine Belästigung nur dann verursachen, wenn die Türen offen gelassen werden. Es muss auch daran erinnert werden, dass mancher Lärm, der tagsüber nicht besonders zu bemerken ist, in der Nacht stärker zu bemerken ist.

Treibende Kraft für die Anwendung
Minderung von Lärm und Vibrationen.

Literatur
[152, TWG, 2004], [152, TWG, 2004]

4.1.9 Techniken für die Stilllegung

Beschreibung

Zur Minimierung von Stilllegungsproblemen und aller damit verbundenen Umweltauswirkungen eignen sich unter anderem folgende Techniken:

a. Berücksichtigung der Stilllegung in der Planungsphase, indem geeignete Pläne zur Risikominimierung während der späteren Stilllegung aufgestellt werden
b. für bestehende Anlagen, in denen potenzielle Probleme erkannt worden sind, kann der Einsatz eines Programms zur Verbesserung des Anlagendesigns helfen. Diese Verbesserungen müssen gewährleisten, dass:
   - unterirdische Tanks und Leitungen vermieden werden. Ist ein Ersatz wirtschaftlich nicht machbar, sollten Betreiber sie durch Rückhaltesysteme oder ein geeignetes Überwachungsprogramm schützen
   - Es müssen Vorkehrungen zum Entleeren und Reinigen von Behältern und Leitungen vor ihrer Demontage getroffen werden
   - Teiche und Deponien unter Berücksichtigung ihrer letztendlichen Sanierung geplant werden
   - eine Isolierung bereitgestellt wird, die leicht, staub- und gefahrenfrei zu demontieren ist
   - alle verwendeten Materialien recycelbar sind (unter Berücksichtigung betrieblicher und anderer Umweltziele)
c. Aufrechterhaltung eines Standortschließungsplans, mit dem gezeigt werden kann, dass die Anlage in ihrem aktuellen Zustand unter Vermeidung jeglichen Umweltverschmutzungsrisikos demontiert werden kann, um den Betriebsstandort in einen zufriedenstellenden Zustand zurückzuführen. Der Plan sollte bei der Änderung von Materialien aktualisiert werden. Der Schließungsplan kann bereits in einem frühen Stadium Einzelheiten zu folgenden Punkten enthalten:
   - Entfernen oder Spülen von Leitungen und Behältern, wenn dies zweckmäßig ist und die vollständige Entleerung von allen potenziell schädlichen Inhalten
   - Pläne, die alle unterirdischen Leitungen und Behälter enthalten
   - Eine Methode und notwendige Ressourcen zum Reinigen von Teichen
   - Eine Methode zum Schließen aller Deponien auf dem Gelände
   - die Entfernung von Asbest und anderen möglicherweise schädlichen Materialien, wenn nicht einvernehmlich beschlossen wurde, dass es vernünftig ist, solche Verantwortlichkeiten den zukünftigen Besitzern zu überlassen
   - Methoden der Demontage von Gebäuden und anderer baulicher Strukturen, die den Schutz von Oberflächen- und Grundwasser auf Bau- und Abbruchgeländen gewährleisten
   - die erforderliche Untersuchung des Bodens, um das Ausmaß aller Verschmutzungen zu ermitteln, die durch die Tätigkeiten am Standort verursacht wurden, und Informationen darüber, was bei der Sanierung notwendig ist, um den Standort in einen befriedigenden Zustand zurückzuführen, wie er im Bericht zum ursprünglichen Standort festgeschrieben ist
d. Beschreibung von vorgeschlagenen Maßnahmen, nach einer definitiven Beendigung der Tätigkeiten, die dazu führen sollen, jegliches Verschmutzungsrisiko zu vermeiden und den Betriebsstandort in einen zufriedenstellenden Zustand zurückzuführen (einschließlich Maßnahmen im Zusammenhang mit Planung und Bau der Anlage, wo es verhältnismäßig ist)
e. Beschreibung von Plänen zur Aufbereitung von abgelagerten Rückständen, Abfällen und jeglichen Verunreinigungen, die durch die Abfallbehandlungstätigkeiten verursacht wurden
f. Gewährleistung, dass die Anlage sowie außer Betrieb genommene Gerätschaften dekontaminiert und vom Standort entfernt werden.

Erreichter Nutzen für die Umwelt

Vermeidet Umweltprobleme während der Stilllegung.

Anwendbarkeit

Die hier erwähnten Techniken sind während der Betriebsdauer der Anlage, im Planungs- und Baustadium und bei der Schließung der Anlage anwendbar.

Treibende Kraft für die Anwendung

Technik e (siehe obige Beschreibung) ist durch die aktuelle EU-Abfallgesetzgebung vorgeschrieben.

Beispielanlagen

Die Demontage ganzer Anlagen oder von Anlagenteilen kommt in der Branche häufig vor.

Literatur

[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.2 Bei der biologischen Behandlung zu berücksichtigende Techniken

Dieser Abschnitt beinhaltet Techniken, die aus Umweltsicht ein günstiges Betriebsverhalten besitzen (z.B. Verwendung eines guten Energiesystems) oder die zu einem günstigen Umweltverhalten führen können (z.B. Umweltmanagementsysteme). Diese Techniken werden in der Regel im Zusammenhang mit einer biologischen Behandlung als Teil einer Gesamt-Abfallbehandlung angewendet. Die biologische Behandlung von Abwässern wird in Abschnitt 4.7 behandelt.

4.2.1 Wahl einer geeigneten biologischen Behandlung

Beschreibung
Ein entscheidender technischer Faktor zur Wahl des geeigneten Verfahrens ist dessen Fähigkeit, einen guten Kontakt zwischen den organischen Bestandteilen des Abfalls und den Mikroorganismen zu gewährleisten. Diese Fähigkeit hängt in erster Linie von Zustand und Konzentration des Abfalls ab. Eine annähernde schematische Darstellung derjenigen Verfahren, die als Funktion dieser beiden Variablen geeignet sind, zeigt Abbildung 4.2.

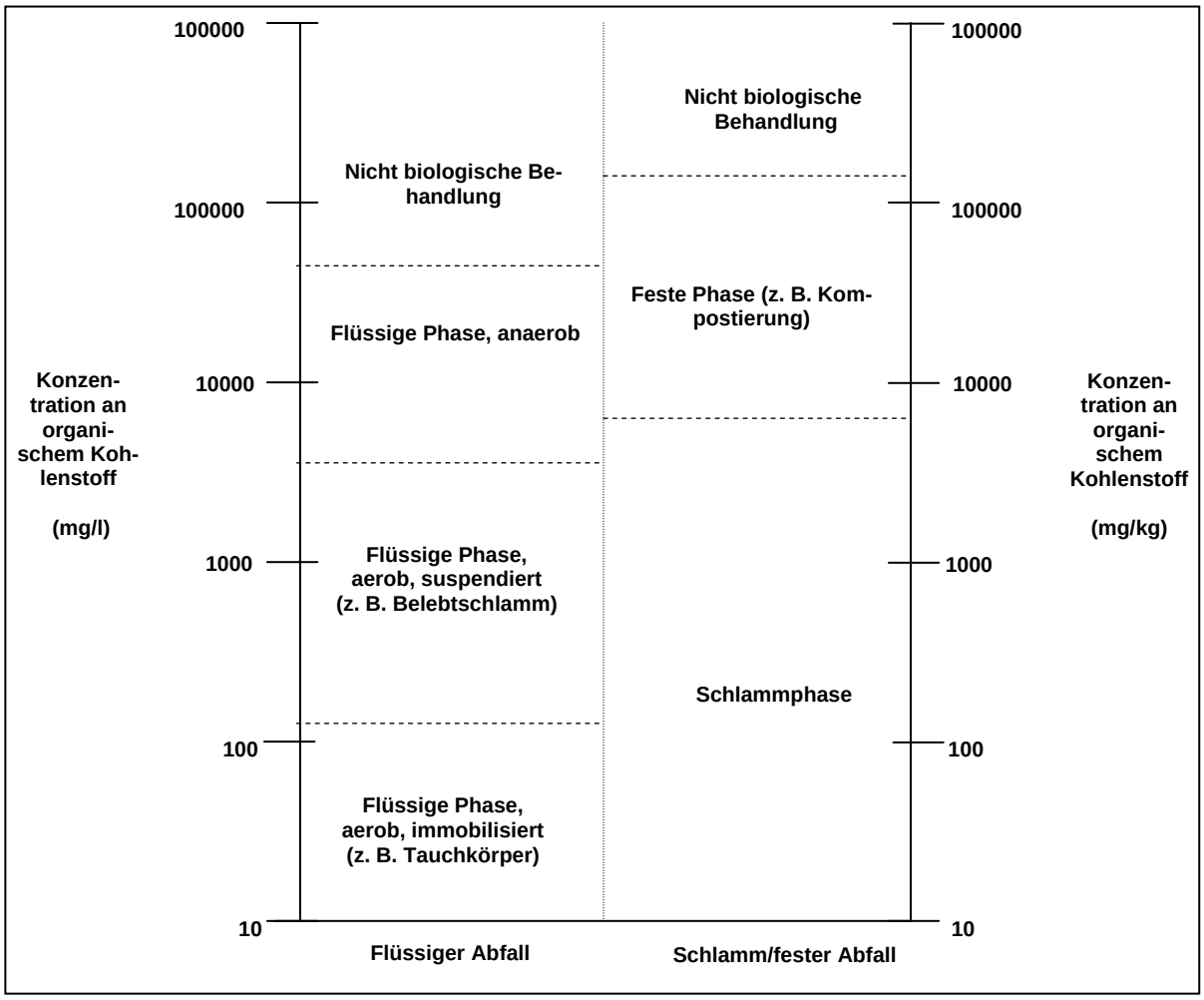


Abbildung 4.2: Wahl eines geeigneten biologischen Behandlungsverfahrens als Funktion von Konzentration und Art des Abfalls
[152, TWG, 2004]

Zusätzlich tragen vollständig eingehauste oder eingekapselte Bioreaktoren dazu bei, die biologische Behandlung besser zu kontrollieren und diffuse Emissionen (z.B. VOC, Gerüche, Staub) zu vermeiden.

Erreichter Nutzen für die Umwelt
Die Wahl der geeigneten biologischen Behandlung für den Abfall trägt dazu bei, sowohl Betriebsprobleme zu vermeiden als auch den größtmöglichen Nutzen aus dem Abfall zu ziehen (z.B. Nutzung als Brennstoff).

Betriebsdaten
Bedeutende Aspekte, die bei der Wahl des biologischen Verfahrens zu berücksichtigen sind, sind die gleichmäßige Verteilung der Nährstoffe und Feuchtigkeit im Abfall selbst (Homogenität) als auch die Verfügbarkeit der ausgewählten Behandlungsmethode.

Treibende Kraft für die Anwendung
Die Abfallhierarchie kann eine Anleitung geben, welche Art von Behandlung eingesetzt werden kann. Wenn die Abfallhierarchie jedoch ohne eine gut zugrunde liegende Analyse angewendet wird, wird möglicherweise kein gutes Ergebnis erzielt. Es ist berichtet worden, dass im Fall der Klärschlammbehandlung wegen des geringen Energiegehalts von biologisch behandeltem Klärschlamm im Vergleich zu thermisch getrocknetem Klärschlamm, es eine gute Lösung sein kann, je nach Abfall entweder eine Vergärung und thermische Trocknung und/oder eine Verbrennung zu wählen.

Literatur
[152, TWG, 2004], [152, TWG, 2004]

4.2.2 Spezielle Lager- und Handhabungstechniken für biologische Behandlungsverfahren

Beschreibung
Einige Techniken in Zusammenhang mit Lagerung und Handhabung bei der biologischen Abfallbehandlung sind:

a. Vorhandensein von Annahmebunker oder Ausgleichstanks
b. Einhausung und Ausstattung der Abfallbehandlungsanlage (einschließlich des Annahmebereichs und Bunkers, der mechanischen Behandlung, der Lagereinrichtungen und aller biologischer Behandlungsschritte) mit einer Einrichtung zur Ablufterfassung (beinhaltet Staub, TOC, Ammoniak, Gerüche und Keime) und ggf. mit einer Abluftreinigungsanlage, wenn es maßgeblich ist. Luftaustauschraten von drei- oder viermal pro Stunde sind üblich
c. Reinigung oder Wiederverwendung der Abluft, z.B. als Zuluft für den biologischen Abbau
d. Niedrighalten von Verunreinigung in der Abluft durch:
   - Vermeidung von Verkehrswegen durch den Anlieferungsbereich
   - Einsatz leicht zu reinigender Oberflächen und Arbeitsgeräte
   - Minimierung der Lagerdauer von Abfällen im Anlieferungsbereich
   - regelmäßige Reinigung des Hallenbodens mit geeigneten Kehrmaschinen oder industriellen Staubsaugern
   - Reinigung von Sonnenschutz, Förderbändern und anderer Gerätschaft mindestens einmal pro Woche
e. Verwendung einer Kombination von automatisch und schnell schließenden Türen mit so genannten Luftwänden, welche in der Praxis auch als Sperre dienen können, wenn die Öffnungszeiten der Tore auf ein Minimum beschränkt werden soll. Dies kann unterstützt werden durch den Einbau von sensorüberwachten Jalousientoren oder Klapptoren und durch eine ausreichende Dimensionierung des Manövrierbereichs vor der Halle. Es muss betont werden, dass die Disziplin des Hallen- und Fahrzeugflottenpersonals mindestens genauso wichtig ist, um kurze Öffnungszeiten tatsächlich zu realisieren. Es muss auch sichergestellt werden, dass die notwendige Wartung der Türen wie erforderlich durchgeführt wird und an der geeigneten Betriebsweise festgehalten wird. Die Installierung einer Luftwand erzeugt einen Vorhang aus Umgebungsluft innerhalb der offenen Tür, womit das Entweichen von Luft aus der Halle verhindert wird. Bei unterirdischen Bunkern, denen sich Fahrzeuge rückwärts nähern um die Ladung abzukippen, kann die Installation einer Luftwand entlang des Fahrzeugumrisses hinter der tatsächlichen Tür ein Weg sein, den Luftaustausch während des Entladens soweit wie möglich zu minimieren
f. geschlossene Aufgabebunker, die mit einer Fahrzeugschleuse betrieben werden. In offenen Lagerhäusern und während des Entladens von Müllfahrzeugen wird die Abluft aus dem Bunker durch Absaugung entfernt und in eine Abgasreinigungsanlage geleitet.

Zusätzlich eignen sich die folgenden Maßnahmen zur Staubminimierung während Lagerung und Handhabung:

g. Abscheidung von Staub durch eine Befeuchtungsanlage[13], obwohl dies nicht obligatorisch ist
h. Absaugung von Punktquellen und Hallenluft mit anschließender Entstaubung
i. Nutzung einer Abdeckung des Förderbands
j. Vermeidung oder Minimierung großer Fallhöhen bei Übertragung zwischen Bändern
k. Verwendung langsam laufender Zerkleinerungsaggregate
l. regelmäßige Reinigung von Aggregatbereichen, Hallenböden und Verkehrswegen
m. Einsatz einer Reifenwaschanlage, um die Verbreitung von Abfall zu den Außenbereichen der Anlage durch die Fahrzeuge zu vermeiden.

Auch sollte der anaerobe Abbau bei der Lagerung von Abfallmaterialien aus öffentlichen Anlagen/Umladestationen, die einen hohen Gehalt an gemähtem Gras enthalten, während warmer feuchter Perioden wirksam verhindert werden. In der Regel hat Gras einen hohen Feuchtegehalt und verdichtet sich, wodurch das Eindringen von Sauerstoff verhindert wird. Wenn solcher Abfall in einer Umladestation für etwa einen Tag aufgeschichtet, danach in einem Container gesammelt und auf einem Haufen bei nassem Wetter gelagert wurde, setzen anaerobe Bedingungen ein. Eine andere Möglichkeit ist, dass Feuchtigkeit bei lang andauerndem nassen Wetter in ungeschützte Mieten eindringt, wodurch aerober Abbau beendet wird. Weshalb sie in geeigneter Weise geschützt oder bedeckt werden müssen.

Erreichter Nutzen für die Umwelt
In biologischen Behandlungsverfahren für flüssige Abfälle ist es zur Aufrechterhaltung des ordnungsgemäßen Betriebs wichtig, dass der Substratzufluss relativ konstant ist, andernfalls können unerwartete Emissionen auftreten. Bei einigen Techniken liegt der Schwerpunkt auf der Vermeidung von Emissionen in die Luft. Zum Beispiel können in Haufen mit organischen Bestandteilen durch eine erhöhte biologische Aktivität nach kurzer Zeit Temperaturanstiege auftreten und zu Emissionen in die Luft führen (Gesamt-C, Gerüche).

Wegen höherer Temperaturen in der Halle entwickelt sich im Winter an den Hallentoren ein Luftströmungsprofil, durch das warme Luft im oberen Bereich der Öffnung die Halle verlässt und kalte Luft am Boden eintritt.

Restabfälle können eine hohe Anzahl von feinkörnigen Partikeln enthalten. Deshalb können im Bunker beträchtliche Staubemissionen durch Kipp- und Ladevorgänge mit mobilen Gerätschaften erwartet werden. Diese sollten möglichst nahe am Entstehungsort wiedergewonnen oder abgelagert werden.

Betriebsdaten
Die Lagerbereiche werden normalerweise durch Tankfahrzeuge oder durch eine Leitung befüllt.

Anwendbarkeit
Da dieses Dokument ein breites Spektrum an biologischen Behandlungsverfahren sowie Abfallarten umfasst (z.B. mit flüchtigen oder geruchsintensiven Inhaltsstoffen), sind einige Techniken möglicherweise für bestimmte biologische Behandlungsverfahren nicht anwendbar (z.B. Aktivschlamm, Belüftungsbecken, MBA, biologische In-Situ-Sanierung, ölverunreinigter Boden und Schlamm, Erzeugung von Biogas zur Nutzung als Brennstoff,...). Einige angewendete Ausnahmen die bei den unten aufgeführten Techniken identifiziert wurden und im obigen beschreibenden Teil aufgeführt sind, sind folgende:

- Technik b für letzte Schritte der biologischen Behandlung oder nach der Behandlung
- Technik e wird in der Regel auf Abfall angewendet, so dass keine Gerüche emittieren
- Technik f wird in der Regel für sehr geruchsintensiven Abfall angewendet.

Treibende Kraft für die Anwendung
Im Zusammenhang mit Technik b aus dem obigen beschreibenden Abschnitt sind in Bereichen, wo Personen arbeiten, nach italienischer regionaler Gesetzgebung drei oder vier Luftwechsel durchzuführen. In Bereichen, wo keine Personen arbeiten, werden in der Regel zwei Wechsel pro Stunde durchgeführt. Technik f stammt aus einer speziellen Anforderung der TA Luft für Vergärungsanlagen und einer allgemeinen Anforderung der 30. BlmSchV. Technik m ist auch eine allgemeine Anforderung der 30. BlmSchV.

[13] Anm.d.Übers.: Im Originaltext wird der Begriff “defogging system” genutzt.

Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.2.3 Wahl des Einsatzmaterials für biologische Verfahren

Beschreibung
Einige zu berücksichtigende Punkte sind:

a. Substanzen, die nicht zu einer vorteilhaften Behandlung führen, wie etwa toxische Metalle, dürfen nur unterhalb festgelegter Grenzen in die biologischen Verfahren gelangen. Zum Beispiel können mechanische Behandlungen dazu beitragen, solche Grenzwerte einzuhalten
b. die Zugabe von Abwasser zur organischen Fraktion von Siedlungsabfall erhöht sowohl den Nährstoff- als auch den Feuchtegehalt. Andere Abfälle, die ebenfalls von Vorteil sein können, sind organische Industrieabfälle, Abfälle aus der Lebensmittelverarbeitung und landwirtschaftliche Abfälle.
c. obwohl das Verfahren an sich selbst einen wichtigen Aspekt darstellt, hat doch die Qualität des Rohstoffs wahrscheinlich den größten Einfluss, und so ist es unverzichtbar, diese Qualität zu maximieren. Sowohl die zulässigen Abfallarten als auch die Trennungsverfahren sind hierbei wichtig. Zu den Techniken gehören:
   - richtiges Verhältnis der Nährstoffe (z.B. Stickstoff zu Kohlenstoff)
   - Minimierung von toxischen und unerwünschten Inhaltsstoffen (einschließlich Schwermetalle, Pathogene und Inertstoffe)
   - Berücksichtigung, dass alle nicht abbaubaren Bestandteile, die in eine Vergärungsanlage gegeben, aber nicht durch das Verfahren beeinflusst werden, unnötig Platz verbrauchen. Zur Maximierung des (ökologischen und ökonomischen) Nutzens bei der Verwendung der Technik und zur Kostenminimierung ist es wichtig, diese Inhaltsstoffe im Rohstoff für die Vergärung auf ein Minimum zu beschränken
d. keine Mischung verschiedener Abfallarten, wenn sie nicht erwiesenermaßen dazu geeignet sind. Dies steht in Verbindung mit Abschnitt 4.1.5
e. ständiges Lernen über den Einfluss der Abfalleigenschaften auf die Betriebseinstellungen wie Zuschlagstoffe, Massenströme, Volumen, Variablen des biologischen Abbaus (z.B. Temperatur, CO_2) sowie auf die gemessenen (gasförmigen) Emissionen (z.B. Nutzung von kontinuierlich erfassten Emissionsdaten ((Rohgas und/oder Reingas), VOC, Methan) zur Regulierung der Einstellungen, d.h. zur automatischen Kontrolle biologischer Verfahren.

Erreichter Nutzen für die Umwelt
Verhindert, dass toxische Verbindungen in die biologischen Verfahren gelangen, d. h. toxisch im Sinne der Verringerung der biologischen Aktivität. Ein ausgewogener Nährstoffgehalt verhindert Emissionen, so zum Beispiel von Stickstoffverbindungen.

Wenn biologisch nicht aktive Bestandteile des Einsatzstoffs abgetrennt werden, können solche Stoffströme leicht wieder verwendet oder verwertet werden (z.B. Glas, Metalle)

Medienübergreifende Auswirkungen
Die Zugabe von Klärschlamm zur organischen Fraktion von Siedlungsabfall kann negative Auswirkungen auf die biologische Behandlung selbst haben, ebenso auf die Qualität des Abgases oder auf die Qualität des Abfall-OUT.

Betriebsdaten
Im Fall von Technik c (siehe obigen Abschnitt „Beschreibung“) wird eine integrierte biologische Trocknung von Siedlungsabfall durchgeführt, da in der Regel die Anwesenheit von Kunststoffen und anderen biologisch nicht abbaubaren Materialien einen Vorteil für die Belüftung darstellt und anaerobe Zonen verhindern kann, was zu geringeren Emissionen führt.
Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.2.4 Allgemeine Techniken für die Vergärung

Beschreibung
Zu den Techniken gehören:

a. enge Abstimmung zwischen Abfallwirtschaft und Abwassermanagement. Dies wäre hilfreich für Weiterentwicklungen und für das Management, um Verbesserungen einzuführen und Daten zu sammeln
b. Recycling der größtmöglichen Abwassermenge im Reaktor, um die Umwandlung gelösten organischen Materials zu Biogas zu erleichtern
c. Betrieb des Verfahrens unter thermophilen Vergärungsbedingungen, um die Zerstörung von Pathogenen, die Biogaserzeugungsrate (folglich eine höhere energetische Verwertung) und die Verweilzeit zu erhöhen
d. Messung von TOC, CSB, N, P and Cl Werten im Zu- und Abfluss, um die Einsatzstoffe im Gleichgewicht zu halten und eine gute Methanproduktion zu gewährleisten
e. Überprüfung relevanter Parameter im Gärwasser, im Gärrückstand und im Abwasser in regelmäßigen Intervallen, um eine gute Betriebsführung der Anlage sicherzustellen
f. geschlossene Aufgabebunker mit Fahrzeugschleuse. In offenen Lagerhäusern und während des Entladens von Müllfahrzeugen muss die Abluft aus dem Bunker durch Absaugung entfernt werden und in eine Abgasreinigungsanlage eingeleitet werden
g. Vorhalten angemessenen Raums insbesondere für den Lagerbereich auf der Grundlage der geschätzten monatlichen Nutzung
h. Planung, Bau und Betrieb der Anlage in einer Weise, dass eine Bodenkontamination durch Abwasser vermieden wird
i. Wiederverwendung der kondensierten Wasserdämpfe aus der Belüftung der Mieten (Nachrotte) und des gesammelten Wassers nur im Fall der offenen Kompostierung, um den festen Abfall zu befeuchten und falls Geruchsbelästigungen vermieden werden können.

Obwohl anaerobe Verfahren in Stufen betrieben werden können, um den Gesamt-CSB im Abwasser zu reduzieren, werden sie normalerweise für eine effiziente Methanproduktion angewandt und ihr Abwasser ist in der Tendenz konzentrierter als Abwasser aus aeroben Verfahren, und macht eine aerobe Endbehandlungsstufe erforderlich. Dies könnte durch eine Einleitung in den Abwasserkanal oder durch eine zweite Stufe auf dem Betriebsgelände umgesetzt werden.

Erreichter Nutzen für die Umwelt
Steigert die Effizienz der Vergärung und ermöglicht eine bessere Nutzung der Produkte. Die Minimierung der Menge potenziell giftiger Stoffe ist auch ein wichtiger Gesichtspunkt für die Qualität des Endprodukts. Anaerobe Verfahren sind wirksam beim Aufbrechen von Ringverbindungen (zum Beispiel Phenolen) und erzeugen Methan, das als Brennstoff verwendet werden kann. Dennoch können nicht alle Verbindungen, die beim anaeroben Abbau aromatischer Ringe (z.B. Xenobiotika) entstehen, unter anaeroben Bedingungen mineralisiert werden. Deshalb muss nach den anaeroben Behandlungsschritten ein aerober Abbauschritt folgen, um das organische Material vollständig zu mineralisieren.

Geruchsemissionen von 500 – 1000 GE/m³ aus der anaeroben Behandlung können durch eine geeignete Kombination von Biofilter und Gaswäscher erreicht werden, falls der NH_3 –Gehalt höher als 30 mg/Nm³ ist.

Medienübergreifende Auswirkungen
Über den Einsatz von Schlamm in Vergärungsverfahren muss von Fall zu Fall entschieden werden, da die Schwermetallkonzentration im Schlamm es dem Betreiber erschweren kann, die strengen Grenzwerte für Qualitätskompostprodukte einzuhalten, die in einigen EU-Mitgliedsstaaten existieren.

Betriebsdaten
Es wird behauptet, dass der hohe Grad der Flexibilität, der mit der Vergärung verbunden ist, einer der bedeutendsten Vorteile der Methode ist. Hiermit können verschiedene Abfallarten behandelt werden, variierend von trockenen zu nassen und von sauberen organischen Materialien bis hin zu Siedlungsabfällen[14]. Die Eignung der Methode für sehr nasse Materialien wurde zum Beispiel als eine wichtige Eigenschaft in Szenarien angesehen, bei denen an der Quelle getrennte Lebensmittelabfälle nicht mit einer ausreichenden Menge von gemischten Trägermaterialien wie Grünabfällen (also Abfall aus vielen Stadtbezirken) gemischt werden können.

[14] Anm.d.Übers.: Originaltext: “grey wastes”

Anaerobe biologische Verfahren sind sensibel gegenüber Chlor- und Schwefelverbindungen, dem pH-Wert und gegenüber Temperaturschwankungen und können eine Ansäuerungsstufe erfordern.

Das Recycling von Abwasser (Technik b in obiger Beschreibung) kann zu einem Anstieg der Konzentration von toxischen/hemmenden Verbindungen führen, die negative Auswirkungen auf die biologische Behandlung haben können.

Thermophile Vergärungsbedingungen (Technik c im obigen Abschnitt „Beschreibung“) sind nicht für alle Anwendungen nützlich oder möglich (z.B. kann eine Anpassung von Mikroorganismen an den Abbau von chlorierten aromatischen Verbindungen oder an die Abspaltung von Chlor aus speziellen Xenobiotika unter thermophilen Bedingungen nicht erreicht werden, keine thermophile Mikrobenpopulation kann an die zu behandelnden Verbindungen angepasst werden).

Unter bestimmten Bedingungen ist es notwendig, wichtige Parameter im Gärwasser, Gärrückstand und Abwasser in regelmäßigen Abständen zu überwachen, um einen guten Betrieb der Anlage sicherzustellen (Technik d im obigen Abschnitt „Beschreibung“). In diesen Fällen reichen die erwähnten Parameter zur Überwachung des Verfahrens nicht aus. Je nach Ziel der Behandlung (Deponierung, Düngemittelherstellung) müssen Parameter zur Überwachung des Outputs festgelegt werden, die sich nach der weiteren Nutzung richten.

Anwendbarkeit
Die Hauptsorge bei der Vergärung gilt der Sicherstellung einer langfristigen Betriebsleistung einer Anlage, was natürlich ein Schlüssel für ihre ökonomische Realisierung ist. Dieses Risiko kann durch Einsatz technischer Entwicklungen gesenkt werden, die damit verbundenen Kosten können jedoch die kurzfristige Wirtschaftlichkeit beeinträchtigen. Der Bau von zusätzlichen Anlagen in der Zukunft wird die Kenntnisse über den Betrieb erweitern, was das Vertrauen in die Technik vergrößern kann (siehe Abschnitt 4.1.2.2). Technik e im obigen Abschnitt „Beschreibung“ eignet sich zur Reduzierung der Geruchsemissionen.

Wirtschaftlichkeit
Die spezifischen Investitionskosten sind im Allgemeinen sehr viel höher als beim aeroben Abbau. Eine enge Abstimmung zwischen Abfallwirtschaft und Abwassermanagement wäre für eine Weiterentwicklung hilfreich. Dies würde die zusätzlichen Kosten senken, die mit der Ableitung von überschüssigem Wasser aus der Vergärung in eine Abwasserbehandlungsanlage verbunden sind. Dennoch geschieht dies in der EU nur selten, am häufigsten, wenn Nutzer des Wassers in den Prozess mit einbezogen sind.

Treibende Kraft für die Anwendung
Bessere Beherrschung des Verfahrens und Anforderungen der Deponierichtlinie. Die Techniken e bis h im obigen Abschnitt „Beschreibung“ sind Anforderungen der TA Luft, und Technik e ist zur Reduzierung der Geruchsemissionen notwendig.

Beispielanlagen
Diese Behandlungsmethode wird zurzeit relativ selten eingesetzt (sie ist lediglich Teil von Abfallwirtschaftsstrategien in vier Staaten, nämlich Deutschland, Österreich, Belgien und Dänemark, obwohl sie in einigen Fällen auf gemischte Abfälle oder Restabfälle in Frankreich, Spanien und Italien angewendet wird und eine kleine Anlage in GB in Betrieb ist). Neuere Entwicklungen der Verfahren zur Sortierung an der Quelle in Italien und Spanien sprechen für eine optimistische Sichtweise im Hinblick auf die zukünftige Verfügbarkeit von qualitativ hochwertigen Einsatzstoffen.

Es ist auch erwähnenswert, dass die Vergärung in Spanien das schnellste Wachstum in Europa erfährt, dank der öffentlichen Förderung von Anlagen durch EU-Programme. Eine solche Förderung senkt die gesamten Betriebskosten, da die Abschreibung einer der Hauptkostenfaktoren ist.

Literatur
[33, ETSU, 1998], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [114, Hogg, 2001], [150, TWG, 2004], [153, TWG, 2005]

4.2.5 Erhöhung der Verweilzeit in Vergärungsverfahren

Beschreibung
Bei dem Verfahren verbleibt das Faulgut längere Zeit unter Abbaubedingungen.

Erreichter Nutzen für die Umwelt
Eine längere Verweilzeit ermöglicht einen intensiveren biologischen Abbau und folglich einen Gärrückstand von höherer Qualität, was wiederum die Biogasproduktion erhöhen kann. Eine ausreichend hohe Temperatur und eine ausreichend lange Verweilzeit gewährleisten, dass das Material gereift, frei von Krankheitserregern und Samen ist und geringere Geruchsemissionen verursacht.

Medienübergreifende Auswirkungen
Der erreichte Vorteil muss einer möglichen geringeren Beladungsrate gegenübergestellt werden, was den Durchsatz verringert und somit die Kosten pro behandelter Tonne erhöht.

Anwendbarkeit
Eine Steigerung der Biogasproduktion hat in der Regel einen Einfluss auf die Qualität von Gärrückstand und Biogas. Dies erfordert eine Optimierung des Biogasaufkommens, der Biogasqualität und der Qualität des Gärrückstands.

Literatur
[152, TWG, 2004], [152, TWG, 2004]

4.2.6 Techniken zur Emissionsminderung bei der Nutzung von Biogas als Brennstoff

Beschreibung
Vor seiner betriebsexternen oder betriebsinternen Nutzung als Brennstoff wird das Biogas aus dem Fermenter entwässert und feste Partikel werden entfernt. Biogas kann in Gasmotoren z.B. in Blockheizkraftwerken, Gaskesseln, Fahrzeugen oder auch für andere Zwecke, wie etwa als Brennstoff für die thermische Abluftreinigung für VOC, eingesetzt werden. Zur Bekämpfung von Emissionen können zwei Arten von Techniken eingesetzt werden. Die erste Art besteht in der Reinigung des Biogases vor seiner Nutzung, um die Emissionen bei seiner Verbrennung zu reduzieren, die andere besteht in einer Abluftreinigung nach der Verbrennung des Biogases. Beide Arten von Techniken werden hier behandelt, dabei gehören zu den speziellen Maßnahmen:

a. Reduzierung der Schwefelwasserstoffemissionen durch eine Wäsche des Biogases unter Verwendung von Eisensalzen, durch Zugabe dieser Eisensalze in den Faulbehälter oder durch eine biologische Oxidation unter kontrollierter Zugabe von Sauerstoff
b. Einsatz der selektiven katalytischen Reduktion (SCR) (Abschnitt 4.6.21) zur NO_X -Minderung
c. Einsatz der thermischen Oxidation zur Emissionsminderung für CO und Kohlenwasserstoffe
d. Einsatz von Aktivkohlefiltern
e. Ausstattung dieser Anlagen mit einer Lagermöglichkeit für Biogas und einer Notfallfackel.

Es muss angemerkt werden, dass bei der Abfackelung von Biogas, das nicht auf dem Betriebsgelände genutzt oder auf die Qualität von Erdgas aufbereitet werden kann, die Abgastemperatur mindestens 900 °C und die Verweilzeit mindestens 0,3s betragen sollte. Die maximal angestrebte Konzentration von Schwefelverbindungen in Biogas liegt bei 50 ppm oder einem Minderungsgrad von mindestens 98 % der Schwefelverbindungen aus dem Biogas.

Unter den Minderungstechniken, die in einem separaten Behandlungsschritt eingesetzt werden können, sind: Biologische Gaswäscheverfahren (biologische Oxidation des Sulfids zu Schwefel oder Schwefelsäure), Gaswäsche mit Wasser oder organischen Lösemitteln, Trockenfilter, die z.B aus Brauneisenerz bestehen und Adsorption, z.B. an Aktivkohle.

Anleitungen für Großfeuerungsanlagen, die Biogas nutzen, werden im BVT-Merkblatt „Großfeuerungsanlagen“ angeführt.

Erreichter Nutzen für die Umwelt

Parameter	Biogas	Abgas
AOX	<150	
CO		100 – 650[1]
Staub		<10 – 50
NO_x		100 – 500 [2]
H_2S		<5
HCl		<10 – 30
HF		<2 – 5
Kohlenwasserstoffe		<50 – 150
SO_2		<50 – 500

Daten in mg/Nm^3 bei 5 % O_2-Gehalt
[1] Bei der Verwendung von Fremdzündungsmotoren mit niedriger Wärmeleistung (z. B. <3 MW_{th}) kann die Erreichbarkeit des Werts von 650 schwierig sein. In diesen Fällen kann ein Wert von 1000 als leicht erreichbar angesehen werden.
[2] Bei der Verwendung von Maschinen mit Voreinspritzung mit niedriger Feuerungswärmeleistung (z.B. <3 MW) liegen die erreichten Werte bei 1000. Werte um 100 können nur mit Abluftreinigung erreicht werden.

Tabelle 4.16: Erzielte Emissionswerte bei der Verwendung guter Motoren und Minderungstechniken [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

Medienübergreifende Auswirkungen
Die Zugabe von Stoffen wie Eisensalzen oder Sauerstoff in den anaeroben Reaktor kann sich auf den Vergärungsprozess kontraproduktiv auswirken.

Betriebsdaten
Oxidationskatalysatoren (Technik a aus dem obigen Abschnitt „Beschreibung“) werden in der Regel als kurzzeitige Technik[15] für möglich auftretende Korrosionsprobleme verwendet.

Anwendbarkeit
Die Reinigung von Biogas (mit Ausnahme der Entwässerung und Entfernung von Feststoffen) vor der Erzeugung von Strom/Wärme in einem Gasmotor und die Reinigung des Abgases sind nach zahlreichen Informationen normalerweise nicht nötig, um viele der Werte aus Tabelle 4.16. einzuhalten. Diese Emissionswerte werden in der Regel allein durch Motoreneinstellungen erreicht. Die einzige herausgestellte Ausnahme ist die Co-Vergärung von Schweinemist. Das erzeugte Biogas muss in der Regel entschwefelt werden, insbesondere um eine Korrosion der Anlage zu verhindern, die das Biogas nutzt.

Wirtschaftlichkeit
Sekundärmaßnahmen zur Emissionsminderung bei der Nutzung von Biogas als Brennstoff. Sie werden für kleine Kraft/Wärme-Anlagen weder als wirtschaftlich tragbar noch unter Umweltgesichtspunkten als gerechtfertigt angesehen. Um dies zu berücksichtigen, haben zum Beispiel in Deutschland Anlagen mit weniger als 3 MW_{th} höhere Emissionsgrenzwerte.

Treibende Kraft für die Anwendung
Mindestens drei Mitgliedstaaten haben Rechtsvorschriften, die sich auf die Emissionen bei der Nutzung von Biogas als Brennstoff beziehen.

Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

[15] Anm.d.Übers.: Im Originaltext wird der Begriff „short term tool“ benutzt.

4.2.7 Steigerung der Energieeffizienz der Generatoren und Vergärungsverfahren

Beschreibung
Einige zu berücksichtigende Punkte sind:

a. Für eine gute Energieeffizienz ist ein Biogas mit einem Energiegehalt zwischen 20 und 25 MJ/Nm^3 vorzuziehen
b. Der Wirkungsgrad bei der Umwandlung in Elektrizität variiert je nach Verbrennungsanlage. Praktische Erfahrungen mit kleinen Verbrennungsmotoren mit einer bemessenen Nennleistung von weniger als 200 kW weisen auf einen elektrischen Wirkungsgrad von etwa 25 % hin, größere Anlagen (bis 17000 kW) können einen höheren Wirkungsgrad um 36 % haben. Wo die zusätzliche Möglichkeit besteht, mit dem Abgas des Motors Wasser zu beheizen, kann dies den Gesamtwirkungsgrad auf 65 – 85 % erhöhen.
c. Der Einbau von Biogasmotoren mit Wirkungsgraden über 30 % ist notwendig, um eine gute Gesamt-Energieeffizienz zu erreichen.

Erreichter Nutzen für die Umwelt
Steigert die Energieeffizienz von Vergärungsverfahren. Einige Daten zur Energieerzeugung zeigen die beiden folgenden Tabellen (Tabelle 4.16 und Tabelle 4.17). Die Spannbreiten in diesen Tabellen sind groß und spiegeln wahrscheinlich nicht nur die Unterschiede in der Leistung der Anlagen, sondern auch die Unterschiede bei den Einsatzstoffen wider.

	Nettoenergieerzeugung (kWh/Tonne Abfall)		
Quelle	**Minimum[1]**	**Durchschnitt [1]**	**Maximum[1]**
1		100	
2		102	
3		110	
4	80	110	140
5	75	113	150
6	100	115	130
7	105	131	157
8	120	145	170
9	100	150	200
10		154	
11	254	273	292
[1]Wenn nur eine Zahl zitiert wird, gab die verwendete Literatur keine Bandbreite an.			

Tabelle 4.17: Zahlen für die Nettoenergieerzeugung, die beim optimalem Betrieb von Vergärungsverfahren erzielt werden können
[152, TWG, 2004]

Parameter	Unterer Wert (kWh/t Abfall)	Oberer Wert (kWh/t Abfall)
Biogasausbeute	70 Nm^3/t Abfall	140 Nm^3/t Abfall
Prozent Methan	55 %	60 %
Heizwert des Biogases	385	840
Erzeugter Strom (30 % Wirkungsgrad)	116	252
Exportierter Strom (70 % des erzeugten Stroms)	81	176
Zurückgewonnene Wärme bei KWK (70 %)	189	412
Exportierte Wärme bei KWK (80 % der zurückgewonnenen Wärme)	151	329

Tabelle 4.18: Bei der Vergärung erzeugter Strom und erzeugte Wärme [59, Hogg, et al., 2002]

Beispielanlagen
Weltweit existieren zahlreiche Beispiele für Vergärungsanlagen.

Literatur
[152, TWG, 2004]

4.2.8 Techniken zur Optimierung der mechanisch-biologischen Behandlung

Beschreibung
Zu den Techniken gehören:

a. Einsatz von Filtern zur Minimierung von Staubemissionen
b. Emissionsminderung von Stickstoffverbindungen durch Optimierung des C:N-Verhältnisses und Einsatz einer sauren Gaswäsche
c. Vermeidung anaerober Bedingungen in Anlagen zur aeroben Behandlung (wenn ein Abfall unter Sauerstoffmangel leidet, liegt er normalerweise gesättigt vor) durch:
   - Zugabe von holzhaltigen Materialien (z.B. Holzschnitzeln) in ausreichender Menge zur Mischung sowie zur Offenhaltung der Struktur. Dies trägt auch dazu bei, die Auswirkungen von überschüssigem Stickstoff zu verringern
   - Meiden von Abfallstoffen, die sowohl einen hohen Wassergehalt als auch wenig Zwischenräume aufweisen, in denen das Wasser unter Schwerkrafteinwirkung ablaufen könnte
d. Kontrolle der Luftzufuhr unter Verwendung eines stabilen Luftkreislaufs. Eine gute Einstellung der Belüftung kann mit Hilfe einer Überwachung der CO_2-Konzentration pro Teilabschnitt oder mit Hilfe von Online-Messungen bestimmter Parameter (z.B. O_2, Temperatur, Feuchtigkeit, Methan, VOC, CO_2) in der Zu- und Abluft durchgeführt werden. Dies gewährleistet unabhängig von der Zusammensetzung des Abfalls eine ausreichende Luftzufuhr. Die Prozessluft wird aus den Hallen, dem Entlüftungssystem usw. erfasst.
e. Kreislaufführung von Luft, um die Konzentration von Kohlenstoffverbindungen in der Luft zu erhöhen. Dadurch wird eine thermische Nachverbrennung zu einer möglichen Alternative zu einem biologischen Filter. Unter diesen Bedingungen müssen z.B. nur 2500 – 8000 Nm³ Luft pro Tonne Abfall behandelt werden (Dies steht im Zusammenhang mit Abschnitt 4.2.11)
f. vollständige Auflistung von Anforderungen an das Einsatzmaterial
g. sorgfältige Platzierung der Mieten, um den erforderlichen Zugang zum Aufschichten und Umsetzen zu ermöglichen
h. effizienter Wasserausgleich zur Minimierung der Entstehung von Sickerwässern
i. Vorhalten einer undurchlässigen, harten Standoberfläche auf einer ausreichend großen Fläche, um Maschinenbewegungen zum Umsetzen der Mieten zu ermöglichen und um Platz für die Drainage zur Erfassung von Sickerwasser bereitzustellen
j. Einbau einer Drainageschicht mit hoher Durchlässigkeit, etwa aus Holzschnitzeln, in die Mietenkonstruktion, um eine Drainage des Sickerwassers und den Luftzufluss in die Miete zu ermöglichen
k. Vorrichtungen zur Sammlung von Sickerwasser mit Rezirkulationssystemen, um das Sickerwasser zurück in die Mieten zu leiten, um einen optimalen Feuchtegehalt aufrechtzuerhalten und die Sickerwasserbehandlung zu erleichtern
l. Behandlung des Kondensationswassers durch Puffer, Bioreaktoren und Ultrafiltration. Das gereinigte Abwasser (Permeat) kann danach als Prozesswasser im Kühlwasserkreislauf genutzt werden, welches im Kühlturm verdunstet
m. Nutzung des Filterkuchens, der an den Staubfiltern der Abluftreinigung entsteht, als fester Brennstoff
n. Wärmeisolierung des Hallendachs der Halle, in der aerobe biologische Abbauprozesse stattfinden, wodurch die Erzeugung von Kondensat minimiert wird
o. Recycling von Prozesswässern oder schlammigen Rückständen innerhalb des aeroben Behandlungsverfahrens, um Wasseremissionen vollständig zu vermeiden
p. Einbau und Betrieb von Förder- und Lagersystemen, als auch von betriebsinternen Behandlungsanlagen für Prozesswässer und Wasserkondensate, in einer Weise, dass sie nicht zu bedeutenden diffusen (flüchtigen) Emissionen führen
q. Vorbehandlung des Einsatzmaterials zur Optimierung der biologischen Behandlung. Dazu können mechanische Techniken gehören wie: Abtrennung von Substanzen, die ungeeignet sind für die biologische Behandlung, störende Substanzen und Schadstoffe, wie auch die Optimierung des biologischen Abbaus der verbleibenden Abfälle durch verbesserte Verfügbarkeit und Homogenität

r. Kontrolle der Luftemissionen für organische Verbindungen, Feststoffe, Gerüche, Ammoniak, Quecksilber, Distickstoffoxid (N_2O) und Dioxine. Einige Techniken hierfür werden im Abschnitt 4.6 erwähnt.

Erreichter Nutzen für die Umwelt
MBA sind sehr flexibel. Sie können auf modularer Basis gebaut werden. Einige der oben erwähnten Techniken tragen zur Vermeidung von Gerüchen, Stickstoff- und Methanemissionen bei.

Optimierte biologische Verfahren verknüpfen eine Reduzierung von Emissionen in Wasser und Luft, die während der Behandlung in der Anlage entstehen. Ein weiterer Vorteil für die Umwelt ist, dass Volumen, Wassergehalt und Gasbildungspotenzial des Abfalls durch die mechanisch-biologische Vorbehandlung deutlich reduziert werden und das Auslaug- und Ablagerungsverhalten auf Deponien deutlich verbessert wird. Ein weiterer Vorteil ist, dass ein Abfallstrom mit hohem Heizwert abgetrennt wird, der zur energetischen Verwertung verbrannt werden kann.

Mechanische und physikalische Behandlungsmethoden, die als Vorbehandlung zur Optimierung der Bedingungen der anschließenden biologischen Behandlung verwendet werden (z.B. Mischen, Homogenisieren, Befeuchten), werden so eingestellt, dass eine erhöhte Abtrennung von wertvollen Materialien (z.B. eisenhaltigen Materialien), Hemmstoffen oder Stoffen für die eine biologische Behandlung nicht geeignet ist, erreicht wird. Manchmal betrifft die erhöhte Abtrennung mehr als eine Art der oben erwähnten Materialien.

Im Zusammenhang mit Technik c (siehe obigen Abschnitt „Beschreibung“) kann allerdings in gut regulierten aeroben Behandlungsverfahren das Erreichen von anaeroben Bedingungen in kontrolliertem Umfang von Interesse sein, um Methan zu erzeugen. Dieses kann als energetischer Input für die thermisch-regenerative Abgasbehandlung verwendet werden, wenn ferner die Qualität des Abfall-OUT immer noch den Anforderungen entspricht, die Abgasbehandlung optimiert ist und die Sicherheitsvorkehrungen (Explosions- und Arbeitsschutz) ausreichend sind.

Medienübergreifende Auswirkungen
VOC-Emissionen aus MBAs können nicht vermieden werden, weil VOCs bereits im Abfall-IN enthalten sind und VOCs im biologischen Verfahren erzeugt werden. Deshalb werden Anforderungen wie die Einhausung/-vollständig gekapselte Bioreaktoren, Erfassung und effektive Behandlung der Abluft (Emissionsgrenzwerte) zur Reduzierung solcher Emissionen eingesetzt. Aerobe Verfahren (MBA) sind zur Behandlung VOC-haltiger Abfälle geeignet. Zusätzlich können anaerobe Verfahren in einer guten Vorbehandlung der Abfälle resultieren, die aber immer noch ein hohes Emissionspotenzial besitzen (Ammoniak und andere bei der anaeroben Behandlung entstehende Verbindungen) und eine hohe biologische Reaktivität (unter späteren aeroben Bedingungen) aufweisen. Deshalb wird in der Regel eine Kombination von anaeroben (Vorbehandlung) und aeroben Behandlungsschritten gefordert.

In Bezug auf Technik c der obigen Beschreibung über die Zugabe ausreichender holzhaltiger Materialien, wird in MBA generell genug Strukturmaterial über den Einsatzstoff (Siedlungsabfall) geliefert. Der Input von holzhaltigen Materialien kann Probleme bei der Einhaltung der Kriterien für die Deponierung verursachen (z.B. TOC).

Im Zusammenhang mit Technik e aus der obigen Beschreibung, kann die Abluftbehandlung Probleme verursachen wenn die rezirkulierte Luft einen hohen Feuchtegehalt besitzt. In einem solchen Fall ist es nötig, den Wasserdampf zu kondensieren und anschließend das Kondenswasser zu behandeln, eine Kühlung ist erforderlich, um den Wasserdampf zu kondensieren.

Im Zusammenhang mit Technik o aus der obigen Beschreibung, muss bei der aeroben Behandlung berücksichtigt werden, dass eine Aufkonzentrierung recycelter Stoffe zu unerwünschten Effekten führen kann (Versalzung --> Hemmeffekte, Recycling von N-Verbindungen --> höhere Luftemissionen von N-Verbindungen (z.B. Ammoniak, Lachgas)).

Betriebsdaten
Aerobe biologische Verfahren sind grundsätzlich robuster als anaerobe Verfahren und sie sind weniger sensibel gegenüber Chlor- und Schwefelverbindungen, pH-Wert und Temperaturschwankungen und erfordern keine Voransäuerungsstufe.

Eine gute Betriebspraxis entscheidet, ob die Anlage aerob bleibt oder nicht. Es liegt im Interesse des Betreibers, aerobe Bedingungen aufrechtzuerhalten, um Geruchsprobleme zu vermeiden und aerobe Abbauprozesse zu beschleunigen. Anaerobe Bedingungen können zu gelegentlichen Problemen, d.h. zu nicht regelmäßigen Vorfällen führen, die im Betriebstagebuch aufgezeichnet werden müssen.

Wenn die relative Feuchte der Abluft hoch ist (über 90 %), sind die Feststoffemissionen niedrig.

Anwendbarkeit
MBA sind weit verbreitet für die Behandlung von Siedlungsabfall, Schlämmen und anderen Abfallarten. Aerobe Verfahren können ungeeignet sein für die Behandlung von Abfällen die VOC-haltig sind, welches in die Luft emittieren könnte. Aerobe Verfahren sind weniger wirksam beim Aufbrechen von Ringverbindungen (zum Beispiel von Phenolen) als anaerobe Verfahren.

Treibende Kraft für die Anwendung
Die Annahmekriterien der Deponierichtlinie für biologisch abbaubaren Abfall. Diese Kriterien haben zum Ziel, den biologisch abbaubaren Anteil des Abfalls so zu senken, dass eine signifikante Reduktion der Gas- und Sickerwasseremissionen von Deponien erreicht wird.

Beispielanlagen
In der ganzen EU weit verbreitet. Aerobe Verfahren werden verwendet, um den fäulnisfähigen Anteil und den Feuchtegehalt im Gesamtabfall vor der Deponierung zu reduzieren oder zur anschließenden Herstellung von Brennstoff aus Abfällen. Dies ist der EU gängige Praxis vor der Deponierung.

Literatur
[152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004], [152, TWG, 2004]

4.2.9 Aerober Abbau von Schlämmen

Beschreibung
Biologische Behandlung von Schlämmen

Erreichter Nutzen für die Umwelt
Ein Beispielverfahren ist ein zweistufiger Batchprozess, der zur Behandlung von teerhaltigen Abfällen eingesetzt wird. Dies beinhaltet die Auflösung der teerhaltigen Abfälle mit oberflächenaktiven Substanzen in einem Behälter für sieben Tage bei 20 % Feststoffgehalt und die anschließende Umfüllung des Überstands in einen Nachreinigungsreaktor für 14 Tage als zusätzliche biologische Behandlung. Dies führt zu PAK-Reduktionen wie in Tabelle 4.19 unten gezeigt:

Bestandteil	Anfangskonzentration (ppm)	Endkonzentration (ppm)
Phenanthren	13000	<100
Fluoren	7000	<100
Fluoranthren	8000	<500
Pyren	6000	<500
Benzo(a)pyren	9000	<100
Benzo(b)fluoranthren	13000	<500
Benzo(a)anthraren	11000	<100

Tabelle 4.19: Berichtete Reduktion von polyzyklischen Aromaten [53, LaGrega, et al., 1994]

Medienübergreifende Auswirkungen
Durch Rühren wird der Schlamm nicht nur homogenisiert, sondern es wird auch die Verflüchtigung von Schadstoffen gefördert.

Anwendbarkeit
Abfälle können Schlämme oder Feststoffe sein. Das Verfahren wird angewandt bei der Behandlung von holzschutzmittelhaltigen Abfällen, teerhaltigen Abfällen, Schlamm aus der Erdölraffination und bei kontaminierten Böden.

Literatur
[53, LaGrega, et al., 1994]

4.2.10 Belüftungskontrolle beim biologischen Abbau

Beschreibung
Zu den Techniken gehören:

a. Anwendung einer Druckbelüftung beim Betrieb
   - Dies hat folgende Vorteile:
     - geringeres Risiko der Befeuchtung und Verdichtung des Belüftungsbodens
     - gleichgerichtete Luftströme und natürliche Wärmeemission
     - geringe Anforderungen an den Bau des Belüftungsbodens
   - Allerdings gibt es auch Nachteile:
     - Mischung von Mietenluft und Hallenluft
     - Eindringen von wasserdampfgesättigter Luft in die Halle
     - eingeschränkte Zugänglichkeit der Halle
     - starke Korrosion der Bauelemente und Maschinen verbunden mit erhöhter Abnutzung und erhöhten Wartungskosten
     - es ist nicht möglich, die Prozessparameter der Abluft zu bestimmen
     - der biologische Abbau kann nur mittels indirekter Messungen und durch Erfahrungen überwacht werden
     - getrennte Behandlung und Reinigung von Mietenluft und Hallenabluft ist nicht möglich
b. Anwendung einer Saugbelüftung (Unterdruck) im Betrieb
   - Der Betrieb einer Saugbelüftung hat im Gegensatz zur Druckbelüftung folgende Vorteile:
     - nur geringfügige Verunreinigung der Hallenluft mit Mietenluft
     - geringe Korrosion der Bauelemente und Maschinen
     - die Halle ist während der Mietenbelüftung zugänglich
     - Möglichkeit der Bestimmung der Prozessparameter in der Mietenabluft
     - Möglichkeit der getrennten Erfassung und Behandlung der Mietenluft
   - Die Nachteile des Betriebs einer Saugbelüftung sind:
     - höhere Anforderungen an den Bau des Belüftungsbodens
     - Gefahr der Vernässung von Zwischenräumen und diffusen Luftschichten
c. Vorhandensein eines Belüftungsbodens mit geschlitzten Platten und einer Unterkellerung, um bei der vollständigen Umsetzung der Miete eine gleichmäßige Belüftung sicherzustellen
d. Anpassung der Belüftung an die biologische Abbauaktivität des Materials durch Unterteilung des Bereiches, in dem biologisch abgebaut wird, in getrennt kontrollierbare Belüftungsfelder. Auch durch die Regulierung der Luftmenge pro Belüftungsfeld in Abhängigkeit von Temperatur und Sauerstoffgehalt, durch frequenzgesteuerte Ventilatoren oder alternierenden zyklischen Betrieb
e. Sicherstellung eines gleichmäßigen Durchflusses durch das biologisch abzubauende Material mittels eines Bodenröhrensystems, bei Nutzung eingebetteter gelochter Röhren und eines relativ hohen Drucks
f. Nutzung von Wärmetauschern, um Abgastemperatur und –feuchte zu senken, zwecks Sicherstellung der Wärmeabgabe im zirkulierenden Luftsystem.

Erreichter Nutzen für die Umwelt
Die Ziele der Belüftung sind:

- Sicherstellung eines ausreichenden Sauerstoffgehalts in der Miete
- Vermeidung der Methanbildung in anaeroben Zonen
- Austrag des sich bildenden Methans
- Ableitung der freigesetzten Reaktionswärme
- Zulassung einer biogenen Trocknung (in MBA mit Trockenstabilisation).

Medienübergreifende Auswirkungen
Die oben genannten Ziele müssen mit dem konkurrierenden Ziel der Minimierung der Luftmenge und der Verdunstungsverluste ausbalanciert werden.

Betriebsdaten
In statischen biologischen Verfahren wird die Miete nicht umgesetzt. Grundsätzlich gilt die Regel, je kürzer die Umsetzintervalle sind (mit gleichzeitiger Bewässerung), umso größer ist die Gefahr des Austrocknens der Miete. Eine Bewässerung der Miete ohne sie umzusetzen befeuchtet oft nur die Oberflächenschichten.

Anwendbarkeit
In gekapselten Verfahren wie etwa Tunnel, Boxen oder Containern, findet die Belüftung des biologisch abzubauenden Produkts unter Druck und bei zirkulierender Luft statt. In eingehausten Hallensystemen werden sowohl Druck- als auch Saugbelüftungen genutzt.

Wirtschaftlichkeit
Die Investitionskosten für den Bau eines Belüftungsbodens mit geschlitzten Platten liegen 40 bis 50 % höher als bei den anderen verfügbarer Verfahren (z. B. Belüftungsröhren oder –kanäle im Hallenboden).

Literatur
[132, UBA, 2003]

4.2.11 Abgasmanagement in MBA

Beschreibung
Ein gutes Abgas-/Abluftmanagementsystem erfordert die folgenden Elemente:

a. getrennte Erfassung von Abgas-Teilströmen
b. Abgasminimierung durch Mehrfach-/Kaskadennutzung, Kreislaufführung
c. Abgasminimierung durch anaeroben Abbau organischer Stoffe (Vergärung mit Biogasnutzung statt aerobem Abbau)
d. Behandlung von Teilströmen durch Kombination von biologischen, chemischen, physikalischen und thermischen Behandlungskomponenten
e. Reduzierung der spezifischen Abluftemissionen auf 2500 bis 8000 Nm^3 pro Tonne Abfall durch Installierung einer Kreislaufführung über Wärmetauscher und durch Ableitung überschüssiger Wärme als Voraussetzung einer effektiven Kreislaufführung
f. Wiederverwendung der Abluft soweit wie möglich. Die verbleibende Luft muss behandelt werden, bevor sie in die Außenluft abgeleitet wird
g. Behandlung der Abluft aus dem Anlieferungsbereich, wie etwa aus Flach- und Tiefbunkern mit oder ohne mechanische Behandlung der angelieferten Abfälle oder Rückfluss des Gases als Luftzufuhr (Prozessluft) für den biologischen Abbau
h. Errichten der Entladestellen, Aufgabebunker, Annahmebunker und sonstigen Einrichtungen zur Anlieferung, zum Transport und zur Lagerung der Input-Stoffe in geschlossenen Räumen mit Schleusen oder gleichwertigen Einrichtungen. Das Ziel dieser Maßnahme ist die Minimierung diffuser Emissionen. Bei Schleusen wird dies durch eine Saugbelüftung im Bereich der Luftwände erreicht, so dass der Umgebungsdruck unterhalb des Atmosphärendrucks gehalten wird
i. für Maschinen, Apparate und sonstige Geräte, die zur mechanischen Behandlung oder physikalischen Trennung des Abfalls genutzt werden, z.B. durch Brechen, Klassieren, Sortieren, Mischen, Homogenisieren, Entwässern, Trocknen, Pelletieren oder Pressen, muss das Managementsystem sicherstellen, dass potenzielle diffuse Emissionen durch Kapselung oder Saugbelüftung (Schwerpunkt auf Saugbelüftung) der einzelnen Aggregate minimiert werden
j. Nutzung geschlossener Behälter zur Beseitigung Staub emittierender Güter
k. Verwendung gekapselter oder eingehauster Anlagen bei der Beförderung und Behandlung der Gärrückstände. Die Abluft von diesen Anlagen muss erfasst werden (Hallen- und Quellenabsaugung), vorzugsweise so, dass sie behandelt oder im Verfahren wieder verwendet werden kann

l. Aufteilung des behandlungsbedürftigen Gesamtvolumenstroms in stark verschmutztes und leicht verschmutztes Abgas. Folglich ist die Wahl eines geeigneten Verfahrens zur Behandlung leicht verschmutzter, aber zu Gerüchen neigender Abluft eine Schlüsselfrage in MBAs mit langzeitigem biologischem Abbau. Allerdings wird das Verfahren zur Vervollständigung durch weitere Komponenten ergänzt, wie etwa eine saure Gaswäsche (Absorption von Ammoniak), einen Staubfilter und eine Oxidationsanlage zur Behandlung von stärker verschmutzten Strömen, hauptsächlich aus der Vorstufe zum biologischen Abbau. Die Art der Oxidationsanlage (thermisch, chemisch, physikalisch) und die zu behandelnden Abgasmengen aus der Vorstufe zum biologischen Abbau müssen an das gewählte Verfahrenskonzept angepasst werden und in jedem Einzelfall festgelegt werden
m. Online-Überwachung der Abgasemissionen und Nutzung der Daten zur Regelung der biologischen Verfahren
n. Nutzung von Absorptions-/Desorptions- und Verbrennungsverfahren im Fall niedriger Konzentrationen von Kohlenstoffverbindungen.

Erreichter Nutzen für die Umwelt
Reduziert die eingesetzte Luftmenge und die Abluftemissionen.

Betriebsdaten
Das Abgasmanagement betrifft beidseitig sowohl den Bau als auch die Verfahrenstechnik der Anlage. Die folgenden Faktoren spielen Schlüsselrollen in jeder Abgasmanagement-Strategie:

- Minimierung des Hallenvolumens
- Aufteilung der Betriebseinheiten
- Messungen nahe an der Quelle zur aktiven und passiven Minimierung der Emissionen.

Anwendbarkeit
Mechanisch-biologische Behandlung (MBA)

Literatur
[132, UBA, 2003], [150, TWG, 2004]

4.2.12 Abgasreinigungstechniken für biologische Behandlungsanlagen

Tabelle 4.20 zeigt Abgasreinigungstechniken, von denen berichtet wird, dass sie in biologischen Behandlungsanlagen angewendet werden. Sie sind detailliert im Abschnitt 4.6 beschrieben.

Technik	Nummer des Abschnitts, in dem sie enthalten ist
Allgemeine Vermeidung	Abschnitt 4.6.2
Adsorption	Abschnitt 4.6.7
Biofilter	Abschnitt 4.6.10
Chemische Gaswäsche	Abschnitt 4.6.12
Schwach- oxidative Verfahren	Abschnitt 4.6.13
Verbrennung	Abschnitt 4.6.14
Katalytische Verbrennung	Abschnitt 4.6.16
Regenerative thermische Oxidation	Abschnitt 4.6.18
Nicht thermische Plasmabehandlung	Abschnitt 4.6.20

Tabelle 4.20: In biologischen Behandlungsanlagen eingesetzte Abgasreinigungstechniken

4.3 Chemisch-physikalische Behandlungstechniken

Dieser Abschnitt beinhaltet Techniken, die aus Umweltgesichtspunkten ein günstiges Betriebsverhalten besitzen (z.B. Verwendung eines guten Energiesystems) oder die zu einem günstigen Umweltverhalten führen können (z.B. Umweltmanagementsysteme). Techniken in diesem Abschnitt beziehen sich auf in Abschnitt 2.3. beschriebene chemisch-physikalische Behandlungsverfahren.

4.3.1 Techniken, die in Anlagen zur chemisch-physikalischen Behandlung von Abwässern angewandt werden

4.3.1.1 Planung des Betriebs einer CP-Anlage

Beschreibung
Folgend Prinzipien sind zu berücksichtigen:

a. alle Mess- und Überwachungseinrichtungen müssen leicht zugänglich und leicht zu warten sein
b. ein Kontroll- und Überprüfungssystem muss eingerichtet werden.
c. die Überprüfung bei der Annahme muss an Informationen aus der Deklarationsanalyse des überprüften Abfalls zur Beseitigung und an die für jede einzelne Behandlung vorgesehene Verfahrensanordnung angepasst sein.
d. die Erzeugung von Abwasser sollte so weit wie möglich durch bauliche Maßnahmen, z.B. durch Überdachung des Annahmebereichs, vermieden werden
e. um unerwünschte Vermischungen zu vermeiden, sollten die Reaktionsbehälter auch als Lagerbehälter dienen
f. eine angemessene Lagerkapazität ist vorzuhalten, da üblicherweise die Zeiten der Nachfrage und Anlieferung nicht zusammenfallen
g. das Anlagenkonzept sollte mögliche Modifizierungen oder Erweiterungen berücksichtigen
h. Sammlung, Transport und Anlieferung von Abfällen sollten (bezüglich Menge und Zeit) dem Betrieb angepasst werden
i. Erzeuger und Anlieferer sollten alle technischen Details und Informationen übermittelt werden (z.B. über Behälter, Leitungen, Pumpen, Ventile und Filter)
j. Planung und Bau (insbesondere rechtliche Gesichtspunkte) sollten frühzeitig mit den zuständigen Behörden und mit technischen Planungsbüros erörtert werden.

Erreichter Nutzen für die Umwelt
Emissionen werden reduziert, wenn richtige Behandlungsverfahren in CP-Anlagen eingerichtet sind.

Betriebsdaten
Die Auslegung einer CP-Anlage wird über einen klaren Weg bestimmt, welcher dem Materialstrom folgt. Z.B. müssen zwei grundsätzlich verschiedene Fälle unterschieden werden:

1. Dimensionierung einer Anlage, die ähnliche Abfallarten behandelt
2. Dimensionierung einer Anlage, die verschiedene Abfallarten behandelt.

Im Fall (1) kann die Anlage an Hand von Experimenten entwickelt werden, die genau auf die Anforderungen des Abfalls zugeschnitten sind. Die notwendigen Verfahrensschritte können einzeln oder in Kombination getestet werden; das Ergebnis ist eine optimale Behandlungslösung. Im Fall (2) müssen verschiedene Behandlungsverfahren geplant werden, die bei kombinierter Anwendung zu einer optimalen Behandlung führen. Zusätzlich gilt, dass im Fall (1) kontinuierlich betriebene Anlagen geeignet erscheinen, im Fall (2) dagegen wegen der Anpassung von Technologie und Betriebsweise an das unterschiedliche Reaktionsverhalten der Abfälle ein diskontinuierlicher Betrieb empfohlen werden sollte.

Anwendbarkeit
Anwendbar auf neue Anlagen.

Literatur
[157, UBA, 2004]

4.3.1.2 Techniken für CP-Reaktoren

Beschreibung

Einige Techniken beinhalten:

a. klare Definition der Zielsetzung und der erwarteten chemischen Reaktionen für jeden Behandlungsprozess. Es ist notwendig einen definierten Endpunkt des Prozesses zu haben, so dass die Reaktion überwacht und kontrolliert werden kann. Geeignete Inputs müssen für den Prozess festgelegt werden und bei der Auslegung müssen wahrscheinliche Variablen, die im Abfallstrom erwartet werden können, berücksichtigt werden

b. Bewerten jeder neuen Reihe an Reaktionen und beabsichtigten Mischungen von Abfällen und Reagenzien vor der Behandlung, dies erfolgt durch Testmischungen im Labormaßstab der Abfälle und Reagenzien die genutzt werden sollen. Dies muss zu allen Reaktionen führen, die bei der Behandlung im Originalmaßstab auftauchen können, wonach dann die Mischung der Abfälle anhand eines vorher zu bestimmenden Chargen-„Rezepts“ durchgeführt werden muss. Dabei müssen potenzielle Effekte der Maßstabsvergrößerung berücksichtigt werden, zum Beispiel die erhöhte Reaktionswärme bei erhöhter Reaktionsmasse im Verhältnis zum Reaktorvolumen, die erhöhte Verweilzeit im Reaktor, die veränderten Reaktionseigenschaften usw.

c. spezifische Auslegung und Betrieb des Reaktionsbehälters, so dass er für den beabsichtigten Zweck geeignet ist. Solche Auslegungen schließen die Betrachtung der Gefahren des chemischen Prozesses, eine Gefahrenbewertung der chemischen Reaktionen, die Betrachtung der geeigneten Vorsorge- und Schutzmaßnahmen und die Betrachtung des geplanten Verfahrensmanagements mit ein, ebenso wie Arbeitsanweisungen, Personalschulung, Anlagenwartung, Überprüfungen, Audits und Verfahrensweisen für den Notfall

d. Einhausung aller Behandlungs-/Reaktionsbehälter und Sicherstellung, dass sie über ein geeignetes Abgaswäsche- und Minderungssystem entlüftet werden

e. wo angemessen, die Sicherstellung, dass Reaktionsbehälter (oder Mischbehälter, in denen die Behandlung durchgeführt wird) mit vorgemischten Abfällen und Reagenzien befüllt werden. Zum Beispiel müssen manche Reaktionsbehälter “vorgekalkt” werden oder zuerst mit der reagierenden Base befüllt werden, um die Reaktion zu kontrollieren. Hierbei kann zum Beispiel Calciumhydroxidlösung verwendet werden, die vor der Beladung des Reaktionsbehälters hergestellt wurde

f. Vermeidung des direkten Ümfüllens von Säcken oder Fässern in den Behälter. Diese Praxis kann zu folgenden führen:
   - Konzentrations-“Hotspots” an der Oberfläche der Reaktionsflüssigkeit
   - Verlust der Reaktionskontrolle
   - Emissionen von Dämpfen aus der sofortigen Reaktion an der Grenzfläche
   - Entweichen von Dämpfen aus offenen Luken, die folglich keiner Abgasreinigung unterzogen werden

g. Überwachen der Reaktion, um sicherzustellen, dass sie unter Kontrolle ist und in Richtung des erwarteten Resultats fortschreitet. Zu diesem Zweck müssen die bei der Behandlung benutzten Behälter mit einer Füllstands-, pH-Wert- und Temperatur-Überwachung ausgestattet sein. Diese müssen automatisch und kontinuierlich arbeiten und mit einem gut sichtbaren Display im Kontrollraum oder Labor sowie mit einem hörbaren Alarm verbunden sein. Die Risikobewertung kann eine Prozessüberwachung erfordern, die mit direkten Abschaltevorrichtungen verbunden ist. Die Überwachung der Reaktion ist notwendig, weil sich die Reaktionseigenschaften im Reaktor von denjenigen, die in den Labortests ermittelt wurden, unterscheiden können. Die Überwachung muss jegliche Abweichungen von den Labortests frühzeitig anzeigen und Möglichkeiten für Maßnahmen um die Reaktion anzuhalten oder zu modifizieren ermöglichen. Folglich sollte eine Vorrichtung zur Kühlung und/oder zum Abschrecken der Reaktionsbehälter vorhanden sein

h. Sicherstellen einer angemessenen Durchmischung im Behandlungsbehälter, denn diese kann über eine erfolgreiche Behandlung im Reaktor entscheiden. Die Standardmethode zum Rühren der Inhaltsstoffe im Behälter ist die Nutzung eines Rührers. Es besteht ein geometrisches Verhältnis zwischen der Größe des Rührers und dem Abstand vom Kessel (bestimmt je nach Art und Größe des Behälters). Dies hängt auch von der Rührgeschwindigkeit und den Abfalleigenschaften ab. Zur Verhinderung von flüchtigen Emissionen ist eine Abdichtung an der Stelle erforderlich, an der der Rührer in den Behälter eingeführt wird. Eine Mischmethode sollte vorgeschrieben werden

i. zwecks Verfolgung und Kontrolle der Änderungen des Prozesses sollte eine Dokumentation hinsichtlich der Vorschläge, Abwägungen und Genehmigungen aller Veränderungen oder technischen Entwicklungen, einschließlich aller Verfahrens- und Qualitätsänderungen, schriftlich niedergelegt werden

j. Sicherstellen, dass alle VOCs, die auf Grund starker Temperaturanstiege in den Reaktionsbehältern emittiert werden, nach Kondensation in den Gaswäschern in das Behandlungsverfahren zurückgeführt werden

k. Überwachen der Reaktion über den gesamten Reaktionsverlauf. Es kann notwendig sein, die Abluft des Reaktors abzuziehen

l. ein Verfahren, wie an den meisten Standorten vorhanden, in dem die Luft oberhalb der Reaktionsbehälter ausgetauscht wird, um sie durch eine Behandlungsanlage zu leiten, um Gase wie Ammoniak, Chlorwasserstoff und Schwefeldioxid zu entfernen. In der Regel werden wässrige Flüssigkeiten aus Gaswäschern in die Behandlungsanlage zurückgeführt, und Aktivkohlesysteme werden regeneriert (z.B. durch Strippen mit Dampf), oder, wenn dies nicht möglich ist, wird die Aktivkohle verbrannt.

Erreichter Nutzen für die Umwelt
Die Kontrolle der Reaktion/Behandlung ist entscheidend für den Umweltschutz und für die Vermeidung möglicher Unfälle. Eine Ausbeute von 96 % bei der Entfernung von Metallen kann erreicht werden.

Anwendbarkeit
Chemisch-physikalische Anlagen überprüfen eingehende Abfälle, um sie in richtige Tanks zu lagern und um Reaktionen abwägen zu können.

Treibende Kraft für die Anwendung
Einige nationale Abwasserstandards liegen vor, z.B. der Surface Waters Pollution Act der Niederlande.

Beispielanlagen
Im Allgemeinen sind Behälter in denen Neutralisationsreaktionen durchgeführt werden, mit alkalischen Gaswäschern ausgestattet. Die meisten sauren Gase werden zusammen mit einigen VOCs und fast den gesamten Feststoffen/Flüssigkeiten in das Verfahren zurückgeführt. Die Kapazitäten der Beispielanlagen liegen zwischen 200 und 40 000 m^3/a.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [156, VROM, 2004]

4.3.1.3 Neutralisation

Beschreibung
Ziel und Prinzip des Betriebs der Neutralisation werden in Abschnitt 2.3.2 gezeigt. Zu den zu berücksichtigenden Punkten gehören:

a. Vermeidung der Mischung von saurem/basischem Abfall mit anderen zu neutralisierenden Strömen, wenn die Mischung gleichzeitig Metalle und Komplexbildner enthält. Das vermeidet die Bildung von Metallkomplexen, welche (aus ökonomischer Sicht) später schwierig abzutrennen sind. Komplexbildende Ionen, auf die hinsichtlich der Einbeziehung zu achten sind, sind zum Beispiel EDTA, NTA und Cyanide
b. Anfertigung der notwendigen Neutralisationgerätschaften in robuster und leicht bedienbarer Weise, was dazu beiträgt, dass die Gerätschaften den Nutzungskräften standhalten, die beim Einsatz in C-P-Anlagen zur Neutralisation von sauren/basischen Abfällen auftreten
c. Sicherstellen, dass die üblichen Messmethoden, z.B. mit Hilfe von Glaselektroden oder ähnlichen Sensoren, beim Betrieb der Neutralisationsanlage zum Einsatz kommen und dass die Elektroden kontinuierlich gereinigt und genau kalibriert werden. Eine Bestimmung des pH-Werts ist auch in Form einer Messung von aufbereiteten Proben oder durch eine Messung mit Lackmuspapier möglich
d. getrennte Lagerung der neutralisierten Abwässer, um negative Effekte auf die Qualität des behandelten Abwassers infolge von Sekundärreaktionen zu vermeiden, die bei gemeinsamer Lagerung auftreten können. Nach ausreichender Lagerzeit muss das behandelte Abwasser einer Endkontrolle unterzogen werden.

Erreichter Nutzen für die Umwelt
Verbessert die Leistung des Neutralisationsverfahrens und verhindert nachfolgende Probleme (z.B. Verminderung einer Vermischung von Abfällen oder anderen Strömen, die dazu führen, dass eine weitere Behandlung des Abwassers nicht mehr möglich ist).

Betriebsdaten
Wenn Schwefelsäure (H_2SO_4) und Kalkmilch ($Ca(OH)_2$) zusammengeführt werden, kann Gips ($CaSO_4 \cdot 2H_2O$) als Reaktionsprodukt entstehen. Gips kann zu Ablagerungen und Verkrustungen führen, die ernsthafte Unterbrechungen des Betriebs verursachen und umfassende Wartungs- und Reparaturmaßnahmen erfordern. Allerdings können diese Probleme durch eine angemessene Steuerung des Neutralisationsverfahrens (unter Nutzung verdünnter H_2SO_4 und einer Vor-Neutralisation mit Kalk) sowie durch kräftiges Mischen minimiert werden. Wenn NaOH statt Kalk zur Neutralisation verwendet wird, können andere Probleme auftreten. Erfahrungsgemäß können hohe Sulfatkonzentrationen im Abwasser, verursacht durch Neutralisation mit NaOH, Abwasserkanäle aus Beton angreifen und somit zu Geruchsemissionen führen.

Anwendbarkeit
Die Neutralisation ist für alle mischbaren flüssigen Abfälle anwendbar.

Beispielanlagen
In einem verdünnten wässrigen System sollte es möglich sein, Neutralisationsprozesse, ohne eine willentliche oder unbeabsichtigte Produktion von Gasen, durchzuführen. In solchen Systemen können Prozesse mit potenziellen Gefahrstoffen, wie etwa die Neutralisation von Säuren, normalerweise so durchgeführt werden, dass keine Stoffe entstehen die eine kontinuierliche Abluftreinigung erforderlich machen, zum Beispiel SO_X usw.

Literatur
[55, UK EA, 2001], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.4 Fällung von Metallen

Beschreibung
Ziel dieser Techniken ist die Fällung von Metallen, die in flüssigen Abfällen enthalten sind. Zu den Techniken gehören:

a. Ansäuern des Abfalls, im ersten Schritt damit alle Metalle in Lösung gehen
b. Einstellen des pH-Werts auf den Punkt minimaler Löslichkeit, an dem die Metalle ausfallen
c. Berücksichtigung, falls möglich, dass der entstandene behandelte Abfall mittels Dekantierung geklärt werden kann (z.B. sind hohe Metallkonzentrationen im Wasser sehr schwer durch Dekantierung zu klären), und/oder durch zusätzliche Entwässerungsvorrichtungen (z.B. Filterpresse oder Zentrifuge)
d. Vermeiden des Inputs von Komplexbildnern Chromate und Cyanide (auf Grund der Gefahr der HCN-Bildung durch säurebildende Abfallstoffe)
e. Ändern der Fällungsbedingungen, zum Beispiel, wenn die beabsichtigte Metallkonzentration im behandelten Abwasser nicht durch Hydroxidfällung erreicht werden kann (z.B. wegen der Anwesenheit von Komplexbildnern). Dann kann eine Sulfidfällung zum Einsatz kommen (z.B. mit Natriumsulfid oder organischen Sulfiden). Diese zielt auf die Bildung von Metallsulfiden ab, die in Wasser schwer löslich sind. Schwefelwasserstoff wird eingesetzt, weshalb die Betriebsbedingungen und Emissionen besonderer Berücksichtigung bedürfen. In der Praxis wird die Sulfidfällung bei der Behandlung von Abwasser, das Komplexbildner enthält, eingesetzt
f. Verhindern, dass organische Materialien in das Verfahren gelangen, da sie grundsätzlich Fällungsreaktionen stören
g. Organisation des Prozesses nach folgenden Schritten:
   - experimentelle Untersuchungen durch das Labor, Festlegung eines Behandlungsprogramms
   - Festlegung von Werten für die Prozesskontrolle, z.B. pH-Wert, Temperatur, Metallkonzentration
   - Festlegung der Art, Menge und Konzentration von Hilfsstoffen
   - Festlegung der Dosierung der Hilfsstoffe, z.B. in l/h
   - Festlegung der Reihenfolge der Zugabe der Hilfsstoffe
   - Funktionsüberprüfung der Geräte
   - Durchführung der Fällung/Flockung; Dokumentation der Verfahrenskontrolle.

Erreichter Nutzen für die Umwelt
Stoffe wie Chrom, Zink, Nickel, Blei liegen normalerweise gelöst oder absorbiert in Feststoffen oder Kolloiden vor. Es handelt sich um eine relativ einfache und robuste Technologie, die Leistungen von bis zu 95 % aufweisen.

Medienübergreifende Auswirkungen
Chrom (III), Zink und Cadmium sind amphoter und die Löslichkeit steigt bei einem pH-Wert oberhalb ihres minimalen Löslichkeitspunkts. Die Entstehung von metallhaltigem Schlamm kann als medienübergreifende Auswirkung betrachtet werden. Das Aufkommen an Filterkuchen kann durch Einsatz von Natriumhydroxid anstelle von Kalk reduziert werden, allerdings werden in diesem Fall Fluoride nicht gefällt.

Die Verwendung der Sulfidtechnik e (aus obiger Beschreibung) führt in der Regel zu einer hohen Sulfidkonzentration im Abwasser. Alternativen dazu sind eine nasse Oxidation oder eine Getrennthaltung an der Quelle.

Betriebsdaten
Ähnlich wie bei der Neutralisation von Säuren/Basen beinhaltet der Prozess die Zugabe von Säure oder Base (was ein Abfall sein kann) in einen gerührten Reaktionsbehälter. In der Regel wird Kalk als Hydroxid verwendet.

In Bezug auf Technik b der obigen Beschreibung wird in Tabelle 3.48 (in Kapitel 3) der Bereich der pH-Werte für die Fällung verschiedener Metalle als Hydroxide gezeigt. Der pH-Wert für die minimale Löslichkeit hängt vom Metall ab, und im Fall einer Mischung von Metallen muss ein optimaler Wert gefunden werden. Bei solch einen pH-Wert Optimum ist es möglich, dass manche Metalle gar nicht ausfällen. Das ist der Grund weshalb in manchen Fällen mehrere pH-Wert-Schritte durchgeführt werden, um die Entfernung der Metalle zu maximieren.

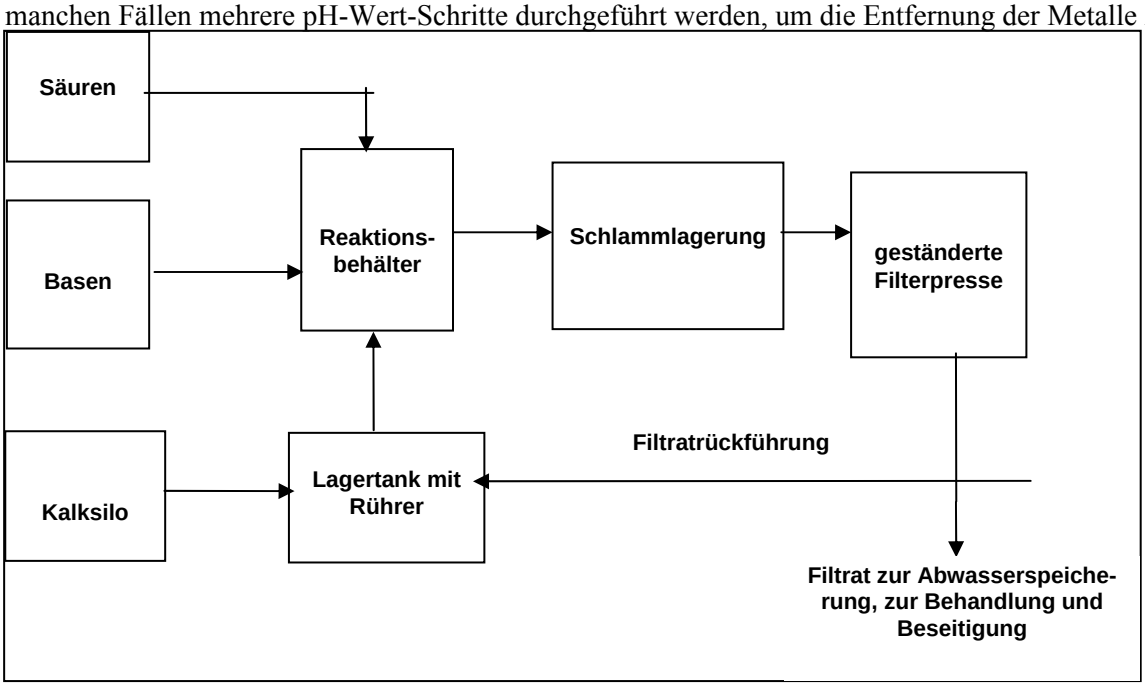


Abbildung 4.3: Darstellung eines Fällungs/Neutralisationsverfahrens [55, UK EA, 2001]

Die Vorteile eines Chargenbetriebs bei der Behandlung von Abfall mit Eigenschaften, die von Charge zu Charge sehr stark schwanken, zeigen sich in den Ergebnissen aus Betrieb und Erfahrung, z.B.:

- bei einem konstanten pH-Wert kann die Metallkonzentration im Abwasser immer noch sinken
- durch wiederholtes Mischen von Abwasser und Sedimentationsschlamm können zusätzliche Mitfällungseffekte erzielt werden; eine Voraussetzung für die Mitfällung ist eine behutsame Schlammzirkulation und ein behutsamer Schlammtransport

Weil im Allgemeinen metallkorrosive Stoffe genutzt werden, muss die Anlage (Behälter, Leitungen, Messtechnik) in geeigneter Weise ausgestattet und/oder geschützt werden (Verwendung synthetischer Materialien, Anstriche usw).

Anwendbarkeit
In Behandlungsverfahren für wässrige Abfälle wird ein breites Spektrum geeigneter wässriger Abfallstoffe behandelt, indem lösliche Metalle und saure Anionen aus der Lösung gefällt werden, wobei gleichzeitig die Partikelgröße suspendierter Feststoffe vergrößert und dadurch eine spätere Phasentrennung zwischen Feststoffen und Flüssigkeiten durch Klärung und Filtration erleichtert wird. Zu den typischen Abfällen gehören u.a. Abscheiderabfälle, Lackierabfälle und Abfall- und Prozessabwässer.

Treibende Kraft für die Anwendung
In den Niederlanden wird die Technik der Aufkonzentration von Metallen im Schlamm bei metallhaltigen Abwässern angewendet (mit Ausnahme von Beizsäure und edelmetallhaltigen Abwässern), wenn das Abwasser eine Metallkonzentration (As, Co, Cr, Cu, Fe, Mo, Ni, Pb, Sn, V und Zn) von über 200 mg/l aufweist, von denen 25 mg/l in der wässrigen Fraktion vorliegen, und/oder die Konzentration von Cd höher als 0,2 mg/l ist.

Beispielanlagen
In einer Beispielanlage wird Galvanisier-/Beizsäure in einen Reaktionsbehälter gegeben und der pH-Wert auf 5 gesenkt. Dies ermöglicht die Freisetzung von Eisenionen aus der Säure, die als Reduktionsmittel wirken und Metalle von hohen auf niedrige Oxidationsstufen reduzieren, die dann durch anschließende Kalkzugabe und einer Erhöhung des pH-Werts auf 9 aus der Lösung (als Hydroxide) entfernt werden können.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [153, TWG, 2005]

4.3.1.5 Emulsionstrennung

Beschreibung
Zu den Techniken gehören:

a. Nutzung von Abfallsäuren und –basen zur Emulsionstrennung
b. Einsatz des Eindampfens, Ultrafiltration oder von organischen Spaltmitteln
c. testen der Anwesenheit von Cyaniden in den zu behandelnden Emulsionen. Falls Cyanide vorhanden sind, benötigen die Emulsionen einen speziellen Vorbehandlungsschritt
d. vorherige Durchführung eines Simulationstests im Labor. In der Regel erarbeitet der Betreiber ein Behandlungsprogramm, das Einzelheiten zu Art und Menge der einzusetzenden Säuren, Laugen und Flockungsmittel enthält. Laboruntersuchungen der Proben können helfen zu ermitteln, ob eine angemessene Wasserqualität erreicht werden kann
e. Ausführen des Prozesses mit hoher Genauigkeit sowie Kontrolle des Verfahrens und der organischen Spaltung.

Erreichter Nutzen für die Umwelt
Die saure Spaltung von Emulsionen ist von außerordentlicher Bedeutung für die Abfallbeseitigung und für den Gewässerschutz, denn zur Behandlung der Emulsionen können Abfälle, wie etwa gebrauchte Säuren und –laugen, eingesetzt werden. Beim organischen Spalten ist im Falle einer Unterdosierung eine unvollständige Spaltung möglich; bei einer Überdosierung ist eine Neubildung von Emulsionen möglich.

Um Umwelt- und Betriebsprobleme zu vermeiden, ist es wichtig, die im obigen Abschnitt „Beschreibung“ aufgeführten Techniken bei der Bestimmung der geeignetsten Methode zum Trennen der einzelnen Emulsionsarten zu berücksichtigen.

Medienübergreifende Auswirkungen
Möglicherweise ist nach der Behandlung der Emulsion eine weitere Behandlung des Abwassers notwendig, zum Beispiel unter Einsatz eines Ionenaustauschers oder einer Adsorption an Aktivkohle. Wenn dies notwendig ist, sollte es in der Betriebsanweisung im Behandlungsprogramm festgeschrieben werden.

Die Nutzung von Abfallsäuren und –laugen (siehe Technik a in obiger Beschreibung) erzeugt in der Regel ein Abwasser mit höheren Konzentrationen an Salzen und Restölen. Der ölige Schlamm ist in der Regel schwierig zu deponieren, und das Öl kann nicht verwertet werden.

Betriebsdaten
Die eigentliche Behandlung der Emulsion, die auch als Emulsionsspaltung bezeichnet wird, besteht aus zwei Behandlungsphasen:

- Destabilisierung (Trennung) der Emulsion durch Mischung der Emulsion mit Säuren
- Flockung und Fällung der gelösten Metalle aus der getrennten Emulsion.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.6 Oxidation/Reduktion

Beschreibung
Zu den Techniken gehören:

a. Vermindern der während der Oxidation/Reduktion erzeugten Emissionen in die Luft
b. Vorhandensein von Sicherheitsmaßnahmen und Gasdetektoren (z.B. zur Aufspürung von HCN, H_2 S, NO_X).

Erreichter Nutzen für die Umwelt
Verringert die Emissionen, die bei Redoxreaktionen auftreten können.

Beispielanlagen
Die Erfassung der Abluft wird mittels Saugbelüftung mit Ventilator und Abluftfilter sichergestellt. Hier werden keine Messungen durchgeführt, da die transportierte Abluftmenge überdimensioniert ist. Der Filter, zu dem saure oder basische Wäscher gehören können, wird regelmäßig überprüft und, falls notwendig, regeneriert.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002]

4.3.1.7 Techniken zur Behandlung cyanidhaltiger Abfälle

Behandlung
Cyanide können durch verschiedene Arten von Oxidationsmitteln zerstört werden, wie etwa Hypochlorit, Chlor, Ozon, Peroxide und Peroxide in Verbindung mit UV-Strahlung. Weitere mögliche Techniken sind die elektrochemische Oxidation oder die nasse Oxidation mit Luft (bei mittlerem bis hohem Druck). Auch hohe Temperaturen können Cyanide in festen Abfällen zerstören. Allerdings werden keine Verbrennungstechniken in diesem Dokument beschrieben. Zu berücksichtigende Punkte sind:

a. Cyanide können in wässrigen Abfallströmen mittels Oxidation durch ein basisches Oxidationsmittel bei einem pH-Wert nicht unter 10 und einer Chlorkonzentration von weniger als 1 g/l zerstört werden. Die Reaktion verläuft sehr schnell
b. Hinzufügen von Natronlauge im Überschuss kann verhindern, dass der pH-Wert zu stark abfällt
c. eine Mischung von Cyanidabfällen mit sauren Verbindungen (z.B. bei der Neutralisation und sauren Emulsionsspaltung) muss vermieden werden

d. da die Behandlung von Cyaniden mittels Oxidation durchgeführt wird, kann die Zerstörung durch Messung des Redoxpotentials überprüft werden (elektrischen Potentials). Die Zugabe von Natriumhypochlorit in den Ablaufsumpf kann daher kontrolliert werden.[16]
e. die Nutzung der Elektrolyse zum Oxidieren von Cyaniden.

Erreichter Nutzen für die Umwelt
Das entstehende Cyanat kann nicht ohne weiteres zurück zu Cyanid reduziert werden und die Einleitung von Cyanat in einen Wasserlauf wird nicht zur Entstehung von freiem Cyanid führen. So besteht wenig Risiko für die Gesundheit. Die Vorbehandlung von cyanidhaltigen Abwässern ist zur Vermeidung der Bildung von Metall-Cyanid-Komplexen notwendig. Durch diese Techniken können Konzentrationen von weniger als 0,1 mg/l Cyanid erreicht werden.

Medienübergreifende Auswirkungen
Verwendung eines Oxidationsmittels (z.B. Hypochlorit, Kaliumpermanganat), falls erforderlich.

Die Nutzung von Hypochlorit oder Chlor erhöht den Salzgehalt des Abwassers und kann auch den AOX-Gehalt erhöhen. Cyanchlorid kann während der Behandlung mit chlorhaltigen Oxidantien entstehen. Bei der Nutzung von chlorierten Oxidantien ist es wichtig, dass der pH-Wert des Systems über 10 bleibt. Wenn der pH-Wert abfällt, können Cyanchlorid und Blausäure entstehen. Falls überschüssiges Hypochlorit vorhanden ist, kann Chlorgas freigesetzt werden, und falls ein Mangel an Hypochlorit besteht, bleiben Reste an Cyanid vorhanden.

Bei Verwendung von H_2O_2 oder Ozon als Oxidationsmittel entstehen keine Nebenprodukte, wie die folgenden Reaktionen zeigen:

$NaCN + OCl \rightarrow OCN + NaCl$ (Hypochloritverfahren)

$CN + H_2O_2 \rightarrow OCN + H_2O$ (Peroxidverfahren)

Betriebsdaten
Die Einleitung von Abwasser in Gewässer wird kontinuierlich überwacht, hinsichtlich des Gehalts an Cyanid, freiem Chlor und pH-Wert. Die Nutzung von reinem Sauerstoff als Oxidationsmittel ist nicht so effizient wie die der anderen erwähnten Oxidationsmittel.

Anwendbarkeit
Chemische und thermische Behandlungsmethoden werden zur Zerstörung von Cyaniden in Abfallströmen weitgehend genutzt.

Treibende Kraft für die Anwendung
Zerstörung von Cyaniden.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [156, VROM, 2004]

4.3.1.8 Techniken zur Behandlung von Chrom(VI)-haltigen Abfällen

Beschreibung
Zu den Techniken gehören:

a. das Mischen von Chrom(VI)-haltigen Abfällen mit anderen Abfällen muss verhindert werden
b. das Umwandeln von Cr(VI) in weniger gefährliches Cr(III) kann durch Zugabe eines Reduktionsmittels, wie z.B. Natriumdisulfit, Beizsäure oder Natriumdithionit, erzielt werden. Das dreiwertige Metall kann dann auf normale Art und Weise ausgefällt werden (siehe Abschnitt 4.3.1.4).

[16] Anm.d.Übers.: Die Bedeutung des Satzes ist im Originaltext nicht eindeutig.

Erreichter Nutzen für die Umwelt
Chrom (VI) ist die höchste Oxidationsstufe des Metalls, ein Beispiel dafür ist Chromsäure oder Chromtrioxid (CrO_3), welches sauer, giftig und wasserlöslich ist und als Oxidationsmittel verwendet wird. Mit diesen Behandlungen können Konzentrationen unter 0,1 mg/l Chrom(VI) erreicht werden.

Medienübergreifende Auswirkungen
Es wird ein Reduktionsmittel benötigt.

Treibende Kraft für die Anwendung
Eine Behandlung durch direkte Neutralisation von Chrom(VI)-Verbindungen ist uneffektiv, demnach muss in einem ersten Schritt eine Reduktion zum dreiwertigen Chrom(III) durchgeführt werden.

Literatur
[55, UK EA, 2001], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [156, VROM, 2004]

4.3.1.9 Techniken bei der Behandlung nitritverunreinigter Abwässer

Beschreibung
Zu den Techniken gehören:

a. Vermeidung der Mischung nitrithaltiger Abfälle mit anderen Abfällen
b. Überprüfung und Vermeidung von Nitrosegasen während der Oxidation und Ansäuerung von Nitriten
c. Überprüfung und Vermeidung von Nitrosegasen während der Reduktion von Nitriten.

Erreichter Nutzen für die Umwelt
Konzentrationen von weniger als 0,2 mg/l Nitrit können durch gute Optimierungen des Nitritbehandlungsverfahrens erreicht werden.

Medienübergreifende Auswirkungen
Der Einsatz von Oxidationsmitteln in Oxidationsverfahren ist erforderlich. Reduktionsmittel sind Harnstoff oder Amidosulfonsäure.

Beispielanlagen
In Österreich gibt es drei Anlagen, die mit solchen Verfahren arbeiten.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.10 Behandlung phenolhaltiger Lösungen durch Oxidation

Beschreibung
Es ist möglich, wässrige Abfälle die Phenol enthalten (3–5 Gew.%), mittels katalytischer Oxidation zu behandeln, wobei Oxidationsmittel und ein Metallkatalysator oder ein starkes Oxidationsmittel (z.B. $KMnO_4$) zum Einsatz kommen.

Erreichter Nutzen für die Umwelt
Verringert den Phenolgehalt in wässrigen Abfällen.

Medienübergreifende Auswirkungen
Nutzung von Oxidationsmittel und Katalysator, wo es notwendig ist.

Betriebsdaten
Bei dem Behandlungsablauf muss das exotherme Verhalten der Reaktion berücksichtigt werden. Einsatzstoffe können vor der Behandlung gelöst werden. Die Prozesstemperatur, pH-Wert und Redoxpotential werden kontinuierlich überwacht.

Beispielanlagen
Eine Beispielanlage in GB zeigt, dass das Verfahren auf Basis eines Drei-Tonnen-Chargensystems in einem doppelwandigen Behälter aus rostfreiem Stahl genutzt wird.

Literatur
[55, UK EA, 2001], [150, TWG, 2004]

4.3.1.11 Techniken für ammoniakhaltige Abfälle

Beschreibung
Zu den Techniken gehören:

a. Ammoniaklösungen bis 20 Gew.%, können unter Nutzung von zwei Kolonnen mittels Luftstrippen und anschließender saurer Gaswäsche behandelt werden. Hierzu wurde ein Zwei-Kolonnen-Prozess entwickelt, wobei in der ersten Kolonne die Temperatur des Einsatzstoffes erhöht und der pH-Wert zwischen 10 und 11 gehalten wird. Der Einsatzstoff wird dann zu einer zweiten Kolonne geleitet, wo er im Gegenstrom mit Luft durch eine gepackte Kolonne geleitet wird
b. Rückgewinnen des Ammoniaks aus den Gaswäschern und Rückführung in den Prozess vor der Absetzstufe
c. Entfernen des Ammoniaks aus der Gasphase durch Waschen des Abfalls mit Schwefelsäure zur Erzeugung von Ammoniumsulfat.

Erreichter Nutzen für die Umwelt
Diese Techniken verhindern hohe Emissionen an Ammoniakgas während des vorgeschalteten Neutralisationsprozesses bei schnell wechselnden pH-Werten, indem der Tankinhalt gerührt wird und die Temperatur ansteigt.

Betriebsdaten
Stark ammoniakhaltige Lösungen können auch einer Vorbehandlung unterzogen werden (z.B. Luftstrippen), um die Ammoniakkonzentration zu senken, bevor sie die Behandlungsanlage erreichen.

Anwendbarkeit
Solche Verfahren werden auf Abwässer mit hohem Ammoniakgehalt angewendet. Es gibt andere ammoniak-/ammoniumhaltige Abfälle, wie z.B. Deponiesickerwasser, für die das beschriebene Verfahren des Strippens, infolge des Übergangs anderer Stoffe in die Gasphase, nicht geeignet ist.

Wirtschaftlichkeit
Die ammoniakhaltigen Lösungen können auch als deNOx Reagenzien eingesetzt werden. Dieser Verbleib kann kostengünstiger als die Sammlung/Behandlung als gefährlicher Abfall sein.

Treibende Kraft für die Anwendung
Ammoniak trägt zum sauren Regen und zur Überdüngung bei.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.3.1.12 Filtration

Beschreibung
Zu den Techniken gehören:

a. Ausweiten der Luftmessungen auf Ammoniak in der Abluft oder den Filterpressenbereichen, um VOCs abzudecken
b. Verbinden des Luftbereichs oberhalb der Pressen mit dem Haupt-Abluftreinigungssystem der Anlage
c. Verbessern des Entwässerungsverhaltens von Schlamm durch Zugabe von Flockungsmitteln, zum Beispiel von Kalk oder synthetischen Flockungsmitteln. Die Konditionierung von Schlamm findet in Behältern mit einstellbaren Rührwerken statt. Eine intensive Mischung des Schlamms mit den Flockungsmitteln kann in kurzer Zeit durch eine Beschleunigung des Rührers erzielt werden; während der Flockenbildung bewegt sich der Rührer normalerweise langsam, um die Flockung nicht zu behindern.

Erreichter Nutzen für die Umwelt
Verbessert den Filtrationsprozess und reduziert flüchtige Emissionen. Filterkuchen mit hohen Metallkonzentrationen, z.B. Nickel und Kupfer, können als Rohstoff in der metallurgischen Industrie eingesetzt werden.

Medienübergreifende Auswirkungen
Die Notwendigkeit der Reinigung der Filtertücher ist ein Nachteil; die Verwendung von Wasser-Hochdruckreinigern oder das Waschen der Tücher in speziellen teilweise sauren Waschlösungen hat sich für diesen Zweck als vorteilhaft erwiesen.

Die Notwendigkeit der Wartung der Pressen sowie die Entfernung von Schlammkuchen bedeutet, dass das System regelmäßig geöffnet wird, was eine Vermeidung von Emissionen in die Luft erschwert.

Betriebsdaten
Zum Betrieb des Verfahrens wird Energie benötigt.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.13 Flotation

Beschreibung
Die Entspannungsflotationsysteme (engl. DAF) erzeugen mit Dampfdruck eine übersättigte Lösung aus Abwasser und Druckluft, indem der Druck des Abwasserstroms auf das Druckniveau der Druckluft erhöht wird und beide anschließend in einem Entspannungstank gemischt werden. Diese übersättigte Mischung aus Luft und Abwasser fließt in einen großen Flotationstank, wo der Druck freigegeben wird, wodurch zahlreiche kleine Luftbläschen erzeugt werden. Durch eine Kombination von Adsorption und Einschluss steigen die ausgeflockten Partikel zur Oberfläche des Reaktors. Die suspendierten Feststoffe schwimmen an der Oberfläche der Flüssigkeit und bilden einen Schaum, der dann abgeschöpft wird. Einige gelöste Kolloide werden aus dem Abwasser durch Zugabe von Eindick- und Flockungschemikalien entfernt, indem sie mit den gelösten Substanzen Niederschläge bilden.

Erreichter Nutzen für die Umwelt
Die Entspannungsflotation ist auf Grund der Effektivität bei der Entfernung eines breiten Spektrums an Feststoffen weit verbreitet.

Medienübergreifende Auswirkungen
Emissionen in die Luft sind möglich, und eine große Menge chemischen Schlammes wird erzeugt (der $FeCl_3$, $Al(OH)_3$, Polyelektrolyte und eingeschlossene Partikel enthält), der vor der Beseitigung behandelt werden muss.

Betriebsdaten
Normalerweise werden Chemikalien wie Polymere, Polyelektrolyte, Aluminiumsalze (z.B. Sulfate) oder Eisensalze (z.B. Eisenchlorid) verwendet, um die Adhäsion der Blasen zu erhöhen. Das Verfahren benötigt zu seinem Betrieb Energie.

Treibende Kraft für die Anwendung
Keine Notwendigkeit für einen Sedimentationsbehälter.

Beispielanlagen
Die Entspannungsflotation ist weit verbreitet.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.3.1.14 Ionenaustauschverfahren

Beschreibung
Zu den Techniken gehören:

a. Nutzen von Ionenaustauschern nur bei Salzkonzentrationen unterhalb von 1500 mg/l. Andernfalls ist die Behandlung nicht wirtschaftlich
b. Nutzen von Vorbehandlungen zur Senkung der Salzkonzentration (z.B. Fällung)
c. entfernen von Feststoffen aus Lösungen vor dem Einsatz von Ionenaustauschverfahren, durch Sandfilter oder Adsorption an Aktivkohle
d. Nutzen der Leitfähigkeitsmessungen zur Überwachung und Betriebsführung der Ionenaustauschanlage (Kationen-Anionen Kombination). Diese Methode ist sehr genau und nicht störungsanfällig.

Weitere Untersuchungsparameter können Öle, emulgierte Stoffe (Glühverlust), Feststoffe im Zufluss des Ionenaustauschers, der pH-Wert, aromatische Kohlenwasserstoffe, chlorierte Kohlenwasserstoffe und organische Säuren sein.

Erreichter Nutzen für die Umwelt
Verbesserung des Ionenaustauschverfahrens.

Betriebsdaten
Ionenaustauscher können nur mit “sauberen” Lösungen funktionieren, d.h. in Lösungen, die in erster Linie Ionen, aber keine festen Bestandteile enthalten.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002]

4.3.1.15 Membranfiltration

Beschreibung
Anforderungen wie die Beständigkeit gegenüber Reinigungen, der Langlebigkeit sowie niedrige Herstellungskosten der Membranen gelten für alle Membranverfahren. Die Wahl der geeigneten Membran ist von zentraler Bedeutung für die Abfallbehandlung. Zu den Techniken für die Auswahl sowie zum Einsatz geeigneter Membranen gehören:

a. Laboruntersuchungen, welche Membran für den zu behandelnden Abfall geeignet ist
b. Permeat und Konzentrat aus der Ultrafiltration einer weiteren Behandlung unterziehen. Im Falle des Permeats kann dies eine Entgiftung, Neutralisation, Fällung oder Eindampfen bedeuten. Im Falles des Konzentrats muss es eventuell entsorgt werden
c. Überwachen der folgenden Parameter in Mikro- und/oder Ultrafiltrationssystemen:
   - pH-Wert
   - Durchsatz
   - elektrische Leitfähigkeit
   - Druck, Temperatur
   - Ölgehalt
   - Effizienz des Permeats und/oder Qualität des Permeats (z.B. Trübungswert, Kohlenwasserstoffe)
   - Cyanide, Nitrite, Chromate
   - Feststoffgehalt.

Erreichter Nutzen für die Umwelt
Zu den Vorteilen gehören:
- keine chemischen Zusätze benötigt (keine Stoffumwandlung)
- keine zusätzliche Abwasserverunreinigung durch Chemikalien (keine Aufsalzung).

Medienübergreifende Auswirkungen
Für das Verfahren wird Energie benötigt.

Betriebsdaten
Es ist möglich, die Membranfiltration zu automatisieren. Zudem benötigen Filtrationsanlagen wenig Platz.

Anwendbarkeit
Membranverfahren sind zur Abfallbehandlung geeignet, wenn der Abfall vorbehandelt ist oder wenn ein definierter Abfall involviert ist, der für die Membranfiltration geeignet ist. Stoffe, die zu nachteiligen Veränderungen an den Membranen, wie etwa Anhaftungen oder die zu einem Verdicken der Membran führen, müssen abgetrennt werden. Wenn diese Beschränkungen im Auge behalten werden, sind Membranfiltrationen:

- geeignet für hoch und niedrig angereicherte Abwässer
- unabhängig von der Art, Konzentration oder Stabilität zur Emulsionstrennung verwendbar.

Art von Stoffen	Auswirkung auf die Membran	Technik zur Überwindung des Problems in der Membran
Feststoffe mit Korngröße >0,5 mm	Blockierung , Abnutzung der Membran	Geeignet mit einer Vorreinigungsstufe
Lösemittel	Anschwellen der Membran, Strukturänderungen, Verringerung der Permeabilität	Verhinderung des Eintrags
Alkalische Lösungen und Säuren mit extremen pH-Werten	Mögliche Zerstörung des Membranmaterials	Einstellung des pH-Werts
Organische Stoffe (bei Celluloseacetatmembranen)	Schaden an der Membran durch Verrotten	Durch Bakterizide
Silikone (ab 0,1 %)	Blockierung der Membran	Verhinderung des Eintrags in die Membran
Freies Öl (ab 1,0 %)	Blockierung der Membran[1]	Verhinderung des Eintrags in die Membran
[1] Umkehrosmose und möglicherweise Nanofiltration arbeiten bei 1 % Ölgehalt über eine längere Betriebsdauer ohne sehr aufwändige Vorbehandlungsschritte nicht effektiv		

Tabelle 4.21: Zu berücksichtigende Techniken bei der Membrantechnologie
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

Grundsätzlich kann die Membrantechnologie für die in Abbildung 4.4 gezeigten Zwecke genutzt werden:

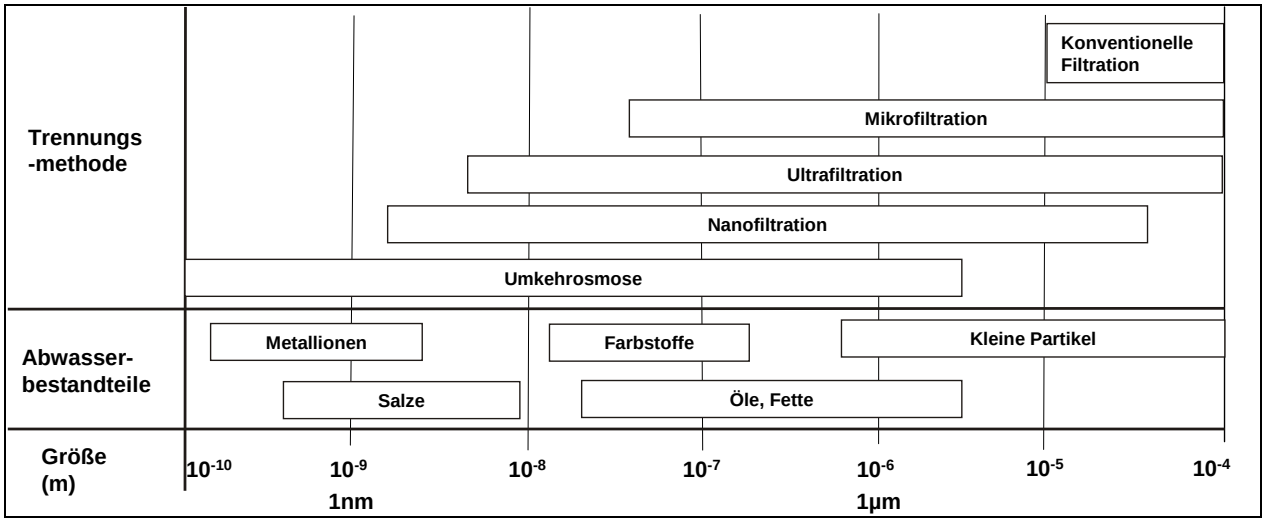


Abbildung 4.4: Einstufung der Membrantechnologie nach der Trennungsaufgaben
[121, Schmidt and Institute for environmental and waste management, 2002]

Wirtschaftlichkeit
Da das Verfahren in der Regel automatisiert ist, sind die Personalkosten niedrig.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.16 Sedimentation

Beschreibung
Absetzprozesse werden in Klärbecken durchgeführt, die dafür mit speziellem Zu- und Ablauf, sowie spezieller Absetzzone und Schlammzone konstruiert werden. Eine Zugabe von Flockungsmitteln, zum zu behandelnden Schlamm und Abwasser, wird empfohlen, um den Sedimentationsprozess zu beschleunigen und die spätere Abtrennung von Feststoffen zu erleichtern.

Erreichter Nutzen für die Umwelt
Erhöht die Sedimentationseffizienz. Die Sedimentation von Feststoffen erleichtert grundsätzlich die darauf folgenden Abfallbehandlungsschritte. Insofern ist die Sedimentation vorteilhaft bei der Behandlung von Abfall in CP-Anlagen, wenn sie im richtigen Bereich des Verfahrens angewendet wird. Allerdings sind nicht beabsichtigte Sedimentationsprozesse, z.B. in Reaktionsbehältern, von Nachteil, da die Verfahren beeinträchtigt werden können und das aufgebaute Sediment nur unter beträchtlichen Kosten entfernt werden kann.

Medienübergreifende Auswirkungen
In der Regel wird ein Rückstand erzeugt. Die Zugabe von Flockungsmitteln birgt in sich, dass sie sich entweder im behandelten Abwasser wiederfinden oder im abgetrennten Feststoff vorliegen.

Betriebsdaten
Die Effizienz des Sedimentationsverfahrens wird beeinflusst durch Eigenschaften des Abwassers sowie der suspendierten Feststoffe und durch Schwankungen im Durchfluss und der allgemeinen Betriebsführung. In der Praxis haben sich folgende Sedimentationshilfsmittel als vorteilhaft erwiesen:

- Kalkmilch $Ca(OH)_2$
- Eisen(III)-chlorid $FeCl_3$
- Polyelektrolyte.

Anwendbarkeit
Die Feststoffe können eigenständig suspendierende Partikel sein, die sich selbst absetzen, oder aber auch ein breites Spektrum von Größen- und Oberflächeneigenschaften aufweisen, welche dann eine Bildung von flockenden Suspensionen erfordern, um zu koagulieren und sich abzusetzen, d.h. durch chemische Konditionierung. In bestimmten Fällen ist es nicht notwendig Flockungsmittel einzusetzen, weil ihr Einsatz uneffektiv ist oder weil sich die Feststoffe von selbst absetzen.

Wirtschaftlichkeit
Der Einsatz dieser Technik ermöglicht Einsparungen bei Einleitungs- und Transportkosten, da nur das Sediment und nicht die gesamte wässrige Suspension behandelt werden muss.

Beispielanlagen
Papierherstellung (Sedimentation von kurzen Cellulosefasern) und andere Anlagen mit hohem Gehalt an suspendierten Feststoffen im Abwasser.

Literatur
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.17 Siebung

Beschreibung
Siehe Abschnitt 2.3.2. Zu den Techniken für Siebungsvorgänge gehören:

a. Vermeiden einer Überladung der Siebeinrichtungen (entweder optisch durch Überwachung der Kontrollvorrichtungen oder automatisch durch Blockieren der Einfüllpumpe über den Füllstandanzeiger des Lagerbehälters)
b. Korrekte Reinigung der Filteröffnungen wie erforderlich (optisch, empirisch). Einige gute Reinigungsmaßnahmen umfassen die Anwendung einer Schnellreinigung sowie Dampf oder Hochdruckwasserstrahlen
c. Sicherstellen, dass der Abfluss des Unter- und Überlaufs des Filters zu keiner Zeit behindert wird (durch Anwendung optischer Kontrollen, Abschaltmechanismen für die Einfüllpumpe oder anderer Kontrollen).

Erreichter Nutzen für die Umwelt
Das Sieben von Abfällen wird als erstes Behandlungsverfahren durchgeführt. Die Abtrennung von Partikeln, die Geräte, Verfahren oder Produkte schädigen können, ist für alle folgenden Abfallbehandlungsmaßnahmen von Vorteil.

Betriebsdaten
Die Vorteile von Sieben liegen in ihrer einfachen, robusten Bauweise, ihrem geringen Wartungsbedarf, ihrer Benutzerfreundlichkeit sowie ihrer Zuverlässigkeit. Die Nachteile werden in der Regel durch die Abfälle selbst verursacht. So kann es z.B. in Abhängigkeit vom Viskositätsgrad des flüssigen Abfalls, zum Verstopfen der Filteröffnungen kommen, was eine Abtrennung verhindert.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002]

4.3.1.18 Extraktion mit Lösemitteln

Beschreibung
Zu den Techniken gehören:

a. Nutzung von gut geführten und geregelten Prozessen
b. Rückführung des Extraktionslösemittels zur Wiederverwendung im geschlossenen Kreislauf
c. Nutzung von Entschäumern, wenn Störungen bei der Extraktion auftreten, infolge von oberflächenaktiven Stoffen (z. B. Tenside) die aus Mischprozessen resultieren
d. Vermeidung der Nutzung von Lösemitteln mit chemischen Eigenschaften die denen der zu extrahierenden Komponenten ähnlich sind, um eine schlechte Abtrennung zu vermeiden, z. B. durch azeotrope Mischungen
e. Verbesserung der Abtrennungsleistung während der Extraktion durch Temperaturerhöhung
f. Abtrennung von Stoffen, die negative Auswirkungen haben können, in Vorbehandlungsverfahren

Ereichte Vorteile für die Umwelt
Steigert die Umweltleistung der Lösemittelextraktion. Einige Gründe für die Nutzung der Extraktion sind: Ihr niedriger Energieverbrauch bei der Trennung von Stoffen, dies reicht von niedrig konzentriertem Abwasser bis zum ppm-Bereich; die Möglichkeit der Extraktion unlöslicher Stoffe und auch der hohe Grad an Selektivität, welcher durch die Verwendung von reaktiven Verbindungen und geeigneten Extraktionsmitteln bei dem Extraktionsprozess erzielt werden kann.

Medienübergreifende Auswirkungen
VOC-Emissionen in die Luft.

Wirtschaftlichkeit
Einsparen von Rohstoff- und Transportkosten, wenn die Destillation auf dem Betriebsgelände durchgeführt werden kann.

Beispielanlagen
Viele Anlagen führen das Extraktions-Lösemittel zur Wiederverwendung in einem geschlossenen Kreislauf

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.3.1.19 Techniken zur Behandlung edelmetallhaltiger Abwässer

Beschreibung
Flüssige Abfälle aus dem fotografischen Gewerbe enthalten verschiedene giftige und schwer abbaubare Verbindungen. Mittels chemisch-physikalischer sowie biologischer Behandlungen, einschließlich einer Eindampfung, kann eine Diffusion dieser Verbindungen in die Umwelt minimiert werden. Zu den Techniken gehören:

a. für Abwässer aus der Schwarz-Weiß-Fotografie die Rückgewinnung der Metalle, wenn die Silberkonzentration höher als 50 mg/l ist und eine Reinigung mit anschließender Eindampfung und Verbrennung des Konzentrats durch Rostfeuerung oder Zementofen durchgeführt wird
b. für Abwässer aus der Farbfotografie die Rückgewinnung der Metalle, wenn die Silberkonzentration höher als 100 mg/l ist und eine Reinigung mit anschließender Eindampfung und Verbrennung des Konzentrats durch Rostfeuerung oder Zementofen durchgeführt wird.

Erreichter Nutzen für die Umwelt
Im Vergleich zur Entfernung der Metalle mittels Chemikalien durch Entgiftung, Neutralisation und Entwässerung, werden eine Reduzierung des Chemikalienverbrauchs und der Schlammproduktion erreicht.

Medienübergreifende Auswirkungen
Im Vergleich zur Entfernung der Metalle mittels Chemikalien durch Entgiftung, Neutralisation und Entwässerung, ist hier der Energieverbrauch höher, z.B. durch:
- Strom für die Elektrolyse
- Wärme für die Eindampfung.

Betriebsdaten
Sulfidfällung und Ultrafiltration erzeugen etwa 5 bis 10 kg Sulfidschlamm pro m^3 Abwasser aus der Fotoentwicklung mittels Flüssigkeiten. Aus dem Schlamm werden Silber und andere Metalle durch pyrometallurgische Verfahren zurückgewonnen, bei denen Schlacken als Reststoff entstehen. Die chemisch-physikalische und biologische Behandlung des entsilberten fotografischen Abwassers erzeugt etwa 0,1 bis 0,2 Tonnen Schlamm pro Tonne Abwasser.

Silber wird zur Wiederverwendung zurückgewonnen sowie die Konzentrationen von Silber und anderen Metallen im Abwasser reduziert. Etwa 95 % des Silbers werden zurückgewonnen. Der Silbergehalt im Permeat der Membranfiltration liegt unter 1 mg/l für Abwässer aus der Schwarz-Weiß-Fotografie und liegt unter 10 mg/l für Abwässer aus der Farbfotografie.

Anwendbarkeit
Die Techniken zur Rückgewinnung von Metallen können nicht nur auf fotografische Abwässer, sondern auch auf andere (edel-)metallhaltige Abwässer angewendet werden, z.B. aus der Galvanikindustrie. Die Elektrolyse liefert höhere Ausbeuten und hat geringere Energiekosten, während die Metalle wertvoller und die Konzentrationen höher sind. Die Kapazität einer der Beispielanlagen zur Metallrückgewinnung liegt zwischen 10 und 20 kt/a.

Die Techniken zur chemisch-physikalischen und biologischen Behandlung von entsilberten fotografischen Abwässern können auf ähnliche Abwässer angewendet werden. Die Tabelle 3.81 zeigt Annahmekriterien für entsilberte fotografische flüssige Abfälle und ähnliche Abwässer (mit demselben Aufbereitungspfad). Die Kapazität einer der Beispielanlagen der chemisch-physikalischen und biologischen Behandlung liegt etwa bei 100 bis 200 kt/a.

Treibende Kraft für die Anwendung
Abwasserstandards, basierend auf dem „Surface Waters Pollution Act“.

Beispielanlagen
Zwei Beispielanlagen in den Niederlanden.

Literatur
[150, TWG, 2004], [156, VROM, 2004]

4.3.1.20 Techniken zur Behandlung von wässrigem Schiffsabfall

Beschreibung
Bei der Behandlung von wässrigem Schiffsabfall kann zwischen ölhaltigen sowie chemikalienhaltigen Abwässern unterschieden werden. Zu den Techniken gehören:

a. Anwendung spezifischer Vorbehandlungsverfahren für den Fall, dass die Abwässer Metalle enthalten (siehe vorhergehenden Abschnitt 4.3.1.19)
b. Anwendung chemisch-physikalischer Vorbehandlungen und biologischer Behandlungen für den Fall, dass Abwässer Öl enthalten
c. Behandlung der Abgase zur Reduzierung der VOC- und Geruchsemissionen
d. Festlegung von Annahme- und Verarbeitungsstandards (maximale Konzentrationen im Abfall) für jeden Behandlungsweg
e. Trennung von Ölen/Chemikalien, Wasser und Schlamm
f. Aufbereitung der Öl- oder Chemikalienfraktion zur Nutzung als Brennstoff, falls diese dafür geeignet ist
g. Anwendung von Standards (Höchstkonzentrationen) für die Mischung von Abfällen, die als Brennstoff genutzt werden
h. keine Mischung oder Verdünnung von Abwässern, um Einleitungsstandards einzuhalten
i. Entwässerung des Schlamms und bei Eignung die Anwendung einer thermischen Behandlung zur stofflichen Wiederverwendung
j. Behandlung des Abwassers.

Erreichter Nutzen für die Umwelt
Im Vergleich zur Einleitung unbehandelter Abwässer oder einer alleinigen biologischen Behandlung reduzieren die beschriebenen Techniken die Schadstoffemissionen ins Oberflächenwasser.

Medienübergreifende Auswirkungen
- Erzeugung eines Schlamms, der entsorgt oder einer weitergehenden Behandlung unterzogen werden muss
- Verbrauch von Chemikalien
- Verbrauch von Energie
- Luftemissionen, z.B. VOC und Gerüche.

Betriebsdaten
Die Abscheidewirkungsgrade der Flockung/Flotation sowie der aeroben biologischen Behandlung in einer Abwasserreinigungsanlage werden in der Tabelle 4.22 aufgeführt:

Bestandteil	Abscheidewirkung Flockung/Flotation (%)	Abscheidewirkung aerobe biologische Behandlung (%)	Abwasserbehandlung Gesamtwirkungsgrad (%)[2]
Suspendierte Partikel	>99	-	>99
Öl	>99[1]	99	>99
CSB	20	85	88
Phenole	-	99	99
Gesamt-N (Kjeldahl)	-	50	50
P	-	50	50
BTEX	75	99	99.7
PAHs	96	95	99
CN	-	75	75
EOX + VOX	30	97	98
EOX	85	85	98
Schwermetalle	80	-	80
Cd	80	-	80
Hg	>90	-	>80

[1] Entfernung der Ölschicht
[2] Total Flockung/Flotation und biologischer Behandlung

Tabelle 4.22: Abscheidewirkungsgrade der Flockung/Flotation und der biologischen Behandlung von Abwasser

VOC-Luftemissionen werden aus Tanks während der Lagerung und des Umschlags, sowie aus Behandlungsanlagen und Dichtungsleckagen freigesetzt. Die Emissionen können reduziert werden, dies durch eingehauste Anlagen, Inspektionen und Wartungen zur Vermeidung von Leckagen.

Eine Behandlung der Abgase mittels Filter, Gaswäsche oder Verbrennung kann diese Emissionen reduzieren. Biofilter oder Aktivkohlefilter können zur Vermeidung von VOC-Emissionen und Gerüchen eingesetzt werden. Eine Alternative, um diese Emissionen zu reduzieren, ist die Belüftung mittels Sauerstoff anstatt mit Luft. Somit wird der Durchfluss der Zuluft und des Abgases gesenkt. Nachteile liegen im höheren Verbrauch von Sauerstoff sowie dem höheren Verbrauch an Pumpenergie, die notwendig ist um die infolge der geringeren Einblasung von Luft verringerte Durchmischung zu kompensieren.

Wenn eine Abgasbehandlung eingesetzt wird, schwanken die Emissionen zwischen etwa 0,01 kg/m^3 Abwasser im Fall einer Verbrennung und einer Abscheidewirkung von 99,9 %, und 0,05 kg/m^3 Abwasser im Fall einer nassen Gaswäsche.

Anwendbarkeit
Die Kapazitäten der Beispielanlagen liegen zwischen 200 und 500 kt/a.

Treibende Kraft für die Anwendung
Abwasserstandards basierend auf der „Surface Waters Pollution Act“ in den Niederlanden.

Beispielanlagen
Drei Beispielanlagen in den Niederlanden.

Literatur
[150, TWG, 2004], [156, VROM, 2004]

4.3.1.21 Minderungstechniken[17] die in CP-Anlagen angewandt werden

Tabelle 4.23 zeigt Minderungstechniken die für Abgase in CP-Anlagen angewendet werden.

[17] Anm.d.Übers.: Im Originaltext wird das Wort “Abatement” genutzt, was hier mit Minderung übersetzt wurde. Inhaltlich passend wäre z.B. auch das Wort *Abgasreinigungstechniken*.

Anlage	Abgasbehandlung für den Behandlungsbereich/die Reaktoren [a)]	Abluftreinigung/Abgasbehandlung in Lagerbereichen
Verfestigung	Beutelfilter	Beutelfilter
Multifunktionale C-P-Anlage	Gaswäsche für Säuren Gaswäsche für NH_3 in Betrieb, falls erforderlich	n.v.
Multifunktionale C-P-Anlage	Gaswäsche für Säuren Oxidierende Gaswäsche	Kohlefilter für einige Tanks, die ölhaltige Abfälle enthalten
Multifunktionale C-P-Anlage	Abgas wird bei [18]der Verbrennung von gefährlichen Abfällen genutzt	n.v.
Multifunktionale C-P-Anlage	4- bis 5-stufiges Behandlungsverfahren: Gaswäsche mit Wasser (Abscheidung von öl- und staubhaltigen Aerosolen) Gaswäsche für Säuren Gaswäsche für NH_3 Biofilter, geschlossenes System Kohlefilter in Betrieb, falls erforderlich	Be- und Entlüftung der gesamten Anlage, Behandlung des Abgases
Multifunktionale C-P-Anlage	Gaswäsche für NH_3 Biofilter	Biofilter
Multifunktionale C-P-Anlage	Gaswäsche für Säuren Gaswäsche für NH_3	Be- und Entlüftung
Multifunktionale C-P-Anlage	Gswäscher in Betrieb während der Oxidation von Cyanid oder Nitrit	Be- und Entlüftung
Multifunktionale C-P-Anlage	Gaswäsche für Säuren Oxidierende Gaswäsche Biofilter für den organischen Teil	Biofilter in Verbindung mit dem Abgas aus der biologischen Behandlung von Siedlungsabfall
Multifunktionale C-P-Anlage	Gaswäsche für Säuren Gaswäsche für NH_3 Biofilter (geschlossenes System) Abgaskamin	Biofilter
Bodenwäsche/ Zerkleinerungsanlage	1-stufige Gaswäsche	n.v.

[a)] Viele Anlagen setzen die Gaswäscher nur während der C-P-Behandlung im Reaktionsbehälter ein. Andere Anlagen betreiben die Abluftreinigungsanlage kontinuierlich.
n. v.: keine Informationen verfügbar

Tabelle 4.23: Abgasbehandlung in großen CP-Anlagen in Österreich [150, TWG, 2004]

Folgende Abbildung 4.5 und Tabelle 4.24 zeigen Abgasreinigungssysteme einer österreichischen Anlage sowie Abwasserparameter, die nach der biologischen Behandlung der Abwässer erzielt werden.

[18] Anm.d.Übers.: Es kann angenommen werden, dass das Abgas aus anderen Verfahren der Verbrennung zugeführt wird, nicht dass Abgas aus der Verbrennung genutzt wird

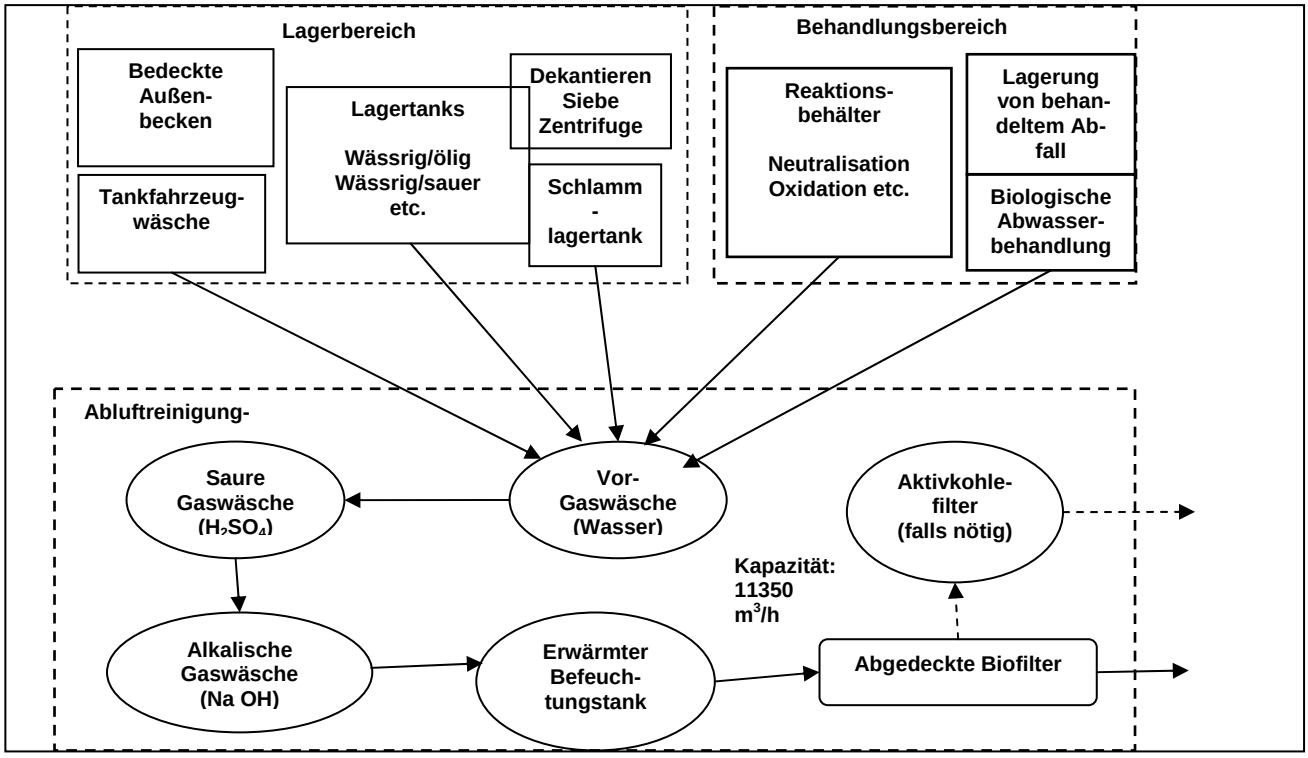


Abbildung 4.5: Kontrolle und Reinigung der Abluft in einer C-P-Anlage
[150, TWG, 2004]

Parameter	Zufluss (Primärabwasser) (mg/l)		Abwasser nach biologischer Behandlung (Sequentielles Batchverfahren) (mg/l)	
	Minimum	Maximum	Minimum	Maximum
CSB	2500	12000	600	1500
NH_4-N [a)]	25	16000	<1	150
Nitrit	10	300	<1	<1
Nitrat	10	1000	<1	<1
Phenole	10	500	<2	<2
Ölgehalt	--	--	<0.5	--
a) Abwasser nach biologischer Behandlung: Oft um 20 mg/l				

Tabelle 4.24: Konzentrationen im Abwasser einer österreichischen Anlage vor und nach tertiärer Abwasserbehandlung (betriebsinterne sequentielle biologische Behandlung im Batchverfahren)
[150, TWG, 2004]

4.3.2 Techniken zur chemisch-physikalischen Behandlung von Feststoffen und Schlämmen

4.3.2.1 Vorbehandlung vor der Immobilisierung

Beschreibung
Eine Vorbehandlung vor der Immobilisierung besteht grundsätzlich aus dem Waschen/Auslaugen von Salzen mittels Wasser und einer chemisch-physikalischen Vorbehandlung von Metallen (insbesondere das unlöslich machen der amphoteren Metalle). Die anschließende Behandlung, die Verfestigung, wird in diesem Abschnitt nicht beschrieben.

Erreichter Nutzen für die Umwelt
Bei dieser Behandlung entsteht ein Filterkuchen mit verringerter Toxizität und Löslichkeit sowie salzhaltiges Wasser. Sie trägt dazu bei, das Auslaugverhalten des Abfall-OUT und somit mögliche Kontamination durch das Auslaugen löslicher Verbindungen zu reduzieren.

Betriebsdaten
Das Verfahren ist anspruchsvoller als die einfache Verfestigung.

Anwendbarkeit
Abfall, der Chromate oder amphotere Metalle wie Pb und Zn enthält, sowie Abfall mit löslichen Salzen, benötigen in der Regel eine Vorbehandlung, bevor sie dem Immobilisierungsprozess unterzogen werden. Diese Vorbehandlung ermöglicht die Behandlung von Flugaschen und Salzen, die bei der Abscheidung von Chlor aus Abgasen von Hausmüllverbrennungsanlagen entstehen. Sie kann auch bei Flugaschen sowohl aus der Abgasreinigung mit Kalk oder Natriumbicarbonat angewendet werden. Im letzteren Fall (Natriumbicarbonat) trennt sie die löslichen und nicht löslichen festen Bestandteile und verringert die zu deponierende Abfallmenge durch das Recycling der löslichen Salze in einer Sodafabrik.

Wirtschaftlichkeit
Die Investitionskosten sind höher als für ein alleiniges Verfestigungsverfahren.

Beispielanlagen
Das Verfahren wird bereits in einer großen Fabrik in Frankreich angewandt, die 1000 Tonnen erzeugte Flugasche pro Jahr behandelt.

Literatur
[136, Straetmans, 2003], [150, TWG, 2004]

4.3.2.2 Labortätigkeiten

Beschreibung
Zu den Techniken, die Labortätigkeiten betreffen, gehören:

a. Vorhandensein des Labors auf dem Betriebsgelände
b. Durchführung einer Qualitätskontrolle (einschließlich Eluattests und der Druckfestigkeit, d.h. für Verfestigungsverfahren), einschließlich eines Screenings aller eingebrachten Abfälle, um sicherzustellen, dass alle Abfälle, die Inhibitatoren enthalten, ausgeschlossen werden. Im Fall, dass Inhibitatoren vorhanden sind, siehe Technik c unten. Für jeden Abfallstrom sollte ein Test im Labormaßstab durchgeführt werden, um eine maximale Effizienz für Mischung und Menge der hinzuzufügenden Absorbentien/Bindemittel zu gewährleisten, und falls der fragliche Abfallstrom als geeignet befunden wurde, um eine optimale "Formel" für die spätere Behandlung in vollem Anlagenmaßstab zu ermitteln. Jeder Test sollte Auswirkungen berücksichtigen, die auftreten, wenn verschiedene Abfallströme in derselben Charge behandelt werden, und zudem eine Mindestverweilzeit im Reaktionsbehälter ermitteln. Aufzeichnungen sollten darüber geführt werden, welche Abfallströme bereits getestet wurden sowie aufzeigen, ob sie als geeignet angenommen oder als ungeeignet zurückgewiesen wurden (siehe Abschnitt 4.1.1)
c. Angehen aller Hemmstoffe, die in der Zusammensetzung eines Bindemittels identifiziert worden sind, mit sekundären Bindemitteln/Additiven. Das Hauptanliegen liegt in der Bestätigung, dass dies der Fall ist, indem Behandelbarkeits-Studien für jeden Abfallstrom durchführt werden.
d. Festlegung der Zeitdauer, in der Proben für eine Analyse verfügbar gehalten werden müssen. Diese muss in Bezug zu der Zeitdauer stehen, die zum Erreichen einer vollständigen Stabilität des Endprodukts notwendig ist (siehe Abschnitt "Medienübergreifende Auswirkungen" unten)
e. Aufzeigen, wie mit Abfall umgegangen wird, der sich nicht mit der Charge verträgt
f. Testen der Auslaugbarkeit anorganischer Verbindungen unter Verwendung der standardisierten CEN-Auslaugverfahren und Anwendung einer angemessenen Teststufe: Grundlegende Charakterisierung, Übereinstimmungsuntersuchungen oder „on site" Untersuchungen
g. Durchführung von Annahmeprozeduren bei Ankunft des Abfalls an der Anlage, einschließlich Eluattests für jede Charge vor der Behandlung, um Konzentration von Schlüssel-Indikatorsubstanzen zu bestimmen, die während der Voruntersuchungen festgelegt wurden,
h. Analyse der folgenden Gruppe an Verbindungen, die Probleme bei der Deponierung verursachen können: Cl, CN, F, Sulfate, Kohlenwasserstoffe, PAH, PCB, Phenole, As, Cd, Gesamt-Cr, Cr(VI), Hg, Ni, Pb, Zn.

Erreichter Nutzen für die Umwelt
Das Betriebslabor bildet das entscheidende Element um sicherzustellen, dass erforderliche Kontrollen des Verfahrens-Inputs durchgeführt werden, und so ein gleichmäßiger Abfall-OUT erzeugt wird.

Medienübergreifende Auswirkungen
Auf Zement oder Kalk basierende Verfahren benötigen Jahre, um sich zu stabilisieren und Jahrzehnte/-Jahrhunderte oder noch länger, um ein Gleichgewicht mit der lokalen Umgebung zu erreichen. Deswegen sind Verweise auf eine vollständige Unveränderlichkeit technisch unrealistisch.

Anwendbarkeit
Verweisend auf Technik f in der obigen Beschreibung wird die chemisch-physikalische Behandlung auf monolithische und gekörnte Materialien angewendet (z.B. Behandlung von Rostaschen).

Verweisend auf Technik g in der obigen Beschreibung wird manchmal in Frage gestellt, ob es ökologisch und ökonomisch gerechtfertigt ist, vor der Behandlung einen Eluattest für jede Charge durchzuführen, wenn Abfallströme gut charakterisiert sind oder die Chargenladung minimal ist.

Treibende Kraft für die Anwendung
Die Deponierichtlinie 1999/31/EG und die Entscheidung des Rates 2003/33/EG (CEN) beziehen sich auf die Parameter, die berücksichtigt werden sollten, um zu bestimmen, ob ein Abfall deponiert werden kann:

- Die Deponierichtlinie (1999/31/EG) legt die Prinzipien der Charakterisierung von Abfall vor der Deponierung fest, dies sind a) Anwendung der 3-stufigen Charakterisierungsprozedur (grundlegende Charakterisierung, Übereinstimmungsuntersuchung, „on site“ Untersuchung) und b) stellt Anhang II der Deponierichtlinie fest, dass die Parameter Zusammensetzung, Auslaugverhalten, Langzeitverhalten und allgemeine Eigenschaften des abzulagernden Abfalls so genau wie möglich bekannt sein müssen
- Die CEN-Verfahren legen fest, welche Arten von Tests unter welchen Bedingungen angewendet werden müssen
- 2003/33/EG stellt Kriterien und Prozeduren für die Annahme von Abfall auf Deponien auf. Dazu gehören auch Kriterien für die Abfallannahme sowie für Probenahme- und Testverfahren.

Im Zusammenhang mit der Anwendung der Technik h (aus obiger Beschreibung) werden in Frankreich PAHs and PCBs vor einer Stabilisierung nicht systematisch untersucht. Eine Analyse wird nur durchgeführt, wenn PAHs and PCBs in großen Mengen gefunden werden (kann aus der Herkunft des Abfalls abgeleitet werden).

Literatur
[51, Inertec, et al., 2002], [55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.3.2.3 Immobilisierung

Beschreibung
Zu den Techniken gehören:

a. Festlegung eines angemessenen Bereichs von Eigenschaften eines Abfalls, der durch das Verfahren effektiv behandelt werden kann. Dieser Bereich wird durch die Möglichkeit des Verfahrens festgelegt, die in Frage kommenden Chemikalien/Ionen zu immobilisieren, um zu gewährleisten, dass das Endprodukt bestimmte Vorgaben erfüllt
b. Verwendung angemessen konstruierter Reaktionsbehälter für alle Immobilisierungsprozesse
c. Durchführung dieser Prozesse innerhalb kontrollierter Reaktionsbehälter. Vorgeben des Grads der Prozesskontrolle die benötigt wird, um sicherzustellen, dass Abfall und Reagenz/Bindemittel im richtigen Verhältnis in den Prozess eingehen und dass eine ausreichende Durchmischung (und Verweilzeit) erreicht wird. Es ist unbedingt erforderlich, dass mit den Behältern solche Ziele erreicht werden. Automatisierte Be- und Entladungs-, Beschickungs- sowie Mischgeräte sind ebenfalls erforderlich, diese müssen überwacht und kontrolliert werden können
d. Nutzen einer geeigneten Prozessüberwachung in eingehausten Anlagen sowie bei den Minderungssystemen
e. Anwendung von Voruntersuchungen zur Bewertung von Abfall
f. Einführung von Maßnahmen zur Begrenzung staubiger Stoffe
g. Einschränkung des Einsatzes von Abfall auf solchen mit geringen Konzentrationen an VOCs oder geruchsintensiven Verbindungen (siehe „Anwendbarkeit“ und „Medienübergreifende Auswirkungen“ unten)
h. Anwendung überwachter und eingehauster Verfahren der Beschickung
i. Mischung von Reagenzien und Abfall mit Hilfe von Rührern oder in den Mischbehälter eingebauten Mischsystemen

j. Nutzung von Schneckenförderern, der Schwerkraft oder Druckluft für die Massenbeförderung von trockenen Abfällen und Reagenzien
k. Wegfall der Erfordernis, flüssige Abfälle aus Fässern und Containern unter Verwendung getrennter „Herstellungstanks“ zu dekantieren, um Flüssigkeiten und pumpbare Schlämme vorzumischen
l. Beförderung der Einsatzstoffe in den Mischbehälter mittels Rohrleitungen
m. Verwendung von Saugbelüftungssystemen, die auf eine Absaugung großer Luftvolumina ausgelegt sind, entsprechend der Dimensionen der Mischbereiche, und die die Notwendigkeit des Zugangs für Fahrzeuge zum Be- und Entladen mit einbeziehen. Es ist auch notwendig zu beweisen, dass die Saugbelüftungssysteme so ausgelegt sind, dass sie alle vorhersehbaren Emissionen erfassen können, außer in Notsituationen
n. Vorhandensein einer zentralen Abluftreinigungsanlage zur Behandlung des Luftdurchflusses, einschließlich der Spitzenbelastungen in Zusammenhang mit dem Be- und Entladen
o. Detaillierte Behandlungs- und Beseitigungsmethoden für alle verbrauchten Gaswäscherflüssigkeiten und Absorbentien, (z.B. Aktivkohle und abgeschiedene Schadstoffe)
p. Vorhandensein regelmäßiger Inspektions- und Wartungsprogramme, einschließlich:
   - Ersetzen von unterirdischen oder teilweise unterirdischen Behältern ohne Rückhaltevorrichtungen durch oberirdische Konstruktionen
   - Ersetzen von Konstruktionen ohne Rückhaltevorrichtungen
q. Durchführung von chemisch-physikalischen Behandlungen, wie etwa Neutralisationsreaktionen in der flüssigen Phase, um die Durchmischung und Verfahrenskontrolle zu steigern
r. Sicherstellung, dass Neutralisationsreaktionen in der festen Phase so durchgeführt werden, dass die Reaktion vollständig abläuft
s. Verwendung von hydraulischen Bindemitteln, ergänzt durch spezifische chemische Reagenzien, insbesondere für:
   - die Fixierung von Quecksilber als HgS und $Hg_3(SO_4)O_2$
   - die Fixierung von Metallen als Metallhydroxidschlamm (z.B. Zn, Pb, Cu, Cr, Cd), als unlösliche Verbindungen und durch Verfestigung
   - die Reduktion sechswertigen Chroms unter alkalischen Konditionen (z.B. durch $FeSO_4$) mit anschließender Fällung und Verfestigung
   - die Fixierung organischer Verbindungen aus Schlamm der chemischen Industrie, der Sulfate und organische Salze enthält, mit anschließender Fällung der Sulfate, um die Dauerhaftigkeit der Struktur zu gewährleisten, dies z.B. durch Zugabe von Ton zur Adsorption organischer Verbindungen
   - einen hohen Arsengehalt (z.B. aus der chemischen oder metallurgischen Industrie oder aus der Erzbehandlung) mittels Oxidation von As(III) mit anschließender Stabilisierung und Verfestigung
t. Berücksichtigung der Möglichkeit, die Qualität des Endprodukts durch die Verwendung von Additiven zu verbessern (zum Beispiel hydrophoben Reaktanten usw.)
u. bei der Beseitigung von problematischen[19] Abfällen, deren Behandlung schwierig und die Verbrennung teuer ist, sollte nicht ausschließlich auf Stabilisierungsverfahren vertraut werden. Zu den problematischen Abfällen gehören feste Cyanide, Oxidationsmittel, Chelatbildner, Abfälle mit hohem TOC, Abfälle die Lösemittel mit niedrigem Flammpunkt enthalten, sowie Gasflaschen
v. Beschränkung der Menge an Reagenzien (einschließlich chemischer und physikalischer Bindemittel und Verfestigungsmittel), die hinzugefügt werden dürfen, um eine Verdünnung zu vermeiden
w. Vorhandensein von Immobilisierungsspezialisten, die bei Bedarf, unter Einsatz von Labortests, spezifische Bindemittel für einen bestimmten Abfall entwickeln

Erreichter Nutzen für die Umwelt

Steigert die Umweltleistung der Immobilisierungstechniken (z.B. Senkung der Permeabilität, Verringerung der spezifischen Oberfläche, chemische Pufferung). Die Stabilisierung ist ein kalter Prozess und benötigt folglich keine Energie. Der Abfall-OUT dieser Technik hat in der Regel sehr gute chemisch-physikalische/-Auslaugeigenschaften. Da es sich um kalte Prozesse handelt, sind Rauchgase oder eine Luftverschmutzung nur gering (z.B. generiert durch die Verwendung von Brennstoff). Eine Wasserdurchlässigkeit von $3{,}7 \cdot 10^{-11}$ m/s kann im Endprodukt erreicht werden, wenn Zement als Mittel zur Immobilisierung verwendet wird.

Medienübergreifende Auswirkungen

Verhältnisse von Abfall-OUT/Abfall-IN liegen gewichtsbezogen zwischen 1,2 und 2,4 und liegen volumenbezogen üblicherweise zwischen 0,9 und 1,4 (infolge der typischen Erhöhung der Dichte des Abfall-OUT im Ver-

[19] Anm.d.Übers.: Im Originaltext wird hier das Wort „intractable“ genutzt, was mit „heikel“ oder „hartnäckig“ übersetzt werden kann. Das Wort „problematisch“ erscheint im Kontext geeigneter.

gleich zum Abfall-IN). Folglich führt das Verfahren zu einem Gewichtsanstieg und einer geringfügigen Änderung des Volumens.

Um VOC-Emissionen zu vermeiden (siehe Technik g in obiger Beschreibung), kann VOC-haltiger Abfall in einem geschlossenen Mischbehälter behandelt werden (z.B. Mischtrommel), die emittierten VOCs, die nicht verfestigt wurden, werden z.B. durch Gaswäscher behandelt. Solche Sekundärbehandlungen können eine doppelte Behandlung vermeiden (z.B. Thermodesorption zur Behandlung von VOCs mit anschließender Stabilisierung/Verfestigung zur Behandlung von Metallen).

Die Immobilisierung ist nicht in der Lage, den Schadstoffgehalt im Abfall zu senken, sie kann nur die chemische Zusammensetzung durch einige chemische Reaktionen ändern. Organische Abfälle werden in der Regel nicht durch Stabilisierung/Verfestigung immobilisiert, sondern durch Feststoffe adsorbiert. Was auch immer die Stabilisierung/Verfestigung letztendlich als Prozess erreicht, so sollte immer berücksichtigt werden, dass der Abfall-OUT nicht für eine lange Zeitdauer stabil ist und die Bestandteile des Abfall-OUT mitunter entweichen können (z.B. durch Auswaschung).

Der wahrscheinliche Anstieg des pH-Werts sowie der Basenkapazität einer Mischung durch diese Behandlung kann zu einem Anstieg der Auslaugbarkeit von Stoffen, wie amphoteren Metallen (Blei, Cadmium bei pH-Werten über 12,5), pH-empfindlichen Arten wie Arsen und Cyaniden, wie auch von einigen organischen Verbindungen, führen.

Betriebsdaten

Diese Technik ist einfach zu handhaben und ein relativ einfaches Verfahren. Der Energieverbrauch der Behandlung ist niedrig. Wenn Zement als Stabilisator verwendet wird, liegt das Verhältnis von zu behandelndem Abfall zum Zement zwischen 1:3 und 1:4, was abhängig von der Abfallart ist.

Anwendbarkeit

Diese Technik ist am wahrscheinlichsten bei der Behandlung anorganischer Abfälle effizient, wenn die Löslichkeit bereits ziemlich niedrig ist. Mit dieser Technik kann ein breites Spektrum an Abfällen behandelt werden (Flüssigkeiten, Feststoffe, viele chemische Schadstoffe, Aschen usw.). Abfall, der Chromate oder amphotere Metalle wie Pb und Zn enthält, und Abfälle mit einem gewissen Gehalt an löslichen Salzen benötigen vor der Immobilisierung eine Vorbehandlung. Zu den Abfällen, die sich nicht für eine Immobilisierung eignen, gehören:

- entzündliche und hochentzündliche Abfälle (z.B. Lösemittel mit niedrigem Flammpunkt)
- Abfälle, die flüchtige Stoffe enthalten. In manchen Fällen können sehr niedrige VOC-Konzentrationen akzeptiert werden
- Oxidationsmittel. In manchen Fällen können sehr niedrige Konzentrationen an Oxidationsmitteln akzeptiert werden
- Geruchsintensive Abfälle. In manchen Fällen können Materialien mit einem sehr geringen Gehalt an Geruchsstoffen akzeptiert werden
- Abfall mit einem leicht löslichen organischen Anteil[20] und einen hohen CSB
- Abfall der Molybdän enthält
- Abfall der lösliche anorganische Salze enthält
- feste Cyanide. In manchen Fällen können sehr niedrigen Konzentration an Cyaniden akzeptiert werden
- Chelatbildner. In manchen Fällen können sehr niedrige Konzentration an Chelatbildnern akzeptiert werden.

Einige der oben erwähnten Abfälle können durch spezifische Reagenzien behandelt werden. Zum Beispiel sind Zement (wie Tabelle 4.26 zeigt) und Kalk als Reagenzien verträglich mit Oxidationsmitteln.

Wirtschaftlichkeit

Kalte Verfahren werden als ökonomisch attraktive Techniken angesehen. Sie erfordern in der Regel einfache Gerätschaften und beinhalten niedrige Investions- sowie Betriebskosten (für Betonmischer, Silos, Pumpen usw.).

Reagenzien/Bindemittel werden verwendet, wenn es möglich ist, um die Behandlungskosten zu senken (Flugaschen aus Kraftwerken, Schlacke aus Stahlwerken, Reststoffe aus Zementöfen). Betreiber sind nicht immer in der Lage (wegen gesetzlicher Regelungen, Verfügbarkeit in der Umgebung, Interesse an einem speziellen Abfall usw.), Abfälle als Reagenzien zu verwenden, obwohl es natürlich im Allgemeinen ökonomisch tragfähig ist.

[20] Anm.d.Übers.: Im Originaltext steht hier „waste“, was aber zu Missverständnissen führen könnte.

Treibende Kraft für die Anwendung
Deponierichtlinie 1999/31/EG. Eine einfache physikalische Verdünnung oder Absorption, die nicht zu einer damit verbundenen physikalisch-chemischen Veränderung führt, ist kein akzeptables Behandlungsverfahren. Zum Beispiel ist die Absorption einer Flüssigkeit in Sägemehl, so dass der Abfall nicht mehr flüssig ist, als Vorbehandlung für die Deponierung inakzeptabel.

Beispielanlagen
13 Anlagen stabilisieren etwa 400 Kilotonnen gefährliche Abfälle vor der Deponierung, gemäß der französischen Gesetzgebung und, seit 2004/2005, nach EU-Gesetzgebung. Es stehen auch mobile Anlagen zur Verfügung, um Abfall auf Industriegeländen zu behandeln.

In Portugal stabilisiert eine Anlage Flugaschen aus der Verbrennung von Siedlungsabfall vor deren Deponierung.

Literatur
[51, Inertec, et al., 2002], [52, Ecodeco, 2002], [53, LaGrega, et al., 1994], [55, UK EA, 2001], [136, Straetmans, 2003], [150, TWG, 2004]

4.3.2.4 Verfestigung mit Zement

Beschreibung
Im Allgemeinen werden Abfälle mit Portlandzement sowie Additiven zur Kontrolle der Zementeigenschaften und genügend Wasser gemischt, um sicherzustellen, dass Hydrierungsreaktionen zum Binden des Zements stattfinden. Sowohl Stabilisierungs- als auch Verfestigungsprozesse finden statt. Die Abfälle werden dabei in die Zementmatrix eingebunden. In der Regel reagiert der Abfall-IN mit Wasser und dem Zement, wobei bis zu einem gewissen Ausmaß Metallhydroxide oder –carbonate gebildet werden, welche üblicherweise weniger löslich vorliegen, als die ursprünglichen Metallverbindungen in der Abfallmatrix.

Zementbasierte Verfestigungstechniken beruhen auf der Nutzung von Gerätschaften, die in der Regel leicht erhältlich sind. Die Misch- und Umschlagstechniken im Zusammenhang mit den Verfahren sind gut entwickelt, und die Technik ist robust im Hinblick auf Schwankungen der Eigenschaften des Abfall-IN.

Das verfestigte Produkt wird entweder oberirdisch oder unterirdisch deponiert. In manchen Ländern darf es als Versatzmaterial in alten Salzbergwerken verwendet werden.

Erreichter Nutzen für die Umwelt
Der Hauptvorteil der Verfestigung mit Zement liegt in der verringerten Kontaktmöglichkeit zwischen Wasser und Abfall-IN und in gewissem Maße auch in der Bildung von weniger löslichen Metallhydroxiden oder –carbonaten. Amphotere Metalle können auch behandelt werden. Die Handhabung des verfestigten Produkts ist relativ einfach, und das Risiko der Staubbildung ist sehr niedrig. Die kurzfristige Freisetzung von Schwermetallen aus den Produkten ist in der Regel relativ gering. Die Technik erleichtert in manchen Fällen die Nutzung des Abfall-OUT als Versatz- oder Baumaterial im Bergbau.

Neuere Weiterentwicklungen dieser Technik, zum Einbau von Additiven, um schwierige Schadstoffe vor der Einkapselung zu binden, werden durchgeführt. Als schwierige Schadstoffe gelten Arsen, Blei, Phenole (einschließlich PCP), PCBs und Dioxine. Es liegen Beweise vor, dass Zement die reduktive Chlorabspaltung von Trichlorethanol (TCE) katalysieren oder an ihr teilnehmen kann.

Medienübergreifende Auswirkungen
Die meisten Studien legten den Schwerpunkt auf mögliche Kurzzeit-Freisetzungen von Schadstoffen aus dem Abfall-OUT. Über das Langzeitverhalten des Abfall-OUT wird sehr viel weniger verstanden. Es wird erwartet, dass die Auslaugung von Kalk mit der Zeit die chemischen Eigenschaften des Abfall-OUT verändert und auch, dass eine erhöhte Auslaugung bei abgesenkten pH-Wert stattfinden kann. Die erforderliche Zeit für eine vollständige Freisetzung aus stabilisiertem Abfall-OUT liegt erwartungsgemäß in der Größenordnung von mehreren hundert bis tausend Jahren. Der hohe pH-Wert bei zementbasierten Systemen kann zu einer signifikanten Auswaschung amphoterer Metalle (Pb und Zn) führen.

Die Nachteile dieser Methode sind, dass die Auslaugung löslicher Salze nicht behindert wird, was schließlich zum physikalischen Zerfall des verfestigten Produkts führen kann, der wiederum eine weitere Auslaugung ermöglicht. In diesem Fall kann die Zufuhr von Luft zu einer Karbonisierung führen, was den Anstieg der Porosität und den Verlust an Festigkeit teilweise ausgleicht.

Die Zugabe von Zement und Additiven erhöht die zu behandelnde Abfallmenge; in der Regel werden etwa 30 – 50 % des Trockengewichts des Abfall-IN als Zement und Additive sowie 30 bis 100 % des gesamten Trockengewichts als Wasser hinzugegeben. Folglich steigt der Abfall-OUT in der Regel von 20 - 30 kg/Tonne Abfallinput auf etwa 40 – 60 kg/Tonne Abfall, inklusive der Zugabe von Wasser entsprechend 50 % des Gesamt-Trockengewichts.

Wenn Schwermetalle nicht aus den Rückständen zurück gewonnen werden, was potenziell möglich, jedoch kostspielig und Energie verbrauchend ist, werden die Schadstoffe früher oder später wieder freigesetzt. Es sollte betont werden, dass dies Zeitperspektiven entspricht, in dem der überwiegende Teil der in Frage kommenden Metalle in einer Zeit freigesetzt wird, in der wahrscheinlich bereits alle Tätigkeiten zur Sickerwassererfassung aus den Deponien seit vielen Jahren eingestellt worden sind. Zusätzlich könnte der Ort der Ablagerung vergessen worden sein, da das fragliche Gebiet zu diesem Zeitpunkt sehr wahrscheinlich seit langer Zeit zu anderen Zwecken genutzt worden sein wird.

Zement kann manche toxischen Bestandteile enthalten, wie etwa Flugasche, Zementofenstaub, Hochofenschlacke und Bitumen.

Betriebsdaten
Der Energie- und Wasserverbrauch schwankt und wurde nicht quantifiziert. Betrieb und Überwachung der bei dieser Technik benutzten Geräte gelten als relativ einfach und sind vergleichbar mit Standardpraktiken in der Betonindustrie.

Anwendbarkeit
Die Verfestigung wird in der Regel in geeigneten Anlagen durchgeführt, die in der Nähe des endgültigen Bestimmungsort des Endmaterials liegen, folglich besteht für einzelne Verbrennungsanlagen nicht die Notwendigkeit, Verfestigungs-Equipment zu installieren. Die Technik kann auf alle Arten von ARA-Abfällen[21] angewendet werden. Die Verfestigung mit Zement wird auch bei vielen anderen Arten von gefährlichen Abfällen, einschließlich der Beseitigung schwach radioaktiver Abfälle, eingesetzt. Weitere Informationen über die Anwendbarkeit der Zementtechnik befinden sich in der Tabelle 4.26 im folgenden Abschnitt 4.3.2.5.

Wirtschaftlichkeit
In den meisten Fällen kann der Abfall-IN an bestehende Anlagen geliefert werden. Die Behandlungskosten für eine alleinige Verfestigung mit Zement werden auf etwa 25 EUR pro Tonne Abfall-IN geschätzt.

Treibende Kraft für die Anwendung
Die Technik ist relativ einfach zu benutzen, und das nötige technische Wissen ist weithin verfügbar. Die Auslaugeigenschaften des verfestigten Produkts können im Vergleich zum unbehandelten Abfall-IN bedeutend verbessert werden. Die Stabilisierung von ARA-Abfällen durch Verfestigung mit Zement existiert seit langem und wird immer noch von Behörden in vielen Ländern der ganzen Welt akzeptiert. Der Hauptgrund für die Einführung dieser Technologie in Holland war der Mangel an Deponiekapazitäten für gefährliche Abfälle.

Beispielanlagen
Die Technik ist wahrscheinlich die gebräuchlichste Methode zur Behandlung von ARA-Abfällen und ist in Europa und Japan weit verbreitet. Einige Beispiele zur Verfestigung mit Zement werden unten aufgelistet:

[21] Anm.d.Übers.: Abfälle aus der Abgasreinigungsanlage (ARA)

Land	Eigenschaften
Österreich	Eine Anlage zur Verfestigung von Schlacken und Aschen aus der Verbrennung von Siedlungsabfällen mit Zement ist in Wien in Betrieb
Deutschland	Verschiedene Salzbergbaufirmen nehmen verschiedene Abfallarten an (z.B. ARA-Abfälle, Schlacken, Abrissmaterial aus Gebäuden) und verfestigen diese mit Zement, indem sie Reststoffe als Füllmaterial verwenden. Der verfestigte Abfall-OUT wird hauptsächlich als Versatzmaterial oder zur Stabilisierung verwendet. Die Verfestigung mit Zement wird für mehrere Bergwerke in einer zentralen Anlage durchgeführt, in der verschiedene Rezepte je nach endgültiger Bestimmung und je nach Anforderungen verwendet werden. Aus der zentralen Verfestigungsanlage wird das Produkt zum Empfängerbergwerk transportiert
Schweden	Auf einem Deponiestandort in Schweden (Hogdalan) wird mit Zement verfestigter ARA-Abfall in Blöcke gegossen und nach dem Aushärten auf einer oberirdischen Deponie untergebracht
Schweiz	In der Schweiz wird eine Variante der Verfestigung mit Zement eingesetzt (welche ursprünglich durch die Schweizer Regierung und Sulzer gefördert wurde), bei der Abfall-IN mit Wasser bei einem Flüssig-Fest-Verhältnis von 2:1 gewaschen und entwässert wird, bevor er mit Zement gemischt wird. Dies hat den Nutzen, dass die meisten löslichen Salze aus dem Abfall-IN entfernt werden und somit die Langlebigkeit des verfestigten Produkts erhöht wird. Nach der Verfestigung wird der Abfall-OUT vor der Aushärtung auf oberirdischen Deponien abgelagert. In einigen Anlagen wird die Mischung in Formen gegossen, um Blöcke herzustellen, die dann zu oberirdischen Deponien transportiert werden

Tabelle 4.25: Beispiele für die Verfestigung mit Zement
[124, Iswa, 2003], [150, TWG, 2004]

Literatur
[113, COWI A/S, 2002], [124, Iswa, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.2.5 Verwendung anderer Reagenzien im Immobilisierungsverfahren

Beschreibung
Zu den Techniken gehören:

a. Einkapselung durch Bitumen
b. Karbonisierung unter Verwendung von CO_2
c. Immobilisierung mit Tonmineralien.

Erreichter Nutzen für die Umwelt
Flugaschepartikel können durch Bitumen eingekapselt werden, wodurch ein möglicher Kontakt mit Wasser eingeschränkt wird. Dies verbessert die Auslaugeigenschaften der Flugasche; wahrscheinlich werden weniger Schwermetalle freigesetzt, als dies im Falle einer Verfestigung mit Zement geschieht.

Reststoffe aus der Abfallverbrennung können eher durch Karbonisierung (Verwendung von CO_2) als durch Hydrierung stabilisiert werden (mit oder ohne Zugabe von Zement). Die Karbonisierung hat einen tiefgreifenden Einfluss auf die Auslaugung von Pb und Zn und führt zu einem Produkt mit niedrigerem pH-Wert (um 9), jedoch ohne Verlust der Neutralisationskapazität für Säuren.

Medienübergreifende Auswirkungen
Bezüglich der Einkapselung mit Bitumen liegen keine Informationen über eine mögliche Auslaugung von Dioxinen aus verfestigten Aschepartikeln vor, aber es wird angemerkt, dass die Verfestigungsmethode an sich nicht den ursprünglichen Gehalt senkt.

Anwendbarkeit

Abfallbestandteil	Reagenz auf Basis von Zement	Reagenz auf Basis von Puzzolan	Thermoplastische Reagenzien	Organisches Polymer als Reagenz
Nichtpolare organische Stoffe, wie etwa: • Öl und Fett • aromatische Kohlenwasserstoffe • halogenierte Kohlenwasserstoffe • PCBs	Können das Aushärten verhindern. Senken die langfristige Beständigkeit der Stabilisierungsprodukte. Flüchtige Bestandteile können beim Mischen entweichen. Bewiesene Wirksamkeit unter bestimmten Bedingungen	Können das Aushärten verhindern. Senken die langfristige Beständigkeit der Stabilisierungsprodukte. Flüchtige Bestandteile können beim Mischen entweichen. Bewiesene Wirksamkeit unter bestimmten Bedingungen	Organische Stoffe können beim Erwärmen verdampfen. Bewiesene Wirksamkeit unter bestimmten Bedingungen	Können das Aushärten verhindern. Bewiesene Wirksamkeit unter bestimmten Bedingungen
Polare organische Stoffe, wie etwa: • Alkohole • Phenole • organische Säuren • Glykole	Phenol verzögert das Aushärten in bedeutendem Maße und senkt die kurz- und langfristige Beständigkeit der Stabilisierungsprodukte	Phenol verzögert das Aushärten in bedeutendem Maße und senkt die kurz- und langfristige Beständigkeit der Stabilisierungsprodukte. Alkohole können das Aushärten verzögern.	Organische Stoffe können beim Erwärmen verdampfen.	Keine bedeutende Auswirkung auf das Aushärten
Säuren: • Salzsäure • Flusssäure	Keine bedeutende Auswirkung auf das Aushärten. Zement neutralisiert die Säuren. Portlandzement der Typen II und IV führt zu größerer Langlebigkeit als Typ I. Bewiesene Wirksamkeit	Keine bedeutende Auswirkung auf das Aushärten. Verträglich, neutralisiert Säuren. Bewiesene Wirksamkeit	Können vor der Einbindung neutralisiert werden	Können vor der Einbindung neutralisiert werden. Harnstoff-Formaldehyd hat sich als wirksam erwiesen
Oxidantien, wie etwa: • Natriumhypochlorat • Kalium permanganat • Salpetersäure • Kalium dichromat	Verträglich	Verträglich	Kann Zusammenbruch der Matrix verursachen. Brandrisiko	Kann Zusammenbruch der Matrix verursachen. Brandrisiko
Salze, wie etwa: • Sulfate • Halogenide • Nitrate • Cyanide	Verlängerte Aushärtungszeiten Verringerte Langlebigkeit. Sulfate können das Aushärten verzögern und Abplatzen verursachen, wenn nicht Spezialzement verwendet wird. Sulfate beschleunigen andere Reaktionen	Halogenide werden leicht ausgelaugt und verzögern das Aushärten. Sulfate können Reaktionen verzögern oder beschleunigen	Sulfate und Halogenide können dehydratisieren und dann rehydrieren, was zu Abspaltungen führt	Verträglich
Schwermetalle, wie etwa: • Arsen • Cadmium • Chrom • Blei • Quecksilber	Verträglich. Können die Aushärtungszeit verlängern. Bewiesene Wirksamkeit unter bestimmten Bedingungen	Verträglich. Bewiesene Wirksamkeit für bestimmte Arten von Stoffen (Blei, Cadmium, Chrom)	Verträglich. Bewiesene Wirksamkeit für bestimmte Arten von Stoffen (Kupfer, Arsen, Chrom)	Verträglich. Bewiesene Wirksamkeit für Arsen

Tabelle 4.26: Eignung von Reagenzien zur Stabilisierung von Abfall [53, LaGrega, et al., 1994]

Die Einkapselung mit Bitumen ist nur auf Flugasche angewendet worden, nicht aber auf Reststoffe der trockenen und halbtrockenen Abgasreinigung, da es Anhaltspunkte dafür gibt, dass diese Probleme verursachen können.

Beispielanlagen
Die Verfestigungsbehandlung durch Bitumen ist in den Niederlanden angewendet worden, die Carbonisierung von Reststoffen aus der Abfallverbrennung wird in GB angewendet und die Immobilisierung durch Tonmineralien in Österreich.

Literatur
[53, LaGrega, et al., 1994], [124, Iswa, 2003], [150, TWG, 2004],

4.3.2.6 Stabilisierung mit Phosphat

Beschreibung
Eine chemische Stabilisierung unter Nutzung von Phosphat als Stabilisierungsmittel wird angewendet. Das Behandlungsverfahren ist relativ einfach und besteht aus einem Mischgerät (wie etwa einer Lehmmühle), in dem der Abfall-IN, bei kontrollierten Anteilen, zugegeben wird. Eine geschützte Form löslichen Phosphats wird anschließend in den Mischer gegeben. Nachdem das Phosphat sorgfältig mit dem Abfall-IN gemischt wurde, wird mit einem Förderband am Ende des Mischers das behandelte Produkt entfernt. In manchen Fällen werden abhängig von den Abfalleigenschaften andere Additive, wie etwa Kalk, verwendet. Die Reaktionskinetik verläuft schnell, und das Material wird ohne weiteres Aushärten als vollständig behandelt angesehen. Manchmal wird die Zugabe von Phosphat zusammen mit der Karbonisierung eingesetzt, um manche Metalle im Abfall zu binden (z.B. Pb).

Erreichter Nutzen für die Umwelt
Das Verfahren hält Salze im Abfall-OUT zurück. Im Vergleich zu anderen ähnlichen Verfahren werden zusammen mit dem Phosphat relativ kleine Wassermengen hinzugefügt. Das Verfahren erzeugt kein Abwasser.

Medienübergreifende Auswirkungen
Augenblicklich gibt es keine Verwendungsvorschläge für das behandelte Produkt. Eine substanzielle Auslaugung ist nach Deponierung möglich, insbesondere ist dies der Fall bei manchen Schwermetallen wegen ihrer erhöhten Löslichkeit (z.B. Cd). Es wird erwartet, dass die Freisetzung von Salz und Schwermetallen höher ist als bei anderen Behandlungen. Die Phosphatstabilisierung kann die Mobilität von Phosphorverbindungen im abgelagerten Abfall erhöhen. In einem Fall wurde gezeigt, dass die Verfügbarkeit des Gesamtphosphats von 2 mg/kg (vor der Behandlung) auf 4900 mg/kg gestiegen ist (nach der Behandlung).

Betriebsdaten
Die spezifischen Mengen sowohl von Wasser und Phosphat als auch von anderen Additiven schwanken wahrscheinlich je nach Eigenschaften des Abfall-IN, allerdings liegen keine Daten zur Quantifizierung vor.

Anwendbarkeit
Das Verfahren wird in allen Fällen, außer einem, als ein integrierter Schritt in der Verbrennungsanlage eingesetzt, es könnte aber auch als zentralisierte Anlage zur Behandlung von Reststoffen aus mehr als einer Verbrennungsanlage errichtet werden. Das Verfahren wurde ursprünglich entwickelt, um Reststoffe aus Hausmüllverbrennungsanlagen zu behandeln, allerdings wurden auch verschiedene andere Abfallarten (z.B. kontaminierter Boden, Schlacken, Schlämme usw.) untersucht.

Wirtschaftlichkeit
Die Behandlungskosten liegen bei 15 EUR pro Tonne ARA-Abfall. Zusätzlich wird dazu eine Lizenzgebühr zur Verwendung des patentierten Verfahrens erhoben, die sich auf 5 – 10 EUR pro Tonne beläuft. Die Investitionskosten liegen abhängig von den bereits vorhandenen Gerätschaften in einer Größenordnung von 150 000 – 500 000 EUR pro Anlage.

Treibende Kraft für die Anwendung
Der Hauptgrund zur Einführung dieser Technik liegt in der Einfachheit des Betriebs. Zurzeit wird sie wirtschaftlich in den Vereinigten Staaten, Japan und Taiwan betrieben. Das behandelte Produkt wird in diesen Ländern im Allgemeinen für die Deponierung als geeignet eingestuft.

Beispielanlagen
Das Verfahren wird zurzeit in den Vereinigten Staaten, Japan und Taiwan bei etwa 90 Hausmüllverbrennungsanlagen eingesetzt und behandelt über 2 Millionen Tonnen Rostaschen und ARA-Abfall pro Jahr.

Literatur
[124, Iswa, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.2.7 Thermische Behandlung von festem Abfall

Beschreibung
Zu diesen Techniken gehören die Verglasung, das Schmelzen und die Sinterung von festen Abfällen (siehe Abschnitt 2.3.3.2). Ihre Anwendung auf feste Abfälle in Abfallverbrennungsanlagen wird im BVT-Merkblatt „Abfallverbrennung“ abgedeckt.

Erreichter Nutzen für die Umwelt
Verschiedene Techniken können zur Erhitzung fester Abfälle eingesetzt werden: Elektrische Schmelzverfahren, brennstoffbefeuerte Brennerverfahren oder Schmelzen im Hochofen. Diese unterscheiden sich nur in der Art, wie Energie auf das feste Material übertragen wird. Im Allgemeinen sind die Techniken durch Öfen der Eisen- und Stahlproduktion beeinflusst.

Abhängig vom Schmelzverfahren können Metalllegierungen aus der Reaktionskammer zurückgewonnen werden. Abhängig von den Temperaturen in der Reaktionskammer sowie Art der Oxidation oder Reduktion in der Gasphase können Schwermetalle (insbesondere Cd und Pb) verflüchtigt und mit dem Abgas ausgetragen werden. Für alle Verfahrenskonfigurationen ist zur Minimierung der Emissionen eine Abgasbehandlung erforderlich.

Ein inhärenter Vorteil dieses Verfahren ist die Zerstörung von organischen Schadstoffen, z.B. von Dioxinen. Thermische Behandlungsanlagen verkleinern im Allgemeinen das Volumen auf etwa 30 – 50 % des Inputvolumens. Das Schmelzen erhöht die Dichte der Produkte in der Regel auf 2,4 – 2,9 Tonnen/m^3.

Geschmolzene und verglaste Produkte haben im Allgemeinen sehr gute Rückhalteeigenschaften, allerdings haben Schweizer Studien gezeigt, dass auch gesinterte Produkte in etwa denselben Stabilitätsgrad im Hinblick auf die Rückhaltung erreichen. Die Verglasung führt in der Regel zu den stabilsten und dichtesten Endprodukten.

Medienübergreifende Auswirkungen
Ein großer Nachteil dieser Techniken ist, dass sie einen beachtlich hohen Energieinput benötigen.

Die Verglasung und das Einschmelzen führen während der Behandlung zu einer Mobilisierung flüchtiger Elemente wie Hg, Pb und Zn, welche in einigen Verfahren, in Kombination mit anderen Parametern, genutzt werden, um ein recyclierbares Produkt mit geringem Schwermetallgehalt zu erzeugen. Wegen der Freisetzung von verdampften Schwermetallen ist bei der thermischen Behandlung ein zusätzliches Abgasbehandlungsverfahren erforderlich.

Thermische Behandlungsverfahren verbrauchen erhebliche Mengen an Energie. Zusätzlich erzeugen die Verfahren feste Rückstände aus der Abgasbehandlung. Andererseits können Metalle aus dem Verfahren zurückgewonnen werden, und in einigen Fällen kann sogar das verglaste Produkt recycelt werden.

Betriebsdaten
In der Regel werden um die 700 – 1200 kWh Energie pro Tonne behandelten Materials gebraucht, um die hohen Temperaturen zu erreichen und aufrechtzuerhalten, jedoch wurden auch Zahlen genannt, die bis zu etwa 8000 kWh/Tonne ansteigen. Energieverbrauch und Betrieb sind je nach Ofentyp und Anlagenkonstruktion unterschiedlich.

Anwendbarkeit
Üblicherweise sollte der Abfall-IN bestimmte Anforderungen erfüllen, zum Beispiel: Wassergehalt <5 %, nicht brennbare Inhaltsstoffe <3 %, Metallgehalt <20 Gew.-% und Aschegröße <100 mm.

Thermische Behandlungen werden zur Behandlung von Rostaschen sowie zur gemeinsamen Behandlung von Rostaschen und ARA-Abfall eingesetzt. Wegen des in der Regel hohen Gehalts an Salzen und Schwermetallen im ARA-Abfall, wird eine getrennte Behandlung von ARA-Abfall eine extensive Abgasbehandlung erfordern, was somit den Gesamtnutzen der getrennten Behandlung der Materialien verringert.

Wirtschaftlichkeit
Die Technik ist im Vergleich zu anderen Behandlungsmöglichkeiten in der Regel relativ teuer. Es wird über Behandlungskosten in der Größenordnung von 100 – 500 EUR/Tonne Input berichtet. Die Investitionskosten werden auf etwa 20 Millionen EUR für eine Anlage mit einer Behandlungskapazität von 1 – 1,5 Tonnen/Stunde geschätzt.

Treibende Kraft für die Anwendung
Der Hauptgrund für die Anwendung der Technik besteht in den guten Rückhalteeigenschaften des Endprodukts, insbesondere im Fall der Verglasung, und in der bedeutenden Volumenreduktion. In dicht besiedelten Gebieten, wie etwa in Japan, kann die Deponiekapazität einen knappen Rohstoff darstellen und die Deponierung folglich relativ teuer sein. Organische Verbindungen wie Dioxine und Furane werden fast vollständig zerstört.

Beispielanlagen
Es gibt 30 – 40 Einschmelz- und Verglasungsanlagen in Japan. In Europa und den Vereinigten Staaten sind auch Anlagen in Betrieb.

Land	Eigenschaften			
USA	Zu einem Verglasungsverfahren gehören Anfangsschritte wie die Extraktion von Wasser, Entwässerung und Trocknung bei 500 °C vor der Zugabe von glasbildenden Additiven und anschließendem Schmelzen. Das anfängliche Waschen und Trocknen wird durchgeführt, um Chloride und den Restgehalt an organischem Kohlenstoff zu entfernen			
Japan	Anlagen zur thermischen Behandlung von Verbrennungsschlacke und ARA-Abfall:			
		In Betrieb	Geplant	Kapazität (Tonnen/Tag)
	Elektrisches Schmelzen:			
	Elektro-Lichtbogen-Verfahren	4	2	655
	Plasma-Lichtbogen-Verfahren	4	2	183
	Elektrischer Widerstand	2	3	148
	Brenner:			
	Reflektierende Oberfläche	12		209
	Rotierende Oberfläche	5		84
	Luft Schmelzen:			
	Koksbett	3		170
	Restkohlenstoffverbrennung	1		15
	Summe	31	7	1464

Tabelle 4.27: Anlagen zur thermischen Behandlung

Literatur
[124, Iswa, 2003], [150, TWG, 2004]

4.3.2.8 Verwertung von Salzen durch Lösung/Eindampfung

Beschreibung
Wenn bei diesem Verfahren feste Abfälle erzeugt werden, sollte das Potential der möglichen Verwertung berücksichtigt werden. So ist die Rückgewinnung von z.B. Salzen (NaCl, $CaCl_2$, HCl und Gips) möglich. Diese Endprodukte können mittels Eindampfen oder der Rekristallisation des Salzes aus dem Abwasser der Abgasbehandlung gewonnen werden, entweder am Entstehungsort oder in einer zentralisierten Eindampfanlage.

Wenn diese Waschflüssigkeiten getrennt behandelt und eingedampft werden, können verwertbare Produkte wie Salze oder Salzsäure gewonnen werden. Das Wiederverwendungspotenzial solcher Produkte hängt stark von der Produktqualität ab. Bei der Rückgewinnung von Salzen wird die Waschflüssigkeit mit Natriumhydroxid und Calciumcarbonat behandelt, um festen Gips zu erzeugen. Nach der Abtrennung bleibt eine Flüssigkeit zurück, die hauptsächlich Natrium- und Calciumchlorid enthält. Die zurückgewonnenen Produkte werden einer Qualitätskontrolle unterzogen oder zur Verbesserung der Qualität weiter behandelt und dann verkauft.

Erreichter Nutzen für die Umwelt
Das Hauptziel des Verfahrens ist es, die Einleitung von salzhaltigem Abwasser in die Kanalisation zu vermeiden. Dies wird mittels Eindampfen der Waschflüssigkeiten der nassen Abgasbehandlungsverfahren erreicht.

Wenn festes Natriumchlorid individuell aus der oben genannten Lösung abgetrennt werden muss, wird dies durch Eindampfen der Lösung auf einen Salzgehalt von über 30 % erreicht, da bei dieser Konzentration reines Salz auskristallisiert. Die oben genannten zurückgewonnenen Salzprodukte werden am häufigsten in Bereichen wiederverwendet, in denen im Winter eine Nachfrage nach Auftausalzen besteht.

Die Wiederverwendung der zurückgewonnenen Salze und Gips kann natürliche Rohstoffe schonen.

Medienübergreifende Auswirkungen
Die Hauptnachteile eines externen Eindampfens von Abwässern für Salz bestehen nicht nur in Zusammenhang mit Betriebs- und Materialproblemen, sondern besteht auch in dem hohen Energieverbrauch, der für das Eindampfen erforderlich ist.

Betriebsdaten
Das Eindampfen von salzhaltigem Abwasser hängt von der Salzkonzentration ab, welche stark schwanken kann. Außer den Korrosionsproblemen müssen auch die relativ hohen Investitions- und Betriebskosten berücksichtigt werden.

Bei der Produktion von Gips gibt es nur wenige Betriebsprobleme. Allerdings wird die Qualität des Gipses nicht nur durch seine Reinheit im Hinblick auf unerwünschte Inhaltsstoffe, sondern auch durch seine Farbe bestimmt. Unter normalen Voraussetzungen ist zu erwarten, dass 2 - 5 kg recycelbare Produkte pro Tonne Abfall erzeugt werden.

Bei der Produktion von Calciumchlorid sollte das Hauptaugenmerk auf das extreme Korrosionspotenzial, das entstehen kann, gelegt werden, sowie auf das Risiko einer unbeabsichtigten Änderung des Aggregatzustands von fest zu flüssig und umgekehrt.

Anwendbarkeit
Kann in Verbrennungsanlagen für Siedlungsabfall mit nasser Abgasbehandlung angewendet werden. Für Siedlungsabfallverbrennungsanlagen in denen die Verbrennungsabgase mittels nasser Abgaswäsche behandelt werden, ist eine Einleitung des Abwassers nach der Gesetzgebung und nach lokalen Anforderungen nicht gestattet. Das gereinigte Abwasser aus der Nasswäsche enthält immer noch Salze, die normalerweise im Abwasserleitungssystem nicht erwünscht sind, weil sie Korrosion verursachen oder den Salzgehalt des Vorfluters erhöhen. Aus diesem Grund wird das Abwasser normalerweise thermisch behandelt oder falls es für Kühlzwecke eingesetzt werden soll, wird es im Rohabgas der Verbrennungsanlage eingedüst und verdampft. Hierbei werden keine verwertbaren Produkte erzeugt.

Eine Eindampfung des behandelten salzhaltigen Abwassers kann sowohl in zentralen als auch in dezentralen Anlagen durchgeführt werden. In letzterem Fall könnte die Siedlungsabfallverbrennungsanlage selbst die benötigte Eindampfenergie bereitstellen.

Bei der Gipsproduktion kann dies in erster Linie durch alleinige Betriebsänderungen erreicht werden, d.h. durch Einführung und Betrieb geeigneter Entwässerungsgeräte, einschließlich Zyklonen, Pumpen usw.

Wirtschaftlichkeit
Die Kosten für Eindampfen und Lagerung der zurückgewonnenen Produkte betragen ein Vielfaches der Kosten der Gewinnung derselben Salze aus natürlichen Ressourcen. Deshalb wird diese Technik primär aus Umweltgründen und nicht aus wirtschaftlichen Gründen angewendet.

Da bei der Energieerzeugung in Kraftwerken bereits große Mengen an qualitativ hochwertigem Gips erzeugt werden, wird Gips, der auf die oben genannte Weise aus Siedlungsabfallverbrennungsanlagen gewonnen wird, bei Anwendungen mit geringeren Anforderungen an die Gipsqualität eingesetzt. Wenn eine Wiederverwendung nicht möglich ist, muss der Gips entsorgt werden, was entsprechende Beseitigungskosten mit sich bringt.

Treibende Kraft für die Anwendung
Aufgrund gesetzlicher Vorschriften sollte eine Ableitung von Waschflüssigkeiten aus nassen Abgasbehandlungsverfahren minimiert werden. Selbst wenn das Abwasser intensiv behandelt wird, um z.B. Schwermetalle und andere schädliche Verunreinigungen zu entfernen, wird der Gesamtgehalt an Salzen kaum beeinflusst. Eine substanzielle Reduzierung der Salzemissionen aus einer Siedlungsabfallverbrennungsanlagen in die lokale Umgebung wird nur durch das Eindampfen der Waschflüssigkeit erzielt. Durch Abtrennung des festen Gipses wird das Aufkommen an ARA-Abfall, der entsorgt werden muss, reduziert.

Beispielanlagen
Eindampfverfahren wurden erfolgreich in verschiedenen Ländern eingeführt, insbesondere in Deutschland wenden verschiedene Verbrennungsanlagen diese Technologie an.

Literatur
[124, Iswa, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.2.9 Säureextraktion

Beschreibung
Zahlreiche Techniken nutzen die Säureextraktion; einige Beispiele hierfür zeigt Tabelle 4.28:

Verfahren	Eigenschaften
Extraktion mit Säure	Dieses Verfahren kombiniert eine Säureextraktion von löslichen Schwermetallen und Salzen mittels Nutzung einer (sauren) Gaswäsche. Vor der Nutzung der Waschflüssigkeit aus dem Gaswäscher wird Quecksilber entweder durch eine Filtration (wenn Aktivkohle in den Gaswäscher eingeführt wurde) und/oder einen speziellen Ionenaustauscher entfernt. Sowohl Kessel- als auch Flugasche werden auf diese Art und Weise behandelt. Das flüssig/fest-Verhältnis liegt im Extraktionsschritt etwa bei 4; der pH-Wert wird durch Zugabe von hydriertem Kalk bei 3,5 gehalten. Während der Verweilzeit von etwa 45 Minuten wird Sulfat (aus der SO_2-Gaswäsche) zu Gips gefällt. Der feste Rückstand wird entwässert, dann im Gegenstrom auf einem Bandfilter gewaschen und schließlich deponiert, normalerweise als Mischung mit Verbrennungsschlacke. Das Filtrat muss behandelt werden, um Schwermetalle durch Neutralisation, Fällung und Ionenaustausch zu entfernen. Der entwässerte und gespülte Filterkuchen enthält etwa 25 % Zink und wird deswegen in metallurgischen Verfahren recycelt
Kombination von Säureextraktion mit thermischer Behandlung	Diese Verfahren kombiniert die Säureextraktion mit einer thermischen Behandlung. Zuerst werden Kessel- und Flugasche mit der Lösung aus der ersten Stufe der nassen Gaswäsche gewaschen und anschließend entwässert. Danach werden die festen Rückstände eine Stunde lang in einem Drehrohrofen bei etwa 600 °C behandelt, wobei der überwiegende Teil der organischen Verbindungen zerstört und Hg verflüchtigt wird. Das Abgas wird in einem Aktivkohlefilter behandelt. Das Abwasser wird behandelt, um Schwermetalle zu entfernen. Die Lösung aus dem zweiten Gaswäscher wird verwendet, um die Verbrennungsschlacke zu waschen und saure Abwasserströme zu neutralisieren
Säureextraktion-Sulfidprozess	Dieses Verfahren mischt Flugasche mit NaOH-Lösung aus dem Gaswäscher und Wasser bei einem flüssig/fest-Verhältnis von 5. Nach der Mischung wird der pH-Wert mit HCl auf etwa 6 – 8 eingestellt, um Schwermetalle zu entfernen, und NaHS zugefügt, um Schwermetalle als Sulfide zu binden. Danach wird ein Koagulationsmittel hinzugefügt und der Schlamm entwässert. Der Filterkuchen wird deponiert und das Abwasser in einer Behandlungsanlage behandelt, um Schwermetalle zu entfernen

Tabelle 4.28: Technologien der Säureextraktion
[124, Iswa, 2003], [150, TWG, 2004]

Erreichter Nutzen für die Umwelt
Das Verfahren kann einen signifikanten Anteil der Gesamtmenge an Schwermetallen aus dem Abfall-IN entfernen (Cd: ≥85 %; Zn: ≥85 %; Pb and Cu: ≥33 %; Hg: ≥95 %); die Auslaugbarkeit des Materials wird um den Faktor 10^2 – 10^3 reduziert. Zink, Cadmium und Quecksilber werden recycelt.

Medienübergreifende Auswirkungen
Der Dioxingehalt der Rostasche steigt, wenn die behandelte Asche „in Kombination“ mit anderen Rostaschen entsorgt wird; allerdings ist wegen der höheren Dichte das Auslaugpotenzial der Mischung höher.

Betriebsdaten
Die meisten Anlagen, die 24 Stunden am Tag in Betrieb sind, können die wöchentliche Betriebsdauer (4 – 7 Tage) an das Aufkommen von ARA-Abfall anpassen.

Anwendbarkeit
Das Verfahren kann nur bei Verbrennungsanlagen mit nassem ARA-System angewendet werden, für die eine Genehmigung zur Einleitung von behandeltem Abwasser vorliegt.

Wirtschaftlichkeit
Die Verfahrenskosten der Behandlung des ARA-Abfalls liegen bei etwa 150 – 250 EUR /Mg (einschließlich Gebühren für das Recycling des zinkhaltigen Filterkuchens).

Treibende Kraft für die Anwendung
Diese Technik bietet eine Methode zur Behandlung von festen Abfällen gemäß Schweizer Gesetzgebung, wobei die Kosten wettbewerbsfähig sind (dies im Vergleich zum Export zur unterirdischen Deponierung in Deutschland).

Beispielanlagen
Die erste Anlage ging 1996 in Betrieb. Zurzeit sind sechs Anlagen in der Schweiz und eine in der Tschechischen Republik in Betrieb.

Literatur
[124, Iswa, 2003], [152, TWG, 2004]

4.3.2.10 Auskoffern und Abtransport kontaminierter Böden

Beschreibung
Zu den Techniken gehören:

a. Identifizierung und Betreiben von Verfahren zur Reduktion von flüchtigen Emissionen, durch ordentliches Management am Anlagenstandort
b. Einhausen des Sanierungsbereichs mittels Abdeckung und Anwendung einer Luftbehandlung
c. Kontrolle des Grads der Auskofferung, der Größe des betroffenen Areals, in dem Boden verunreinigt ist sowie die Dauer, in der Böden unbedeckt zurückbleiben. Der Zeitpunkt der Aushebung kann auch von Bedeutung sein. Die Festlegung des Auskofferungstermins auf Tages- oder Jahreszeiten an denen niedrige Windgeschwindigkeiten und Temperaturen vorherrschen, kann Emissionen reduzieren. Die Arbeit kann auch so geplant werden, dass Jahreszeiten mit trockenen Bodenbedingungen vermieden werden, wodurch die Emissionen weiter reduziert werden.

Erreichter Nutzen für die Umwelt
Reduziert flüchtige Emissionen bei der Aushebung und Entfernung von kontaminiertem Boden. Die VOC-Emissionskontrolle kann auch mittels Kontrolle der Betriebsbedingungen innerhalb voreingestellter Parameter erzielt werden.

Medienübergreifende Auswirkungen
Eine gewisse Freisetzung von flüchtigen Schadstoffen ist während der Auskofferung unvermeidlich. Stagnierende Windbedingungen können zu inakzeptablen Umgebungsluftkonzentrationen am Arbeitsplatz führen.

Anwendbarkeit
Die Einhausung des Sanierungsbereichs mittels einer Haube ist keine übliche Maßnahme.

Literatur
[30, Eklund, et al., 1997]

4.3.2.11 Thermodesorption bei Böden

Beschreibung
Siehe Abschnitt 2.3.3.9. Zu den Techniken gehören:

a. die Nutzung eines Tests im Labormaßstab, um die Eignung der Thermodesorption sowie die optimale Verweilzeit und Temperatur zu ermitteln. Die Effektivität der Thermodesorption ist bedingt von der Endtemperatur, die im Boden erreicht wird, die wiederum eine Funktion der Verweilzeit und der Wärmeübertragung ist. Die Temperaturen und Verweilzeiten, die sich im Labormaßstab als wirksam erwiesen haben, haben sich auch im Pilotanlagenmaßstab als wirksam bewährt
b. die Anwendung einer geeigneten Temperatur. Die typische Behandlungstemperatur für Erdölbrennstoffe aus undichten unterirdischen Lagertanks, liegt zwischen 200 und 480 °C. Zur Behandlung von Böden, die Pestizide, Dioxine und PCBs enthalten, müssen die Temperaturen 450 °C übersteigen
c. die Senkung des Feuchtigkeitsgehalts des zu behandelnden Bodens innerhalb eines spezifischen Bereichs, da die Kosten der Behandlung von Abfällen mit hohem Wassergehalt hoch sind. Der typische akzeptable Feuchtigkeitsgehalt für Drehrohrtrockner und Asphaltöfen liegt zwischen 10 und 30 %, während Schaufeltrockner höhere Wasserbeladungen von 30 – 80 % verarbeiten können. Um VOCs zu entfernen, sollten die Böden im Idealfall 10 – 15 % Feuchtigkeit enthalten, da über den Wasserdampf einige VOCs austragen werden
d. das Vorhandensein von Gerätschaften zur Erfassung und Reinigung von Abluft, wie etwa Nachbrenner, thermische Oxidation, Gewebefilter, Aktivkohle oder Kondensatoren zur Behandlung der Gase.

Erreichter Nutzen für die Umwelt
Flexibilität, da mit der Thermodesorption ein breites Spektrum von organischen Schadstoffen behandelt werden kann und die Anlagen mobil sein können. Thermodesorber arbeiten bei niedrigeren Temperaturen, so dass im Vergleich zur Verbrennung signifikante Mengen an Brennstoff eingespart werden können. Sie erzeugen auch kleinere Mengen von behandlungsbedürftigen Abgasen. Typische Spezifikationen der Thermodesorption werden in Tabelle 4.29 gezeigt.

	Drehrohrtrockner	Asphaltanlage	Thermische Schnecke	Durchlaufofen
Mobilität	Stationär und mobil	Stationär	Mobil	Mobil
Typische Standortgröße (Tonnen)	450 – 23000	0 – 9000	450 – 4500	450 – 5000
Durchsatz an Boden (t/h)	9 – 45	23 – 90	3 – 14	5 – 9
Maximale Korngröße des Boden-Inputs (cm)	5 – 8	5 – 8	3 – 5	3 – 5
Wärmeübertragungsmethode	Direkt	Direkt	Indirekt	Direkt
Bodenmischungsmethode	Mantelrotation und Heber	Mantelrotation und Heber	Schnecke	Bodenrührer
Bodentemperatur bei Austritt aus der Anlage (°C)	150 – 300 [a] 300 – 650 [b]	300 – 600	150 – 250 [c] 300 – 250 [d] 500 – 850 [e]	300 – 800
Verweilzeit des Bodens (Minuten)	3 – 7	3 – 7	30 – 70	3 – 10
Temperatur des Abgases aus dem Thermodesorber (°C)	250 - 450[a] 400 – 500[b]	250 – 450	150	500 – 650
Gas/Feststoff-Fluss	Gleichstrom oder Gegenstrom	Gleichstrom oder Gegen-strom	Nicht anwendbar	Gegenstrom
Atmosphäre	Oxidativ	Oxidativ	Inert	Oxidativ
Nachbrennertemperatur (°C)	750 – 1000	750 – 1000 [f]	Im Allgemeinen nicht verwendet	750 – 1000
Maximale thermische Last (MJ/h)	10500 – 105000	5300 – 105000	7400 – 10500	10500
Aufheizzeit aus kaltem Zustand (Stunden)	0,5 – 1,0	0,5 – 1,0	Liegt nicht vor	0,5 – 1,0
Abkühlungszeit aus heißem Zustand (Stunden)	1,0 – 2,0	1,0 – 2,0	Liegt nicht vor	Liegt nicht vor
Mineralöl-Kohlenwasserstoffe An-fangskonzentration (mg/kg) Endkonzentration (mg/kg) Entfernter Prozentsatz (%)	800 – 35000 <10 – 300 95,0 – 99,9	500 – 25000[h] <20[h] Liegt nicht vor	60 – 50000 n. n. – 5500 64 – 99	5000 <10,0 >99,9
BTEX Anfangskonzentration (mg/kg) Endkonzentration (mg/kg) Entfernter Prozentsatz (%)	 Liegt nicht vor <1,0 Liegt nicht vor	 Liegt nicht vor Liegt nicht vor Liegt nicht vor	 155 <1,0 >99	 Liegt nicht vor <0,01 Liegt nicht vor

[a] Baumaterialien aus unlegiertem Stahl
[b] Baumaterialien aus Legierungen
[c] Wärmeübertragungsverfahren mit Thermoöl
[d] Wärmeübertragungsverfahren mit geschmolzenem Salz
[e] Elektrisch beheiztes Verfahren
[f] Nicht in allen Verfahren eingesetzt
[g] Gesamtlast von Thermodesorber plus Nachbrenner
[h] Informationen des Herstellers
n. n.: nicht nachweisbar

Tabelle 4.29: Vergleich der Eigenschaften von Thermodesorptions- und Abgasbehandlungsverfahren

Medienübergreifende Auswirkungen

Um Schadstoffe zu zerstören ist eine Nachverbrennung und Abgasbehandlung nach dem Desorptionsprozess erforderlich. Der Grund hierfür ist, dass Schadstoffe bei der Desorption nur aus der festen oder flüssigen Phase freigesetzt und in die Gasphase überführt werden. Deshalb sind Installationen zur Emissionsminderung notwendig. Die Wirksamkeit des Thermodesorptionsverfahrens hängt von den chemischen und physikalischen Eigenschaften der spezifischen Schadstoffe ab. Metalle (z.B. Blei) neigen dazu, nach der Behandlung im Boden zu verbleiben, so dass eine zusätzliche Aufbereitung oder Behandlung des Bodens erforderlich sein kann (z.B. eine Stabilisierung). Thermodesorber arbeiten bei oder über 500 °C, so dass zusätzlich zur Verdampfung von Wasser und den organischen Verbindungen eine Pyrolyse sowie Oxidation auftreten können.

Anwendbarkeit

Anwendbar bei kontaminierten Böden, die mit Schadstoffen beladen sind, die bei den Betriebstemperaturen flüchtig sind. Organische Verbindungen mit hohem Molekulargewicht können Gewebe oder Kondensatoren verschmutzen oder verstopfen. Aus diesem Grunde sind die Typen an Erdölprodukte, die durch spezifische Technologien behandelt werden können, begrenzt. Drehrohrtrockner können in der Regel Böden mit einem Organikgehalt von weniger als 2 % behandeln. Thermische Schnecken können Böden behandeln, die bis zu 50 % organische Verbindungen enthalten.

Wirtschaftlichkeit
In der Regel preiswerter als Verbrennung.

Treibende Kraft für die Anwendung
Die Thermodesorption unterscheidet sich von der Verbrennung im Hinblick auf rechtliche sowie Genehmigungsanforderungen. Vielleicht ist es am wichtigsten, dass die Thermodesorption in der Öffentlichkeit eine höhere Akzeptanz genießt als andere Methoden der thermischen Behandlung.

Literatur
[30, Eklund, et al., 1997], [51, Inertec, et al., 2002], [150, TWG, 2004]

4.3.2.12 Dampfextraktion

Beschreibung
Siehe Abschnitt 2.3.3.10. Sobald die Dämpfe aus dem festen Abfall entfernt worden sind, werden sie zur Reduzierung der Luftemissionen behandelt. Wenn der Kohlenwasserstoffgehalt des Abgases hoch genug ist, ist eine direkte Verbrennung theoretisch möglich, aber die Konzentration sinkt in der Regel signifikant während der Austreibung. Deshalb wäre Erdgas oder ein anderer Brennstoff erforderlich, um die Verbrennung aufrechtzuerhalten. Ebenso wird in der Regel aus Sicherheitsgründen Verdünnungsluft zugegeben, damit die VOC-Konzentration unterhalb der unteren Explosionsgrenze bleibt. Bei niedrigeren Konzentrationen an Kohlenwasserstoffen kann eine katalytische Oxidation oder eine Adsorption an Aktivkohle effektiv sein.

Erreichter Nutzen für die Umwelt
Emissionen in die Luft werden von punktuellen Quellen freigesetzt und können deshalb leicht kontrolliert werden. Der Erfolg der Technik hängt von der Flüchtigkeit (Dampfdruck) der vorliegenden Schadstoffe ab.

Medienübergreifende Auswirkungen
Signifikante Restkontamination können nach der Behandlung im festen Abfall verbleiben.

Betriebsdaten
Die Gerätschaften sind einfach zu installieren und zu betreiben.

Anwendbarkeit
Die Behandlung ist bei ausgekoffertem Boden anwendbar. Allerdings ist sie nicht bei gesättigten Böden oder bei Böden mit geringer Luftdurchlässigkeit anwendbar, wobei sie wiederum für die Behandlung von PCB-verunreinigtem Boden anwendbar ist.

Wirtschaftlichkeit
Große Volumen von ausgekoffertem Boden können kosteneffektiv behandelt werden.

Literatur
[30, Eklund, et al., 1997], [100, UNEP, 2000], [150, TWG, 2004], [152, TWG, 2004]

4.3.2.13 Bodenwäsche

Beschreibung
Siehe Abschnitt 2.3.3.13. Zu den Techniken gehören:

a. ein möglichst weitgehendes Recycling der abgeleiteten Abwässer
b. die Nutzung von Kohlefiltern zur Behandlung der erfassten Emissionen am Sanierungsstandort oder in der Bodenwascheinheit
c. die Sicherstellung, dass Schlämme und Feststoffe aus der Abwasserbehandlung einer geeigneten Behandlung und Beseitigung unterzogen werden.

Erreichter Nutzen für die Umwelt

Anlage	Schadstoffe	Konzentration im unbehandelten Boden (ppm)	Bereich des Wirkungsgrads der Entfernung (%)	Restkonzentrationen (ppm)
1	Öl und Fett		50 – 83	250 – 600
2	Pentachlorphenol		90 – 95	<115
	Andere organische Verbindungen		85 – 95	<1
3	Öl und Fett		90 – 99	<5 – 2400
4	Flüchtige organische Verbindungen		98 – >99	<50
	Halbflüchtige organische Verbindungen		98 – >99	<250
	Die meisten Erdölprodukte		98 – >99	<2200
5	Aromaten		>81	>45
	Rohöl		97	2300
6	Gesamte organische Stoffe		96	159 – 201
	PAHs		86 – 90	91,4 – 97,5
7	Öl		>99	20
8	Kohlenwasserstoffe		96,3	82,05
	Chlorierte Kohlenwasserstoffe		>75	<0,01
	Aromaten		99,8	<0,02
	PAHs		95,4	15,48
9	Heizöl	7666	65	2650
10	Heizöl	7567	73	2033
11	Heizöl	9933	72	2833

Tabelle 4.30: Zusammenfassung von Leistungdaten der Bodenwäsche
[30, Eklund, et al., 1997]

Folgende Tabelle 4.31 zeigt Daten zu allgemeinen Wirkungsgraden der Bodenwaschanlagen.

Schadstoffe	Allgemeine Wirkungsgrade [1]
Mineralöl-Kohlenwasserstoffe (C_{10}-C_{40})	90 – 98
PAHs	90 – 97
BTEX	90 – 97
PCBs	90 – 97
Metalle	
As	60 – 80
Cd	60 – 80
Cr	80 – 90
Cu	75 – 85
Hg	85 – 95
Ni	85 – 90
Pb	90 – 95
Zn	85 – 95
[1] Allgemeine Wirksamkeit = (1 – Konz. im dekontaminierten Sand/Konz. im verunreinigten Boden) * 100	

Tabelle 4.31: Wirkungsgrade der Bodenwaschanlage für verschiedene Inhaltsstoffe

Literatur

[30, Eklund, et al., 1997], [123, Perseo, 2003]

4.3.2.14 Lösemittelextraktion

Beschreibung
Siehe Abschnitt 2.3.3.11.

Erreichter Nutzen für die Umwelt

Verbindung	Anfangs-konzentration (mg/kg)	Endkonzentration (mg/kg)	Entfernung (%)
Anthracen	28,3	0,12	99
Benzol	30,2	0,18	99
Benzo(a)pyren	1,9	0,33	83
Bis-(2-ethylhexyl)phthalat	4,1	1,04	75
Chrysen	6,3	0,69	89
Ethylbenzol	30,4	0,23	99
Naphthalin	42,2	0,66	98
Phenanthren	28,6	1,01	96
Pyren	7,7	1,08	86
Toluol	16,6	0,18	99
Gesamt-Xylol	13,2	0,98	93

Tabelle 4.32: Ergebnisse der Sanierung von Schlämmen aus API-Abscheider mittels Lösemittelextraktion [30, Eklund, et al., 1997]

Anwendbarkeit
Anwendbar zur Entfernung von PCB aus Böden. Das verunreinigte Lösemittel muss dann behandelt werden, damit die PCBs zerstört werden.

Literatur
[30, Eklund, et al., 1997], [100, UNEP, 2000]

4.3.2.15 Eindampfung

Beschreibung
Die Eindampfung ist in der Regel ein bedeutender Bestandteil der C-P-Anlage. In Eindampfanlagen werden gefährliche Abfälle aufkonzentriert. Das Konzentrat wird in der Regel verbrannt. Das Abwasser (Konzentrat) wird zwischengelagert und nach Untersuchung und Kontrolle zu einer Abwasserbehandlungsanlage transportiert. Die Abluft wird mittels Kohlefilter gereinigt.

Vor dem Eindampfen werden in C-P-Anlagen bestimmte Vorbehandlungsschritte durchgeführt. Dazu gehören Flockung, Fällung, Ultrafiltration und organische Spaltung. Nach dem Eindampfen wird eine Flockung des Kondensats durchgeführt, falls es mit Öl verunreinigt ist. Das Abgas wird mit einem alkalischen Wäscher und einem Kohlefilter behandelt.

Erreichter Nutzen für die Umwelt
Reduzierung der anfallenden Abwassermenge. Erreichbare Konzentrationen in Abgas und Abwasser werden in folgender Tabelle 4.33[22] aufgezeigt.

[22] Anm.d.Übers.: Im Originaltext wird auf die Tabelle 3.32 verwiesen.

Verbindung	Wert	Einheit	Beladung	Einheit
Abluftparameter				
TOC	63	mg/Nm³	96	kg/a
Parameter des erzeugten Abwassers				
Temperatur	30	°C		
pH-Wert	9,3			
Leitfähigkeit	900	µS/cm		
sedimentierte Stoffe (105 °C)	0,1	mg/l	2	kg/a
BSB	3000	mg/l	60000	kg/a
CSB	5000	mg/l	100000	kg/a
Kohlenwasserstoffe	2	mg/l	40	kg/a
Phenol		mg/l		kg/a
AOX	0,1	mg/l	2	kg/a
Nitrit	0,01	mg/l	0,2	kg/a
Cyanid	0,02	mg/l	0,4	kg/a
Al	2	mg/l	40	kg/a
Fe	0,1	mg/l	2	kg/a
As	0,01	mg/l	0,2	kg/a
Gesamt-Cr	0,1	mg/l	2	kg/a
Cr(VI)	0,01	mg/l	0,2	kg/a
Cu	0,1	mg/l	2	kg/a
Hg	0,001	mg/l	0,02	kg/a
Ni	0,1	mg/l	2	kg/a
Pb	0,1	mg/l	2	kg/a
Zn	0,1	mg/l	2	kg/a
Behandeltes Abwasser: 20000 Tonnen pro Jahr				

Tabelle 4.33: Erreichbare Konzentrationen durch Eindampfverfahren, das für Abwässer angewendet wird [147, UBA, 2003]

Literatur
[147, UBA, 2003]

4.3.2.16 Aufreinigung und Reycling von ARA-Abfällen

Beschreibung
Abfälle aus natriumbasierter Abgasreinigung bestehen größtenteils aus Natriumchlorid (als Ergebnis der HCl-Neutralisation), Natriumsulfat (als Ergebnis der SO_2-Neutralisation), Natriumcarbonat (als Resultat von Natriumbicarbonat-Überschuss), Flugasche und Adsorbentien (Aktivkohle oder Braunkohlenkoks).

In Verfahren mit einstufiger Abgasfiltration wird die Flugasche mit Neutralisationssalzen gemischt und der lösliche Anteil stellt etwa 50 % des Abfall-IN dar. In Verfahren mit zweistufiger Filtration hält der erste Filter den größten Teil der Flugasche zurück; und die Abfälle aus der natriumbasierten Abgasreinigung werden am zweiten Filter gesammelt, die etwa 90 % lösliche Salze enthält.

Zum Verfahren gehören die folgenden Schritte:

a. Mischung des ARA-Abfalls mit hydraulischen Bindemitteln: Vorbereitung der Verfestigung des unlöslichen Teils
b. Lösung in Wasser und Zugabe von Additiven: der lösliche Teil wird gelöst und die meisten Schwermetalle werden gefällt
c. Filtration dieser Suspension: die resultierenden Produkte sind ein sich selbst verfestigender Filterkuchen mit einer sehr kleinen noch löslichen Fraktion (nach dem Waschen) und eine Salzlauge, die lösliche Salze enthält
d. Reinigung der Salzlauge (in mehreren Schritten einschließlich Ionenaustauscherharzen) auf eine Art, dass sie zur Herstellung von Natriumcarbonat (Soda) wiederverwendet werden kann

Dieses Verfahren hat keine Outputs außer dem (zu deponierenden) verfestigten Filterkuchen und der gereinigten Salzlauge, die einen Teil des neuen Rohstoffs ersetzt der in Sodafabriken eingesetzt wird. Abwasser wird nicht erzeugt.

Erreichter Nutzen für die Umwelt
Die hier beschriebene Technik realisiert die Trennung zwischen löslichen und unlöslichen Anteilen des ARA-Abfalls, verfestigt den unlöslichen Anteil und reinigt den löslichen Anteil (der aus anorganischen Salzen besteht), der in einigen Branchen wiederverwendet wird. Deshalb:

- besitzt der deponierte feste Anteil des ARA-Abfalls eine schwerlösliche Fraktion und somit eine gute Verfestigung. Folglich werden weniger hydraulische Bindemittel verbraucht und die letztendlich erzeugte Abfallmenge ist kleiner
- der lösliche Anteil des ARA-Abfalls wird in der chemischen Industrie wiederverwendet und ersetzt den Einsatz von Neumaterialien (Salz ist einer der Hauptrohstoffe für Sodafabriken). Dieser lösliche Anteil wird zu über 95 % recycelt.

Die Behandlungen erzeugen keine Abwässer (alle Flüssigkeiten werden als Prozesswasser wiederverwendet, um die recycelte Salzlauge zu bilden) und es wird über keine signifikanten Emissionen in die Luft berichtet (Verfahren bei Umgebungstemperatur).

Medienübergreifende Auswirkungen
Liegen nicht vor.

Betriebsdaten
Das Verfahren erfordert keinen hohen Energieeinsatz: Es arbeitet bei Umgebungstemperatur.

Anwendbarkeit
Das Verfahren wird auf ARA-Abfall aus der trockenen Abgasreinigung mit Natriumbicarbonat, die bei der Verbrennung von Siedlungsabfall eingesetzt wird, angewendet. Dieses Verfahren wird in speziell dafür errichteten zentralen Anlagen durchgeführt, die sich in der Nähe einer Sodafabrik befindet, in der die erzeugte gereinigte Salzlauge eingesetzt werden kann, und die ARA-Abfälle aus verschiedenen Siedlungsabfallverbrennungsanlagen annimmt.

Wirtschaftlichkeit
Dieses Verfahren muss mit der Verfestigung und Deponierung von ARA-Abfall verglichen werden. Von diesem Gesichtspunkt aus wird zum einen die Verfestigung sehr durch die Abtrennung des löslichen Teils erleichtert, und zum anderen die Menge der letztendlich anfallenden Reststoffe verringert, so dass Berichten zufolge das Verfahren in einigen Staaten wettbewerbsfähig ist. Die Betriebskosten sind niedrig, die Investitionskosten der Behandlungsanlage sind der Schlüsselfaktor für die Wirtschaftlichkeit. Folglich muss dieses Verfahren in zentralisierten Einheiten durchgeführt werden, in denen zahlreiche Verbrennungsanlagen bedient werden.

Treibende Kraft für die Anwendung
Dieses Verfahren wird durch die folgenden beobachteten Entwicklungen begünstigt:

- strenge Anforderungen an die Deponierung: Wenn eine sichere Verfestigung gefordert wird
- Widerstand gegenüber neuen Deponiestandorten, sowie ein Trend, so wenig wie möglich zu deponieren
- Trend zur Begünstigung des Recyclings.

Beispielanlagen
Zwei Anlagen nutzen dieses Verfahren oder leichte Abwandlungen im industriellen Maßstab: Eine in Italien (Toskana) mit einer Kapazität von 10 kt ARA-Abfall/a und eine in Frankreich (Lorraine), mit einer Kapazität von 50 kt ARA-Abfall/a. Beide versorgen eine Sodafabrik mit gereinigter Salzlauge als Rohmaterial.

Literatur
[150, TWG, 2004], [152, TWG, 2004]

4.3.3 Chemisch-physikalische Behandlung besonderer Abfälle

4.3.3.1 Behandlung von PCB-verunreinigten Ölen

Beschreibung
Das Verfahren ist eine Dehalogenierung von PCB-verunreinigten Ölen aus Transformatoren. Das Verfahren ermöglicht auch die Elimination von niedrig siedenden Verbindungen und Oxidationsprodukten, die für die geringen Dielektrizitätseigenschaften des verunreinigten Öls verantwortlich sind. Am Ende des Verfahrens wird eine Filtration durchgeführt, um die Nebenprodukte der Reaktion zu eliminieren.

Erreichter Nutzen für die Umwelt
Das Verfahren erzeugt ein Öl mit dielektrischen Eigenschaften, die eine Wiederverwendung für gleiche Zwecke ermöglicht, mit einem PCB-Gehalt von unter 1 ppm.

Anwendbarkeit
Angewendet bei Transformatorenölen mit PCB-Gehalten zwischen 25 und 2000 ppm. Das Verfahren kann angewandt werden bei:

- Dehalogenierung und Verwertung von gemischten PCB-verunreinigten Mineralölen aus Transformatoren
- Reinigung und Verwertung PCB-verunreinigter Mineralöle während des Betriebs der Transformatoren. Dieser Schritt wird durchgeführt, indem das dehalogenierte Mineralöl rückgeführt wird, und erlaubt die Extraktion von Rest-PCB, dass in den verschiedenen Bestandteilen der Transformatoren (z.B. Papier und Holz) absorbiert ist.

Wirtschaftlichkeit
Der Konzentrationsbereich der im vorigen Abschnitt “Anwendbarkeit” genannt wird, ist der typische Bereich, in dem sich diese Technik als wirtschaftlich tragbar erwiesen hat. Technisch ist die Anwendung bei höheren Konzentrationen kein Problem, doch es hat sich herausgestellt, dass es andere Typen von PCB-Behandlungsverfahren gibt, die hier wirtschaftlicher sind.

Treibende Kraft für die Anwendung
Es existieren mobile Anlagen, die bei in Betrieb befindlichen Transformatoren angewendet werden können, ohne die Notwendigkeit, dass die Trafos bewegt werden müssen.

Beispielanlagen
Eine Beispielanlage ist in Italien in Betrieb.

Literatur
[52, Ecodeco, 2002], [150, TWG, 2004]

4.3.3.2 Thermo-chemische Umwandlung von Asbestabfällen

Beschreibung
Die Technologie der thermo-chemischen Umwandlung nutzt eine Kombination aus chemischer Behandlung und Wärme, um eine Re-Mineralisation von Asbest und anderen Silikatmaterialien zu bewirken. Mit dem Re-Mineralisationsverfahren werden verschiedene Ziele erreicht, einschließlich:

- Umwandlung von Asbestmineralien in Nicht-Asbest-Mineralien ohne Notwendigkeit des Schmelzens
- Zerstörung von organischen Verbindungen durch Pyrolyse und/oder Oxidation
- Immobilisierung von Metallen und Radionukliden.

Das Verfahren beinhaltet das Schreddern und anschließende Mischen des asbesthaltigen Materials mit Fließmitteln und das Erwärmen der Mischung. Die Anwesenheit des Fließmittels bei erhöhten Temperaturen (etwa 1200 °C) führt zur schnellen Re-Mineralisierung der Asbestfasern, die zu Nicht-Asbest-Mineralien wie Diopsid, Wollastonit, Olivin und Glas umgewandelt werden.

Die Verfahrensausstattung setzt sich aus vier Hauptsystemen zusammen, welches die Zubereitung der Beschickung, der Rotationsherd-Konverter, die Abgasbehandlung sowie die Produktentfernung, sind.

Die Pyrolyse der organischen Verbindungen findet im Drehherd statt. Die Pyrolyseprodukte werden über einen Saugzug zu einer thermischen Oxidationseinheit geleitet, mittels der alle möglich verbliebenen organischen Verunreinigungen des Abgases zerstört werden. Die Abgase der thermischen Oxidation werden gekühlt und durch eine Gaswäsche von allen vorhandenen Partikeln und sauren Bestandteilen gereinigt. Die Anwesenheit von Entmineralisierungsmittel beschleunigt die molekulare Diffusion in anorganischen Abfällen während des Erwärmens, was anorganische Verbindungen wie Asbest zerstört und zu einer gleichzeitigen Oxidation und molekularen Bindung von Metallen und Radionukliden im Abfallmedium führt. Dies resultiert in einer Immobilisierung von Metallen und Radionukliden. Das Verfahren führt auch zur einer signifikanten Reduktion des Abfallvolumens. Die Höhe der Volumenreduktion hängt von der Art des behandelten Materials ab und liegt zwischen 10 % für Böden und über 90 % bei asbesthaltigen oder primär organischen Materialien.

Erreichter Nutzen für die Umwelt
Die Technologie bietet einen Wirkungsgrad, der vergleichbar mit der Verglasung ist, ohne die Anforderung, den Abfall zu schmelzen. Im Einzelnen:

- wandelt Asbestmaterialien in Inertmaterialien um
- führt zu signifikanten Abfallvolumenreduktionen. Das Volumen des behandelten Produkts kann im Vergleich zum ursprünglichen Abfall signifikant reduziert werden (bis zu 90 %), doch muss der Abfall, abhängig von seinen Schadstoffen, eventuell auf einer Deponie entsorgt werden.

Das Verfahren führt auch zur Zerstörung organischer Stoffe, einschließlich PCBs mit einem Wirkungsgrad von 99,9999 %. Giftige Metalle werden im gesinterten Produkt durch molekulare Bindung stabilisiert, und der Technologieentwickler glaubt, basierend auf Vorversuchen, dass das Verfahren auch für Radionuklide wirksam ist.

Anwendbarkeit
Das Verfahren ist auch für andere Abfallarten wirksam, einschließlich Bauschutt und Abfällen, die vor allem organische Stoffe beinhalten. Die Technik ist auf flüssige und feste Abfälle anwendbar, die angemessen homogen sind oder ohne hohe Kosten homogenisiert werden können. Das Verfahren kann Abfälle behandeln, die mit einem breiten Spektrum an Schadstoffen verunreinigt sind. Dies schließt organische Schadstoffe wie VOCs, halbflüchtige organische Verbindungen, PCBs, Dioxine sowie anorganische Schadstoffe wie Asbest und Cyanide, Metalle einschließlich Arsen, Blei, Chrom, Barium, Zink, Selen, Cadmium, verglasbare Radionuklide wie Transurane, Caesium, Thorium und Uran, sowie Mischungen dieser Schadstoffe, mit ein.

Zu den Abfällen, für die nur begrenzte Daten vorliegen oder von denen angenommen wird, dass die Technik nicht wirtschaftlich oder technisch vereinbar ist, zählen Quecksilber, gasförmige Radionuklide wie C^{14}, Sprengstoffe und einige chemische Agenzien (obwohl hier erwähnt wird, dass die Technik anwendbar sein könnte, aber es liegen keine Daten vor, um eine solche Behauptung zu unterstützen).

Wirtschaftlichkeit
Die Technologie bietet einen Behandlungswirkungsgrad, der gleichwertig mit demjenigen der Verglasung ist, ohne die Anforderungen, den Abfall zu schmelzen. Dies macht die Technik bei bestimmten Abfällen weniger kostspielig und vielseitiger als die Verglasung. Die Investitionskosten für eine Anlage mit einer Kapazität von 37 Tonnen pro Tag liegen bei etwa 3 Millionen US$. Unter Voraussetzungen, die am Ende dieses Abschnitts genannt werden, kann eine 37 Tonnen/Tag-Anlage asbesthaltiges Material für etwa 175 – 225 USD pro Tonne behandeln.

Die drei größten und meistens auch signifikanten Anteile an den Gesamtkosten sind der Brennstoff, die Betriebsausstattung und die Arbeitskosten. Der Brennstoff macht ungefähr 36 % der Gesamtkosten aus, die Betriebsausstattung 30 % und die Arbeit etwa 22 %. Verbleibende Punkte wie Reagenzien, Wartung, Wasser, Elektrizität, persönliche Schutzausrüstungen und Filter machen die verbleibenden 12 % der Gesamtkosten aus.

Die in diesem Abschnitt genannten Kostenabschätzungen basieren auf folgende Annahmen:

a. Anlagenbeschreibung: 37 Tonnen/Tag-Anlage, direkt befeuert mit Verwertung der Wärme und trockener Kalkwäsche
b. Investitionskosten: basieren auf einer Rücklaufzeit des Kapitals von 7 Jahren bei einem realen Diskontsatz von 3,0 % (2002)
c. Betriebsbedingungen: 24 h/Tag-Betrieb, 80 % betriebliche Leistungsfähigkeit, 9-Personen-Mannschaft
d. Kosten beinhalten Brennstoff (Erdöl), Elektrizität, Prozesschemikalien, persönliche Schutzausrüstungen, regelmäßige Wartung und HEPA-Filter
e. Gemeinkosten und Profite inbegriffen
f. Beseitigung der behandelten Materialien nicht inbegriffen
g. Transport zur Behandlungsanlage nicht inbegriffen.

Treibende Kraft für die Anwendung
Asbestabfall wird in der Regel auf Deponien entsorgt. Allerdings kann Asbest manchmal mit Radionukliden, PCBs und Metallen kontaminiert sein. Aus diesem Grund ist bei diesen Materialien vor der Beseitigung auf der Deponie eine Vorbehandlung erforderlich.

Beispielanlagen
Eine neue Anlage wird zurzeit in Irland geplant.

Literatur
[94, USA DoE, 2002], [150, TWG, 2004]

4.3.3.3 Behandlung von quecksilberhaltigem Abfall

Beschreibung
Zu den Techniken gehören:

a. Vorbehandlung des quecksilberhaltigen Abfalls wie folgt:
   - Schreddern/Brechen von Batterien und Knopfzellen
   - Sortieren/Zerbrechen/Trennen von Thermometern und Schaltern
   - Zentrifugieren des quecksilberhaltigen Schlamms, um den größten Teil des metallischen Quecksilbers zu entfernen. Der verbleibende Schlamm hat einen niedrigen Quecksilbergehalt und wird im Vakuumdestillations-Verfahren behandelt.
   - Schreddern/Sieben von Gasentladungslampen, Entfernung des Eisens und Trennung in Fraktionen. Das quecksilberhaltige Fluoreszenzpulver wird durch Vakuumdestillation behandelt
   - "end-cut/air-push" Behandlung der Gasentladungslampen, bei der mittels Erwärmen und Kühlen die Enden abbrechen. Danach wird das quecksilberhaltige Fluoreszenzpulver ausgeblasen (air-push). Eine Trenneinheit kann dieser Vorbehandlungstechnik hinzugefügt werden. Diese detektiert das Pulver, um es selektiv auszublasen. Die Wiederverwendung der Pulver ist möglich.
b. Durchführung der folgenden Abfolge von Behandlungen:
   - Abtrennung und Aufkonzentration des Quecksilbers durch Verdampfen und Kondensation
   - Behandlung der Abgase mit Staub- und Aktivkohlefiltern
   - Rückführung des Staubs und der verunreinigten Kohle aus der Abgasbehandlung ins Verfahren

c. Behandlung des Destillats (Wasser und organische Fraktionen) durch:
   - Verbrennung in einer Abfallverbrennungsanlage
   - Weiterleitung der Gase aus der Destillation zu einen Nachbrenner (bei ungefähr 850 ºC) und Kondensator. Die Abgase werden durch eine Abgasbehandlung (z.B. Gaswäsche, Staubfilter und Aktivkohlefilter) gereinigt. Der abgetrennte Staub und die verunreinigte Kohle werden in den Destillationsbehälter rückgeführt. Durch diese Möglichkeit wird die Verwertungsquote erhöht
   - Reinigung der Wasserfraktion (nach der Abtrennung) und Rückführung des Rückstands/der Ablagerung in den Destillationsbehälter. Diese Variante erhöht die Verwertungsquote.

Erreichter Nutzen für die Umwelt
Das Quecksilber wird als Sekundärrohstoff recycelt. Der Verbleib des Reststoffs aus dem Vakuumbehälter hängt vom behandelten Abfall ab. Er kann als Sekundärrohstoff (z.B. für Batterien) genutzt werden oder deponiert werden (z.B. im Fall quecksilberhaltigen Schlamms).

In einer thermischen Bodensanierungsanlage, mit einem Durchsatz von 2 Mg/h quecksilberhaltigen Bodens und Quecksilberkonzentrationen im Rohgas von bis zu 20 mg/Nm^3, wurde eine maximale Entfernungsquote von 99,9 % erreicht. Es wurde auch berichtet, dass der Quecksilbergehalt des Bodens (1 - 300 mg/kg) infolge der thermischen Behandlung auf weniger als 5 mg/kg sank. Von einer anderen Behandlung wurde berichtet, dass der resultierende, in die Luft emittierte Prozentsatz an Quecksilber bei 0,0015 % lag. Die Emissionen reichen von 0,04 bis 0,2 mg/Nm^3.

Bei der Vakuumdestillation von quecksilberhaltigem Schlamm (1 – 4 % Quecksilber) werden 99,6 % des Quecksilbers zurück gewonnen. Etwa 0,1 % des Quecksilbers verbleibt im Rückstand und etwa 0,15 % verbleibt im Destillat, welches verbrannt werden muss. Der letztere Prozentsatz landet letztendlich in den Abgasen. Mittels Aktivkohlefilter werden 99,9 % des Quecksilbers abgetrennt. Die maximale Konzentration an Quecksilber im Reststoff liegt bei 50 mg/kg Trockensubstanz.

Medienübergreifende Auswirkungen
- Energieverbrauch für das Destillationsverfahren und mögliche Vorbehandlung
- Verbrauch von Aktivkohle und Wasser bei der Abgasbehandlung
- Emissionen in die Luft.

Betriebsdaten
Der Elektrizitätsverbrauch für das Erwärmen des Vakuumbehälters und für die Vakuumpumpe beläuft sich auf 3,5 GJ/Mg Abfall. Der Verbrauch an Kühlwasser liegt ungefähr bei 13 Mg/Mg quecksilberhaltigen Abfalls. Bei der Behandlung von Schlamm mit einem Quecksilbergehalt von 2 % liegt der Aktivkohlebedarf bei 24 kg/Mg Schlamm.

Wegen des gefährlichen Charakters der quecksilberhaltigen Dämpfe sind Sicherheitsmaßnahmen erforderlich. Hierzu gehören Abgasanlagen, Testmessungen, Verriegelungen sowie Sicherheitsmaßnahmen für das Befüllen, Entleeren, Verbinden und Trennen der Vakuumbehälter und Einrichtungen zur Dekontamination. Zur Minimierung des Explosionsrisikos werden weitere Sicherheitsmaßnahmen durchgeführt, wie etwa ein luftdichter Betrieb der Anlage, eine automatische Drucküberwachung sowie rauch- und funkenfreie Bereiche.

Anwendbarkeit
Die Vakuumdestillation ist anwendbar bei quecksilberhaltigen Schlämmen aus der öl- und gasverarbeitenden Industrie, Batterien, Katalysatoren, Aktivkohlefiltern, Thermometern, Abfällen des Dentalsektors, Leuchtstoffröhren, Sandstrahlabfällen und Boden. Verschiedene Abfallströme werden bei der Vakuumdestillation separat behandelt. Die Kapazitäten der Beispielanlagen liegen zwischen 300 und 600 Mg/a quecksilberhaltigen Abfalls.

Treibende Kraft für die Anwendung
- Für verschiedene quecksilberhaltige Abfälle ist die Deponierung verboten. Im Vergleich zur direkten Deponierung oder Verbrennung des quecksilberhaltigen Abfalls ist das Abfallaufkommen geringer und enthält kein Quecksilber, und die Diffusion in die Umwelt wird verhindert.
- die Präferenzfolge der Abfallwirtschaft im Einklang mit der Abfallrahmenrichtlinie und dem Sechsten Umweltaktionsprogramm der Europäischen Union.

Beispielanlagen

Eine thermische Bodensanierungsanlage in Schweden, zwei Beispielanlagen der Vakuumdestillationsbehandlung in den Niederlanden. Beispielanlagen, in denen eine Vorbehandlung durchgeführt wird: Eine in den Niederlanden (Schreddern von Gasentladungslampen) und eine in Belgien (end-cut/air-push Behandlung).

Literatur

[81, VDI and Dechema, 2002], [150, TWG, 2004], [152, TWG, 2004], [156, VROM, 2004]

4.4 Zu berücksichtigende Techniken bei Behandlungen, die hauptsächlich angewandt werden, um Materialien aus Abfall zurückzugewinnen

In diesem Abschnitt werden Techniken aufgeführt, die aus Sicht der Umwelt ein günstiges Betriebsverhalten besitzen (z.B. Verwendung eines guten Energiesystems) oder die zu einer günstigen Umweltperformance führen können (z.B. Umweltmanagementsysteme). Sie beziehen sich auf Behandlungen zur hauptsächlichen Rückgewinnung von Materialien aus Abfall.

4.4.1 Altöl

Dieser Abschnitt enthält die bei der Festlegung der BVT zu berücksichtigenden Techniken für die Re-Raffination von Altöl.

4.4.1.1 Allgemeine Techniken zur Steigerung der Ausbeute der Re-Raffination

Beschreibung

Die Ausbeute einer Re-Raffinationsanlage liegt zwischen 55 und 75 %, abhängig vom Verfahren und in geringerem Maße von der Zusammensetzung des Altöls. Zu den Techniken zur Steigerung der Effizienz gehören:

a. Leitung des Rückstands aus der Vakuumdestillationskolonne zu einer Selectopropan Einheit, in der 80 % des Brightstocks verwertet werden können, bei gleichzeitiger Reduzierung des Rückstandanteils
b. Leitung der Bodenrückstände aus der Vakuumdestillationskolonne zu einer thermischen Crackanlage, um Gasöl zu produzieren
c. Auswahl des geeigneten Vakuums in den Vakuumdestillationseinheiten (z.B. eine dreistufige Gruppe mit Dampfejektoren bei 17 mm Hg). Das Vakuum kann durch trockene Vakuumpumpen oder hochwirksame mehrstufige Dampfinjektoren erzeugt werden.
d. Nutzung einer Gaswäsche zur Reduzierung der VOC-Emissionen und zur Rückgewinnung von Rohmaterial
e. Nutzung von Sieben zur Entfernung von Substanzen wie Polymerfasern
f. Vorhandensein eines Zwischentanks zwischen der Dehydrobehandlung und den Destillationen, um Materialien abzutrennen, die in folgenden Anlagenteilen zu Verschmutzungen führen können (z.B. Ofen und Destillationskolonne) und Nutzung einer ausreichenden Verweilzeit für die eintretende Reaktion des Additivs mit dem Altöl. Der Niederschlag aus der Fällungsreaktion wird vom Boden des Tanks entfernt und in ein Lager gepumpt, wo der Anteil an dehydriertem Öl abgetrennt werden kann, um eine Wiederverwendung zu ermöglichen.

Erreichter Nutzen für die Umwelt

Steigert die Effizienz der Re-Raffination von Altöl. In Zusammenhang mit Technik b der obigen Beschreibung fällt beim Einsatz von trockenen Vakuumpumpen kein kontaminiertes Wasser an.

Medienübergreifende Auswirkungen

Erhöht den Verbrauch von Energie oder anderen Betriebsmitteln. Beim Einsatz von Dampfinjektoren zur Vakuumerzeugung fällt verunreinigtes Wasser an.

Betriebsdaten

Der Betrieb von trockenen Vakuumpumpen kann durch (feste) Verunreinigungen beeinträchtigt werden.

Treibende Kraft für die Anwendung

In der EU existiert bereits eine rechtlich bindende Regel zur Förderung der Re-Raffination von Altöl zu Basisöl.

Beispielanlagen
Emissionen in die Luft werden teilweise an einigen Standorten kontrolliert und an anderen nicht.

Literatur
[5, Concawe, 1996], [7, Monier and Labouze, 2001], [14, Ministry for the Environment, 2000], [36, Viscolube, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.4.1.2 Auswahl der Altöle für die Re-Raffination

Beschreibung
Altöle die für das Recycling geeignet sind:

a. (schwarze) Motorenöle, die homogene Eigenschaften aufweisen und von Re-Raffinationsanlagen nachgefragt werden
b. schwarze Industrieöle sind potenziell für eine Regeneration geeignet, werden aber wegen ihres Gehalts an Additiven und anderen Stoffen von Re-Raffinationsanlagen in der Regel nicht bevorzugt
c. leichte Industrieöle, die relativ sauber sind. Sie können entweder vor Ort re-raffiniert oder für andere Zwecke wiederverwendet werden. Ihr Markt ist sehr speziell und unabhängig von klassischen Bezugswegen des Recyclings.

Erreichter Nutzen für die Umwelt
Eine Qualitätssteigerung des Eingangsmaterials kann sowohl die Umweltleistung einer Anlage als auch die Produktqualität erhöhen. Abgetrennte gebrauchte Schmierstoffe können einen höheren Verwertungswert als Brennstoff und als ein neuer Werkstoff der Re-Raffination haben. Wenn verhindert wird, dass chlorierte Verbindungen (z. B. Lösemittel oder PCBs) in das Re-Raffinationsverfahren gelangen, können Betriebs- und Umweltprobleme vermieden werden.

Anwendbarkeit
Ein Report berichtet, dass 60 bis 65 % der Altöle für eine Regeneration geeignet sind, obgleich andere Experten eine Größenordnung von etwa 50 % der Altöle nahe legen. Die zur Regeneration geeigneten Altöle sind diejenigen, die nicht zu stark verunreinigt sind und die einen hohen Viskositätsindex aufweisen, sowie keine Ester und biologischen Schmierstoffe enthalten. (Schwarze) Motorenöle repräsentieren über 70 % des Altölstroms. Schwarze industrielle Öle repräsentieren etwa 5 % des gesamten Altöls, wovon etwa 25 % leichte industrielle Öle sind. Experten halten die folgenden Altöle für recyclierbar:

a. nichtchlorierte Maschinen-, Getriebe- und Schmieröle auf Mineralölbasis (EAV-Code: 130205)
b. nichtchlorierte Hydrauliköle auf Mineralölbasis (EAV-Code: 130110)
c. nichtchlorierte Isolier- und Wärmeübertragungsöle auf Mineralölbasis (EAV-Code: 130306)[23]
d. chlorierte Maschinen-, Getriebe-, und Schmieröle auf Mineralölbasis (EAV-Code: 130204) – doch nur unter bestimmten Bedingungen (d.h. Begrenzung des Chlor- oder PCB-Gehalts)
e. Hydrauliköle, die PCB enthalten (EAV-Code: 130101) – doch nur unter bestimmten Bedingungen (d.h. Begrenzung des Chlor- oder PCB-Gehalts)
f. chlorierte Hydrauliköle auf Mineralölbasis (EAV-Code: 130109) – doch nur unter bestimmten Bedingungen (d.h. Begrenzung des Chlor- oder PCB-Gehalts).

Treibende Kraft für die Anwendung
Ökonomische Gründe, um ein gutes Produkt herzustellen.

Literatur
[7, Monier and Labouze, 2001], [55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004], [153, TWG, 2005]

[23] Anm.d.Übers.: Die hier aufgeführte ASN ist nicht korrekt. Die korrekte ASN ist 130307*.

4.4.1.3 Destillations/Bleicherde-Verfahren

Beschreibung
Siehe Abschnitt 2.4.1.5.

Erreichter Nutzen für die Umwelt
Dieses Verfahren hat wegen der großen Menge zu entsorgender öliger Bleicherde potenziell sehr nachteilige Auswirkungen auf die Umwelt. Eine bei hohen Temperaturen aktivierte Bleicherde ermöglicht ein niedrigeres Bleicherde/Öl-Verhältnis, womit die Gesamtausbeute erhöht und die Menge öliger Bleicherde, die entsorgt werden muss, gesenkt wird. Im Vergleich zum Säure/Bleicherde-Verfahren muss weniger ölhaltige Bleicherde entsorgt werden.

Medienübergreifende Auswirkungen
Schlechte Produktqualität und niedrige Ausbeute.

Betriebsdaten
Die erwartete Schmierölausbeute liegt bei diesem Verfahren im Bereich um 50 % auf Trockenbasis.

Beispielanlagen
Es sind keine Anlagen bekannt.

Literatur
[56, Babtie Group Ltd, 2002]

4.4.1.4 Destillation und chemische Behandlung oder Lösemittelextraktion

Beschreibung
Dieses Verfahren besteht aus einer Serie von Vakuum-Zyklonverdampfern mit anschließender chemischer Behandlung der erhaltenen Schmierölfraktionen.

Erreichter Nutzen für die Umwelt
Die für dieses Verfahren erwartete Schmierölausbeute liegt im Bereich von 65 – 70 % Trockengewicht. Die Wahl eines geeigneten Verfahrens kann zur Entfernung praktisch aller PAHs führen, zum Beispiel mittels Lösemittelextraktion. Einige Verfahren dieses Typs generieren keine Reststoffe, da die Reststoffe in Produkte umgewandelt werden (z.B. Erzeugung eines Düngers durch Wiederverwendung von Reaktionswasser).

Anwendbarkeit
Mittelgroße Raffinationsanlagen (~25 kt/a).

Wirtschaftlichkeit
Finanziell attraktiv. Die Investitionskosten einer 108 kt/a Anlage liegen bei 29 Millionen USD (1994). Voraussetzungen: Einsatz der Vakuumdestillation und Bleicherde- oder chemischer Behandlung, Lagerung: 15 Tage und Betriebsmittel: 15 Tage.

Beispielanlagen
Eine Anlage, die für dieses Verfahren ausgelegt wurde, ist in Spanien in Betrieb.

Literatur
[5, Concawe, 1996], [86, TWG, 2003]

4.4.1.5 Lösemittelextraktion und Destillation

Beschreibung
Siehe Abschnitt 2.4.1.5. Das Interline[24] Verfahren der Propanextraktion verbessert durch Sener, enthält drei Stufen, ein Nachbehandlungsschritt ist nicht erforderlich:

a. chemische Vorbehandlung mit Reagenzien und Katalysatoren
b. Extraktion der Schmierstoffbasen mit flüssigem Propan unter Abtrennung von Wasser und Asphalt
c. Atmosphärische und Vakuumdestillation zur Abtrennung der Leichtfraktionen und der Basisöle für Schmierstoffe.

Erreichter Nutzen für die Umwelt
Das Verfahren erzeugt keinen festen Abfall. Die chemische Behandlung der entstandenen Ölfraktion mit einer Mischung von Chemikalien wandelt das organisch gebundene Chlor in NaCl um. Nach weiterer Destillation haben alle Endprodukte einen reduzierten Chlorgehalt (unter 10 ppm). Im chemischen Reaktor werden Kontaminationen und praktisch alles Chlor, bis unter 5 ppm, entfernt.

Betriebsdaten
Für dieses Verfahren wird eine Schmierölausbeute von 79 % Trockengewicht angegeben. Aus einer anderen Quelle geht hervor, dass die Anbieter der Technologie Ausbeuten zwischen 72 – 74 % Trockengewicht bei Basisölen und 21 – 22 % Trockengewicht bei Asphalten voraussehen.

Anwendbarkeit
Es besteht die Möglichkeit der Re-Raffination in Bereichen mit geringen Altölaufkommen, da die Anlage gut an relativ kleine Kapazitäten adaptiert ist (25 – 30 kt/a).

Wirtschaftlichkeit
Reduzierte Investitions- und Betriebskosten. Anbieter der Technologie behaupten, dass diese Technik im Vergleich zu anderen Re-Raffinationstechnologien die Investitions- und Betriebskosten senkt. Die Wirtschaftlichkeit des Verfahrens ist für Anlagen relativ geringer Kapazität (25 – 30 kt/a) gut ausgewogen.

Beispielanlagen
An einer Anlage in Spanien, die seit 2000 in Betrieb ist, zeigt sich, dass Emissionen in die Luft reduziert werden können, indem die Entlüftungsströme und die Gasphase der Destillationsanlagen in eine thermische Oxidationsanlage geleitet werden, wo Schadstoffe bei 850 ºC und einer Verweilzeit von zwei Sekunden oxidiert werden.

Literatur
[5, Concawe, 1996], [11, Jacobs and Dijkmans, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.4.1.6 Dünnschichtverdampfer und verschiedene Nachbehandlungsverfahren

Beschreibung
Die Vakuumdestillation (Dünnschichtverdampfer - engl. TFE) ist eine übliche Komponente in vielen Re-Raffinationsanlagen. Eine zu berücksichtigende Technik ist die Anwendung von mechanischen Dichtungen für die rotierende Welle des Dünnschichtverdampfers.

[24] Anm.d.Übers.: Ebenso wie „Sener“ eine Firma.

Erreichter Nutzen für die Umwelt

Dünnschichtverdampfer zusammen mit	Ausbeuten (%) (im Verhältnis zum Input für jede einzelne Tätigkeit)
Bleicherdebehandlung	Gesamtausbeute: 54 – 73 % Entwässerung: 88 – 92 %; Destillation mit Dünnschichtverdampfer 80 – 81 %; Vakuumdestillation 76 %, Bleicherdebehandlung 95 %
Wasserstoffbehandlung	Hohe Produktqualität Die von den Lizenzgebern angegebene Schmierölausbeute liegt im Bereich von 72 % Trockengewicht Zwei bestehende Anlagen berichten über Ausbeuten von bis zu 94 – 98 % Andere Quellen geben die folgenden Ausbeuten an: 88 % Dehydration/Destillation; 84 % Destillation mit Dünnschichtverdampfer; 86 % Hydrierung als Nachbehandlung, was zu einer Gesamtausbeute von 64 % führt
Extraktion mit Lösemittel	Die Gesamtausbeute liegt im Bereich von 50 – 67 %. 88 – 92 % Dehydration/Destillation; 80 – 91 % Vakuumdestillation; 83 – 91 % Extraktion als Nachbehandlung
Extraktion mit Lösemittel und Hydrierung als Nachbehandlung	Gesamtausbeute 91 % Dehydration/Destillation 81 % Vakuumdestillation; 97 % Extraktion als Nachbehandlung

Tabelle 4.34: Vorteile der Dünnschichtverdampfer-Technologie für die Umwelt
[13, Marshall, et al., 1999], [139, UBA, 2003], [150, TWG, 2004]

Medienübergreifende Auswirkungen
Dünnschichtverdampferanlagen erzeugen ohne weitere Behandlung ein dunkel gefärbtes Öl, das geeignet ist zum Verschnitt mit Diesel, jedoch nicht als Basisöl für eine Beimischung in Schmierölen. Die derzeit vorliegenden Erfahrungen berichten von aufgetretenen Geruchsproblemen.

Anwendbarkeit
Die Größe dieser Anlagen liegt zwischen 25 und 160 kt/a.

Wirtschaftlichkeit
Die notwendigen Investitionen für eine Vakuumdestillations- und Wasserstoffbehandlung mit einer Kapazität von 108 kt/a liegen bei 43 Millionen USD (1994). Aus einigen anderen neueren Daten geht hervor, dass die Kosten einer Dünnschichtverdampfer/Bleicherde-Anlage mit einer Kapazität von 100 kt/a bei 221 EUR/Mg Öl liegen; die Kosten einer Dünnschichtverdampfer/Wasserstoff Anlage mit einer Kapazität von 50 kt/a betragen 333 EUR/Mg Öl; und die Kosten einer Dünnschichtverdampfer/Lösemittel Anlage mit einer Kapazität von 50 kt/a liegen bei 308 EUR /Mg Öl.

Beispielanlagen
Eine Anlage in Newcastle (Australien) und zwei in Deutschland (85 und 160 kt/a) nutzen diese Technologie. Mindestens sechs verschiedene kommerziell angewandte Verfahren stehen zur Verfügung.

Literatur
[5, Concawe, 1996], [13, Marshall, et al., 1999], [150, TWG, 2004]

4.4.1.7 Thermische Entasphaltierung

Beschreibung
Für weitere Informationen zur thermischen Entasphaltierung siehe Abschnitt 2.4.1.5.

Erreichter Nutzen für die Umwelt
Die Schmierölausbeute beträgt nach Angaben des Lizenzgebers auf Basis von dehydratisiertem Altöl 74 % bei einer Nachbehandlung mit Bleicherde (97 % entwässerte Kraftstoffentfrachtung, 80 % Entasphaltierung, 95 % Nachbehandlung) und 77 % Trockengewicht bei einer Wasserstoffbehandlung (97 % entwässerte Kraftstoffentfrachtung, 80 % Entasphaltierung, 96 % Nachbehandlung).

Anwendbarkeit
Dieses Verfahren wird in großen Anlagen von 100 –180 kt/a und bei Wasserstoffbehandlung von 40 - 100 kt/a eingesetzt.

Wirtschaftlichkeit
Die Kosten einer thermischen Entasphaltierung/Bleicherde-Anlage mit einer Kapazität von 100 kt/a liegen bei 280 EUR/t Öl und für eine thermischen Entasphaltierung/Wasserstoff-Anlage bei 304 EUR /t Öl.

Beispielanlagen
Eine Anlage in Italien und zwei weitere außerhalb der EU.

Literatur
[13, Marshall, et al., 1999], [36, Viscolube, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.4.1.8 Recycling in einer Schmierölraffinerie

Beschreibung
Siehe Abschnitt 2.4.1.5.

Erreichter Nutzen für die Umwelt
Die erwartete Schmierölausbeute liegt bei diesem Verfahren im Bereich von 65 – 70 % Trockengewicht. Diese Technologie verbessert die Qualität des re-raffinierten Öls, wenn im Vergleich zu bestehenden Re-Raffinationsanlagen eine Vordestillation, Entasphaltierung und Nachbehandlung mit Bleicherde eingesetzt wird. Darüber hinaus wird behauptet, dass die Ölqualität in mancher Hinsicht sogar höher sein kann als die des konventionellen Mineralöls, das in derselben Produktionslinie erzeugt wird.

Wirtschaftlichkeit
In Bezug auf den Standort der Anlage, werden durch das Vorhandensein von Infrastruktur und weiterer Ausstattungen natürlich die Investitionskosten gesenkt. Es ist aber schwierig, mögliche Einsparungen zu quantifizieren, da Wartungs- und Nachrüstungskosten in jedem Fall notwendig sind.

Investitionskosten (1995): 45 Millionen USD. Voraussetzungen: Behandlung von 108 kt/a, Lagerung für 15 Tage und Betriebsmittel: für 15 Tage.

Beispielanlagen
Dieser Verarbeitungsweg wird seit kurzem in Deutschland kommerziell angewendet.

Literatur
[5, Concawe, 1996], [13, Marshall, et al., 1999]

4.4.1.9 Wasserstoffbehandlung

Beschreibung
Siehe Abschnitt 2.4.1.4. Eine zu berücksichtigende Technik ist die Gaswäsche (siehe Abschnitt 4.6.10) oder die Verbrennung (siehe Abschnitt 4.6.14) der sauren Abgase aus der Wasserstoffbehandlung.

Erreichter Nutzen für die Umwelt
Die Wasserstoffbehandlung ist ein sehr wirksames Nachbehandlungsverfahren, denn sie:

- reduziert oder entfernt den Restgehalt an Metallen und Metalloiden im Altöl
- reduziert den Conradson Koks (Messung der Tendenz eines Kohlenwasserstoffs zur Koksbildung)
- reduziert organische Säuren sowie chlor-, schwefel- und stickstoffhaltige Verbindungen
- stellt Farb-, UV- sowie thermische Eigenschaften wieder her
- reduziert PAH, wenn der Betrieb unter Hochdruck und bei hohen Temperaturen läuft
- ermöglicht einen Viskositätsindex, der gleich oder besser als der des Original-Einsatzstoffes ist.

Medienübergreifende Auswirkungen
Wasserstoff muss erzeugt oder gekauft werden. Es scheint, dass die Wasserstoffbehandlung den Gehalt an synthetischen Ölen, die im Altöl bereits vorhanden sind, nicht ändert.

Betriebsdaten
Die Wasserstoffbehandlung erhöht in der Regel die Sicherheitsrisiken (infolge der Notwendigkeit des Umgangs mit Wasserstoff unter Druck und bei erhöhter Temperatur). Druck: 100 bar Partialdruck; Temperatur: 340 °C; Katalysator: NiMo.

Wirtschaftlichkeit
Die Investitionskosten der Wasserstoffbehandlungsanlage sind sehr hoch. Tabelle 4.35 gibt einige Beispiele.

Anlage	Kosten
Moderne Re-Raffination mit Wasserstoffbehandlung ohne Sammlungskosten	4 – 47 EUR /Tonne [1]
Durchschnittliche Sammlungskosten in Europa	110 EUR /Tonne
Moderne Re-Raffination mit Wasserstoffbehandlung, Sammlungskosten inbegriffen	106 bis 63 EUR /Tonne
Freistehende scharfe Hydrierungsanlage	10 Millionen EUR
Freistehende scharfe Hydrierungsanlage falls Claus-Einheit eingebaut, H_2–Erzeugung, sauere Stripper- und Amin Einheiten sind auch notwendig	20 Millionen EUR
Wasserstoffbehandlung für eine 108 kt/a-Anlage	65 Millionen USD (1994)[2]
[1] Wert am Anlagentor (1994) unter Voraussetzung eines internen Zinsfußes von 15 % nach Steuern und Betriebsmitteln für 15 Tage. Ein neuer Bericht von Europia (2003) berichtet über Werte von 300 – 333 EUR /Tonne. [2] Solventextraktion und Hydrierung, Lagerung: 15 Tage und Betriebsmittel: 15 Tage	

Tabelle 4.35: Wirtschaftlichkeit einer Wasserstoffbehandlungsanlage
[5, Concawe, 1996], [36, Viscolube, 2002], [86, TWG, 2003], [150, TWG, 2004]

Treibende Kraft für die Anwendung
Verbesserung der Produktqualität.

Beispielanlagen
Die Wasserstoffbehandlung ist das einzige Re-Raffinationsverfahren, das von dem American Petroleum Institute (API) gebilligt wird. Zwei Wasserstoffnachbehandlungsanlagen stehen in Italien (eine mit scharfer Wasserstoffnachbehandlung und eine andere mit sanfter Wasserstoffnachbehandlung).

Literatur
[5, Concawe, 1996], [7, Monier and Labouze, 2001], [13, Marshall, et al., 1999], [36, Viscolube, 2002], [66, TWG, 2003], [86, TWG, 2003], [150, TWG, 2004]

4.4.1.10 Direktkontakt Hydrierungsverfahren

Beschreibung
Siehe die Beschreibung zu Direktkontakt Hydrierungsverfahren in Abschnitt 2.4.1.5.

Erreichter Nutzen für die Umwelt
Zu den Vorteilen der Technik gehören:

- das Verfahren ist sehr effizient bei der Abtrennung von Kontaminationen aus dem Altöl
- halogenierte und sauerstoffangereicherte Verbindungen werden zerstört
- reinere Produkte werden erzeugt (z.B. schwefelarme (<0,03 Gew.-%) Brennstoffe)
- das gesamte Altöl wird in einer reduzierenden Umgebung behandelt. Dies unterstützt die Bildung von polymeren und kohlenstoffhaltigen Nebenprodukten
- in der Behandlung wird weiter katalytisch behandelt, um vorhandene toxische Schwefelverbindungen in nicht toxische Sulfate umzuwandeln
- wasserstoffreiches Gas wird recycelt
- die im Umwandlungsreaktor erzeugten sauren Gase werden mit einer basischen Lösung neutralisiert.

Medienübergreifende Auswirkungen
Wasserstoff muss erzeugt oder gekauft werden. Zu den festen Materialien, die entsorgt werden müssen, gehören verbrauchte Katalysatoren, Natriumchlorid und Natriumsulfat. Das Verfahren erzeugt ein Abwasser mit niedrigem CSB, ohne Sulfide und organische Chloride sowie einen stabilen schweren Rückstand, von dem behauptet wird, dass er für die Beimischung zu Asphalt geeignet ist.

Wirtschaftlichkeit
Ökonomisch attraktive Produkte hoher Qualität und eine höhere Ausbeute pro Tonne Input.

Treibende Kraft für die Anwendung
Verbessert die Qualität des erzeugten Basisöls durch:
- bessere Qualität und Eigenschaften als diejenigen von Frischölen
- Basisöl der Gruppe II mit geringem Schwefel-, Phosphor- und Aromatengehalt
- Erhöhung des Viskositätsindexes und der Oxidationsstabilität.

Beispielanlagen
Das Direktkontakt Hydrierungsverfahren wird industriell eingesetzt, seit eine erste Anlage in Deutschland im November 2003 fertig gestellt wurde.

Literatur
[5, Concawe, 1996], [139, UBA, 2003], [150, TWG, 2004]

4.4.1.11 Lösemittelextraktion

Beschreibung
Siehe Abschnitt 2.4.1.4.

Erreichter Nutzen für die Umwelt
Führt nicht zu verunreinigter Bleicherde als Abfallprodukt.

Medienübergreifende Auswirkungen
Nur 98 % des Lösemittels werden nach der Extraktion des Basisöls regeneriert.

Anwendbarkeit
Voll anwendbar im Sektor.

Wirtschaftlichkeit
Preiswerter als die Hydrierung als Nachbehandlung.

Beispielanlagen
Mindestens eine Anlage ist in Deutschland in Betrieb

Literatur
[86, TWG, 2003]

4.4.1.12 Natronlauge- und Bleicherdebehandlung

Beschreibung
Siehe Abschnitt 2.4.1.4.

Erreichter Nutzen für die Umwelt
Als Resultat wird eine hohe Schmierölausbeute erreicht. Das erzeugte Basisöl ist von hoher Qualität (Gruppe II), die Basisöl-Ausbeute ist höher als bei anderen verfügbaren Technologien. Die Neutralisierung wird durch eine Säure- und Bleicherdebehandlung durchgeführt. Nur 25 % der Bleicherde und Säure werden im Vergleich zum üblichen Bedarf an Bleicherde/Säure verbraucht.

Betriebsdaten
Verwendung von Natronlauge.

Anwendbarkeit
Auf Altöle angewendet.

Wirtschaftlichkeit
Es wird berichtet, dass das Verfahren ökonomisch attraktiv ist, da Produkte hoher Qualität entstehen und eine höhere Ausbeute pro Tonne Input erzielt werden kann.

Treibende Kraft für die Anwendung
Durch diese Technik wird die Qualität des Basisöls verbessert:

a. gleiche Qualität und Eigenschaften wie Frischöle
b. Basisöl der Gruppe I mit geringem Schwefel-, Phosphor- sowie geringem Aromatengehalt
c. hoher Viskositätsindex und hohe Oxidationsstabilität.

Beispielanlagen
Seit 2000 ist eine Anlage in Deutschland in Betrieb.

Literatur
[5, Concawe, 1996], [150, TWG, 2004]

4.4.1.13 Behandlung in einer Raffinerie

Beschreibung
In einer Raffinerie bestehen zwei Möglichkeiten der Mischung:

<u>Mischung mit dem Einsatzmaterial (in der Regel Rohöl)</u>
Das vorbehandelte Öl wird mit dem Rohöl gemischt, die Mischung passiert den Entsalzer und wird anschließend der Rohöldestillationseinheit einer bestehenden Raffinerie zugeführt. Bei dieser Option durchläuft das Altöl alle Prozesse in der Raffinerie und der Hauptteil des Altöls landet im Sumpfprodukt der Vakuumdestillationskolonne. Dieser Vakuumdestillationsrückstand enthält den Großteil der Metall- und Schwefelverbindungen des Altöls. Seine letztendliche Nutzung hängt von der Raffinerie ab.

<u>Mischung in den Vakuumdestillationsrückstand</u>
Vorbehandeltes Altöl wird als Zusatzkomponente dem Bodenprodukt aus der Vakuumdestillationskolonne beigemischt. Bei dieser Option kommt das Altöl kaum mit den Raffinationseinheiten der Anlage in Berührung. Die Mischung enthält alle Metalle, Chloride und Schwefelverbindungen, die aus dem Altöl stammen.

Untersuchungen haben gezeigt, dass die meisten Metalle aus dem Altöl in den Asphaltrückstand eingehen. Die Qualität des Gasöls aus der Vakuumdestillation wird bis auf leicht erhöhte Chlorgehalte nicht verändert und kann als geeignet für den Einsatz im katalytischen Crackprozess angesehen werden. Allerdings haben Versuche auch Hinweise darauf ergeben, dass eine zusätzliche Vorbehandlungen des vordestillierten Altöls notwendig ist, um den Gehalt an polyorganischen Chloriden zu senken, die bei der Vordestillation nicht entfernt wurden. Andernfalls würden diese Chloride in die Leichtsiedern der Vakuumdestillationskolonne eingehen und Korrosion im Kolonnenkopf und bei der nachfolgenden Wasserstoffbehandlung verursachen.

Erreichter Nutzen für die Umwelt
Zusätzlich zu dem Nutzen, einen Sekundärrohstoff für die energetische Nutzung bereitzustellen, senkt es die komplexen Anforderungen an das Rohöl. In der Regel wird so der Betriebsmittelverbrauch der Schmierölanlage gesenkt, weil die Regeneration von Altölen weniger Hilfsmittel erfordert als die Produktion aus Frischölen und zwar hauptsächlich wegen des geringeren Wachsgehalts (weshalb ein Entwachsen in geringerem Umfang erforderlich ist). Die Schwefelemissionen werden nur geringfügig reduziert.

Medienübergreifende Auswirkungen
Die (potenzielle) Anwesenheit organischer Chloride kann während der Wasserstoffbehandlung eine schwache Säure entstehen lassen, was zu schweren Korrosionsproblemen und potenziellen Zwischenfällen führen kann. Bei normaler Abfolge des Raffinationsverfahrens werden nicht alle Metalle aus dem Altöl entfernt, mit dem Ergebnis, dass die verbleibenden Metalle den Katalysator beim katalytischen Cracken schädigen können.

Darüber hinaus könnten Raffinerien das Altöl ohne weitere Aufarbeitung mit Schweröl vermischen und es als Sekundärbrennstoff in einer Brenneinheit verwenden. Die Verbrennung dieses Brennstoffs kann zu höheren SO_x- und Metallemissionen führen. In manchen Ländern sind diese Schwerölbrenner nicht mit einer Abgasreinigungsanlage ausgestattet, weil die Genehmigungen dieser Anlagen nach dem „Glocken-Prinzip“ angepasst wurden (siehe BVT-Merkblatt “Raffinerien”).

Betriebsdaten
Diese Technik kann in die Raffinerie integriert werden. Die Vermischung von Altöl mit Rohöl wird nicht durchgeführt, weil das Altöl in der Anlage schwere technische Probleme, z.B. Verschmutzungen des Katalysators und schwere Korrosion verursachen kann.

Ein Recycling von Altöl innerhalb einer Mineralölraffinerie wird im Allgemeinen wegen der schwerwiegenden technischen Probleme, die das Altöl in der Anlage verursachen kann, nicht durchgeführt. Einige Beispiele dafür sind Metalle im Altöl, die das Katalysatorbett für das katalytische Cracken schädigen können sowie die Präsenz organischer Chloride im Altöl, die Korrosionsprobleme verursachen können, da sie in den Hydrierungsstufen in schwache Salzsäure umgewandelt werden.

Anwendbarkeit
Diese Technik führt zu einer Verzerrung des Produktspektrums der Mineralölraffinerie. Um den Bedarf ihrer Kunden, die schwere Schmieröle nachfragen, erfüllen zu können, muss die Raffinerie auch diese Fraktion herstellen (durch Erhöhen des Verbrauchs an Rohöl in der Brennstoffeinheit).

Die technische Machbarkeit ist nicht gewährleistet, weil die Technik schwerwiegende technische und betriebliche Probleme verursachen kann.

Wirtschaftlichkeit
Der ungefähre Wert von Altöl ohne Sammlungskosten liegt bei 27€/t (Wert am Anlagentor (1994) unter Voraussetzung eines internen Zinsfußes von 15 % nach Steuern und von Betriebsmittel: für 15 Tage) und bei -83€/t einschließlich der Sammelkosten (bei durchschnittlichen Sammelkosten von 110 USD/t in Europa). Im Hinblick auf den Standort der Anlage kann das Vorhandensein von Infrastruktur und anderen Einrichtungen die Investitionskosten senken. Einsparungen sind hierfür schwer zu quantifizieren, da eventuell Wartungs- und Nachrüstungskosten notwendig sind.

Die Investitionskosten liegen bei 11 Millionen USD (1994) unter folgenden Voraussetzungen: 120 kt/a, Lagerung: 15 Tage und Betriebsmittel: 15 Tage.

Ökonomische Vorteile stehen im Zusammenhang mit Synergien des Verfahrens und der Verringerung des Rohöl- und Energieverbrauchs. Gemäß [7, Monier and Labouze, 2001], ist die Integration einer thermischen Crackanlage für Raffinerien aus ökonomischer Sicht vorteilhafter als die Integration einer Re-Raffinationseinheit.

Treibende Kraft für die Anwendung
Die potenziell schwerwiegenden Betriebsprobleme machen diese Behandlungsmethode für Raffineriebetreiber unattraktiv.

Beispielanlagen
Das Verfahren wird bis jetzt noch nicht in der Industrie angewendet. Die Methode war Gegenstand einer Pilotstudie in Frankreich und einer Studie in Kanada.

Literatur
[5, Concawe, 1996], [6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [11, Jacobs and Dijkmans, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.4.1.14 Wassermanagement in Re-Raffinationen für Altöl

Beschreibung
Zu den Techniken gehören:

a. Sicherstellung, dass jegliches Abwasser (z.B. destilliertes Wasser aus dem Altöl, Prozesswasser einschließlich des Abwassers aus der basischen Gaswäsche) vor der Einleitung behandelt wird
b. Nutzung einer Abwasserbehandlungseinheit (z.B. Demulgator und Flockungsmittel, Flockung und biologische Behandlung, Ultrafiltration und Mikrofiltration). Weitere Informationen sind in Abschnitt 4.7 zu finden
c. Wiederverwendung des gereinigten Abwassers als Kühlwasser nach Behandlung in einer geeigneten Abwasserbehandlungsanlage und durch die Aufbereitung des Wassers, das außerhalb der Anlage wiederverwendet werden kann
d. Einspeisung des Abwassers zusammen mit den Ölen in den Verbrenner, um schädliche Bestandteile zu verbrennen.

Erreichter Nutzen für die Umwelt
Drei Beispiele für die durch die Behandlungen erreichten Konzentrationen zeigen Abbildung 4.6, Abbildung 4.7, Abbildung 4.8, Tabelle 4.36 und Tabelle 4.37.

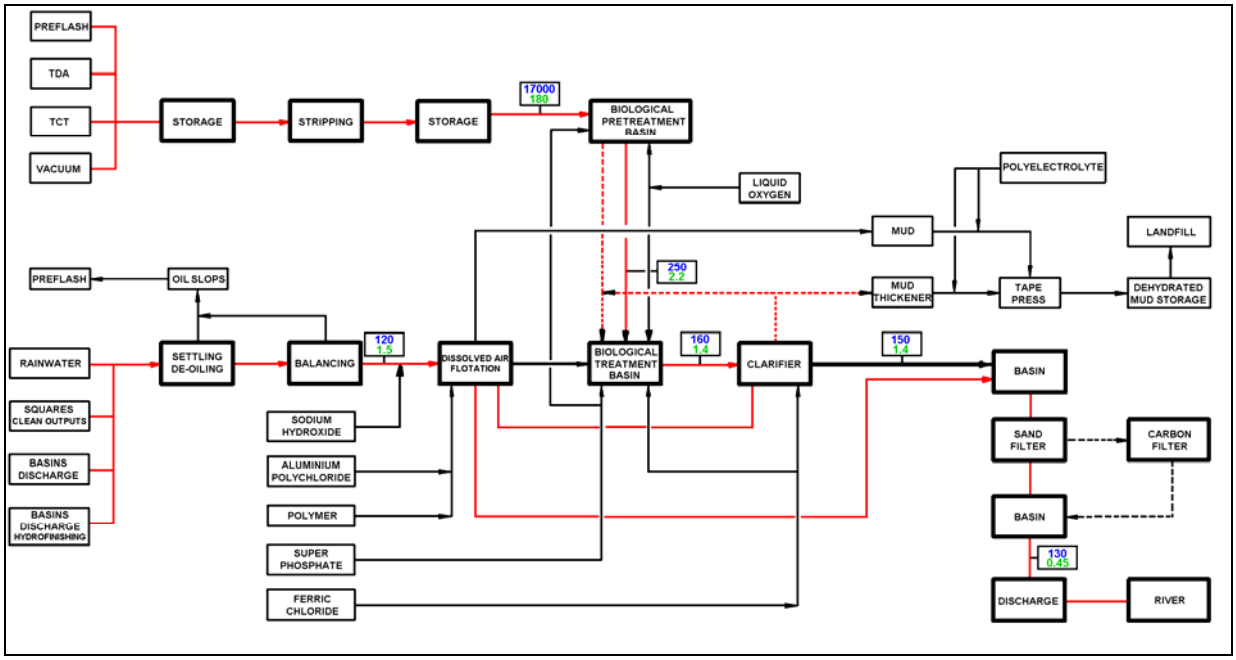


Abbildung 4.6: Erreichbare Konzentrationen in einer Abwasserbehandlungsanlage, die in einem Re-Raffinationsverfahren eingesetzt wird
Anmerkung: Die Zahlen in Kästchen sind in ppm angegeben. Die oberen Zahlen beziehen sich auf CSB und die unteren Zahlen auf den Phenolgehalt

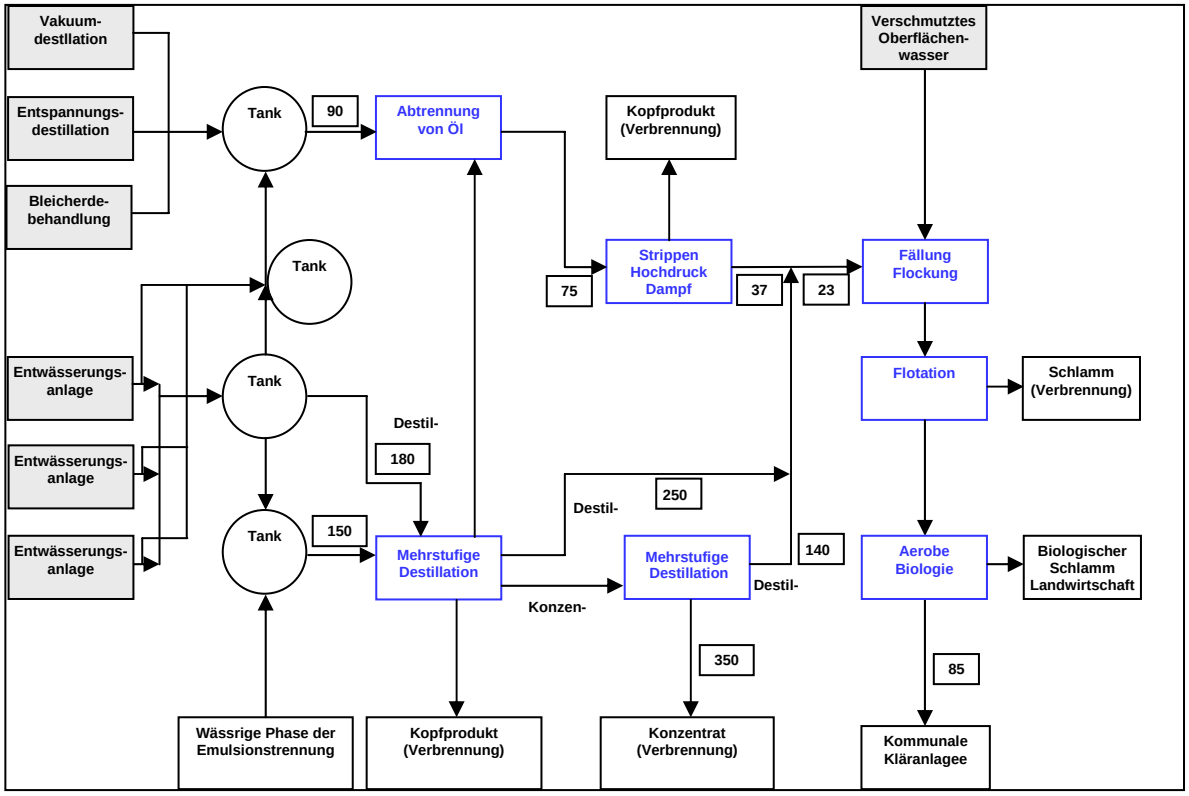


Abbildung 4.7: Abwasserbehandlung in einem Re-Raffinationsverfahren (Dünnschichtverdampfung/Bleicherde-behandlung)
Anmerkung: Die Werte in der Abbildung beziehen sich auf TOC-Gehalte in ppm

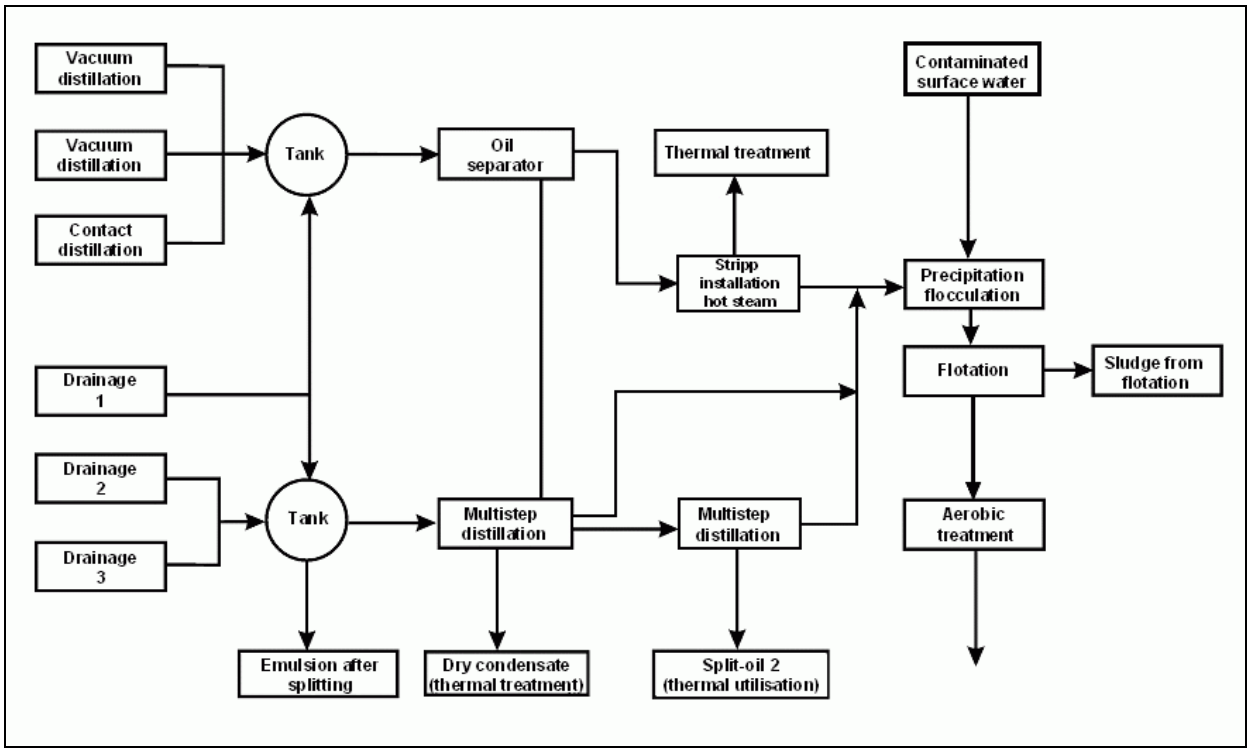


Abbildung 4.8: Abwasserbehandlung in einer Altölbehandlungsanlage

Die Parameter in der unten angeführten Tabelle 4.36[25] können mit derselben Abwasserbehandlungsanlage wie oben erreicht werden.

[25] Anm.d.Übers.: Im Originaltext steht Tabelle 4.35, in der jedoch Kosten aufgeführt werden.

Parameter	Fällungs-/Flockungsteil (mg/l)	biologischer Teil (mg/l)	nachgeschaltete betriebsinterne biologische Behandlung (mg/l)
CSB			200 – 500
TOC	1800 – 3500	1300 – 2200	60 – 150
Nitrit-N		1 – 20	<0,1 – 1,0
Gesamt-Stickstoff		80 – 280	10 – 60
Gesamt-Phosphor		1 – 15	2,0 – 5,0
AOX		0,1 – 0,4	<0,10 – 0,25
Kohlenwasserstoffe	50 – 300	<1,0 – 10	<0,1 – 2,0
Benzole und Benzolderivate		0,01 – 0,03	<0,01
Phenolindex		1 – 50	<0,2
Pb	<0,05 – 0,06	<0,05	<0,05
Cd	<0,02	<0,02	<0,02
Cr	<0,02 – 1,0	<0,02	<0,02
Fe	1 – 10	1 – 20	1 – 10
Cu	<0,02 – 0,2	<0,02 – 0,1	<0,02 – 0,1
Ni	<0,02 – 0,5	<0,02 – 0,3	<0,02 – 0,1
Zn	<0,1 – 1,0	<0,1 – 0,1	<0,1

Tabelle 4.36: Zusammensetzung verschiedener Inputs und Outputs aus verschiedenen Strömen der Abwasserbehandlungsanlage in einer Altölraffinerie

Abwasserparameter	Wert (ppm)
Kohlenwasserstoffe	<0,01 – 5
CSB	20 – 400*
Phenole	0,15 – 0,45
* Werte von 400 können ohne Verdünnung des behandelten Abwassers mit anderen Wasserströmen erreicht werden	

Tabelle 4.37: Erreichbare Konzentrationen im Ablauf einer biologischen Abwasserbehandlungsanlage in Altölbehandlungsanlagen
[42, UK, 1995], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

Medienübergreifende Auswirkungen
In Abwasserbehandlungsanlagen entstehen in der Regel Ammoniak- und VOC-Emissionen in die Luft.

Betriebsdaten
Die biologische Behandlung ist eine zu berücksichtigende Möglichkeit, allerdings hat sie sich bisher als nicht betriebssicher herausgestellt. Zur kontinuierlichen Überwachung des Abflusses in die Kanalisation gehört die Überwachung der Konzentration von Ammoniak, jedoch nicht die des Gesamt-Stickstoffs. Eine Überwachung von Phosphorkonzentrationen findet nicht statt.

Beispielanlagen
Die biologische Einheit einer Ölverwertungsanlage in GB bestand aus vier Belüftungseinheiten, die gebrauchte Tanks waren, in denen sowohl die wässrige Schicht aus der Behandlung von Öl als auch Deponiesickerwässer behandelt wurden. Es gibt manche Re-Raffinationsverfahren, die kein Abwasser erzeugen, welches extern behandelt werden muss. Diese Verfahren nutzen das in Altöl enthaltene Wasser vollständig (z.B. Nutzung des behandelten Wassers als Kühlerflüssigkeit oder bei der Produktion eines Düngermittels).

Literatur
[36, Viscolube, 2002], [42, UK, 1995], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [139, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.4.1.15 Abfallwirtschaft in Altölaufbereitungsanlagen

Beschreibung
Zu den Techniken gehören:

a. Verbrennung der zurückgewonnenen Nicht-Schmieröle in einer Feuerungsanlage, der mit einer Gaswäsche ausgestattet ist, und anschließende Nutzung der Energie in der Anlage
b. Behandlung und Beseitigung aller benutzten Filter
c. Anwendung einer thermischen Behandlung aller Reststoffe
d. Nutzung der Reststoffe aus den Vakuumdestillationseinheiten und Verdampfern als Asphaltprodukte.

Erreichter Nutzen für die Umwelt
Senkt das durch die Behandlung erzeugte Reststoffaufkommen.

Treibende Kraft für die Anwendung
Es werden weniger Abfälle erzeugt.

Beispielanlagen
In der Regel in Anlagen zur Regeneration von Altöl eingesetzt.

Literatur
[56, Babtie Group Ltd, 2002], [150, TWG, 2004]

4.4.2 Lösemittelabfälle

4.4.2.1 Auswahl von Lösemittelabfällen für das Recycling

Beschreibung
Lösemittelabfälle, die aus sortenreinen Strömen bestehen, werden in der Regel regeneriert. Ein Lösemittelabfall kann als regenerierbar angesehen werden, z.B. wenn:

- er ein sortenreiner Abfall ist (eine Charge von einem Abfallerzeuger)
- er eine Ausbeute von mindestens 60 % Destillat erzielt
- er ein bestimmtes Mindestaufkommen pro Charge aufweist
- die Kosten einer Destillation gleich oder niedriger als die der Verbrennung sind.

Erreichter Nutzen für die Umwelt
Vermeidung von Umweltproblemen in der Anlage. Durch Destillation werden Lösemittelabfälle in wiederverwertbare Lösemittel und in einen nicht wiederverwertbaren Destillationssumpf getrennt.

Anwendbarkeit
Nicht chlorierte Lösemittel, FCKW und Halone.

Literatur
[150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

4.4.2.2 Verbesserung der Regeneration von Lösemittelabfällen

Beschreibung
Zu den Techniken gehören:

a. Anwendung der azeotropen Destillation
b. Anwendung der Vakuumdestillation
c. Einsatz von Dünnschichtverdampfern
d. Erwärmung des Einsatzmaterialstroms durch das Destillat mit Hilfe eines Wärmeaustauschers und Isoliermaßnahmen
e. Anwendung einer abgestuften Wiederverwertung der Lösemittel (d.h., indem das Lösemittel zuerst bei einer Reinigung mit hohen Qualitätsanforderungen verwendet wird und nachfolgend für andere Reinigungs- oder Arbeitsgänge, bei denen keine reinen Lösemittel erforderlich sind)
f. Nutzung von Gaspendelsystemen und Leitung des Abgases zu Abluftreinigungsanlagen (z.B. Aktivkohlefiltration, eingehauste Systeme und Verwendung von Gaspendelsystemen während der Beladung). Der Abscheidewirkungungsgrad eines Aktivkohlefilters liegt bei mindestens 90 %.
g. Nutzung der Destillation zur Abtrennung von Feststoffen aus organischen Lösemitteln
h. Nutzung der Rektifikation zur Entfernung von Verunreinigungen und zum Erzielen einer bestimmten Qualität des Abfalls-OUT
i. Entwässerung mittels Dekanter, falls die Lösemittel Wasser enthalten.

Erreichter Nutzen für die Umwelt
Verbessert die Trennung von Lösemittelabfällen sowie die effiziente Nutzung von Lösemitteln. Der Energieverbrauch der Destillation kann reduziert werden (z.B. Techniken b-d im obigen Abschnitt „Beschreibung“).

Emissionswerte von 50 mg C/Nm³ sind im Abgas mittels der Behandlung erreichbar, die in Technik f im obigen Abschnitt beschrieben ist.

Medienübergreifende Auswirkungen
Die Anwendung einer abgestuften Wiederverwertung von Lösemitteln könnte dazu führen, dass Lösemittel in offenen Geräten und zum Beispiel zur Reinigung von Maschinen oder Beschichtungsgeräten verwendet werden. In solchen Fällen muss eine definierte Zusammensetzung der Lösemittelmischung bekannt sein, und die Lösemittel sollten keine flüchtigen organischen Verbindungen enthalten, die als Risikostoffe für die menschliche Gesundheit eingestuft sind.

Die Destillation von Lösemittelabfällen erzeugt Kohlenwasserstoff-Emissionen in die Luft und in das Abwasser, das behandelt werden muss.

Betriebsdaten
Die Nutzung von Gaspendelsystemen während der Beladung mit Lösemitteln wird in der Regel benutzt, um flüchtige VOC-Emissionen zu reduzieren (z.B. in Deutschland). Das Abgas wird üblicherweise durch Adsorption an Aktivkohle behandelt.

Anwendbarkeit
Die Destillationstechnik ist auf alle regenerierbaren Lösemittel und Kühlmittel anwendbar. Die Kapazitäten der Beispielanlagen liegen zwischen etwa 2 - 60 kt/a.
Die azeotrope Destillation wird üblicherweise genutzt, um die Verwertung der Lösemittel zu erhöhen. Eine azeotrope oder azeotropische Mischung ist eine Mischung von Flüssigkeiten, die sich beim Sieden wie ein einziger Stoff verhält (d.h. sowohl der Dampf als auch die Flüssigkeit haben dieselbe Zusammensetzung). Die azeotrope Destillation nutzt die Zugabe eines Stoffes (in der Regel Dampf), um eine azeotrope Mischung mit dem zu recyclierenden Lösemittel zu bilden. Die azeotrope Mischung hat einen niedrigeren Siedepunkt als die Originalmischung, wodurch die Rückgewinnung des Lösemittels erleichtert wird.

Die Vakuumdestillation ist darauf ausgelegt, Lösemittel mit höheren Siedepunkten (über 200 °C) zu behandeln.

Treibende Kraft für die Anwendung
Einige organische Lösemittel sind für die menschliche Gesundheit besonders gefährliche Verbindungen. Einige Restriktionen (z.B. eingehauste Anlagen) werden in Richtlinie 1999/13/EG genannt.

Vorrangige Ordnung in der Abfallwirtschaft in Bezug auf die Abfallrahmenrichtlinie und das Sechste Umweltaktionsprogramm der Europäischen Gemeinschaft.

Beispielanlagen
Re-Raffination von N-methyl-2-pyrrolidon (NMP) das in der Elektronikindustrie verwendet wird.

Literatur
[53, LaGrega, et al., 1994], [130, UBA, 2003], [150, TWG, 2004]

4.4.2.3 Abwasserbehandlung in einer Lösemittelabfall-Behandlungsanlage

Beschreibung
Siehe Abschnitt 4.7. Einige Techniken, die in Lösemittelabfall-Behandlungsanlagen eingesetzt worden sind, sind Anlagen zum Strippen von Abwasser, Bioreaktoren, Hauptlagertanks für Abwasser, Tanks zur Zwischenlagerung von Abwasser und Ultrafiltrationsanlagen.

Erreichter Nutzen für die Umwelt
Die Eigenschaften des Abwassers nach der Behandlung zeigt dieTabelle 4.38:

Verbindungen	Durchschnittswert	Einheiten
Farbe	-	
Geruch	-	
pH	8,7	
Elektrische Leitfähigkeit	989	µS/cm
Gesamt-P	0,46	mg/l
Gesamt-N	32,9	mg/l
CSB	18	mg/l
BSB_7	<3	mg/l
Sb	<0,01	mg/l
Pb	<0,010	mg/l
Cd	<0,002	mg/l
Gesamt-Cr	<0,002	mg/l
Co	0,006	mg/l
Ni	<0,002	mg/l
Zn	0,02	mg/l
Leichtflüchtige halogenierte Kohlenwasserstoffe	4	µg/l
AOX	320	µg/l
Anmerkung: Daten von 2002		

Tabelle 4.38: Eigenschaften des Abflusses einer Abwasserbehandlungsanlage in einer Regenerationsanlage für Lösemittelabfälle
[130, UBA, 2003]

Medienübergreifende Auswirkungen
Siehe Abschnitt 4.7

Betriebsdaten
Siehe Abschnitt 4.7

Anwendbarkeit
Siehe Abschnitt 4.7

Wirtschaftlichkeit
Siehe Abschnitt 4.7

Treibende Kraft für die Anwendung
Siehe Abschnitt 4.7

Beispielanlagen
Behandlungsanlagen für Lösemittelabfälle haben in der Regel Abwasserbehandlungsanlagen.

Literatur
[130, UBA, 2003]

4.4.2.4 Eindampfung von Destillationsrückständen

Beschreibung
Vakuumtrockner sowie andere Trocknungstechniken werden für Rückstände aus Destillationssümpfen genutzt.

Erreichter Nutzen für die Umwelt
Anstieg des Prozentsatzes von verwertetem Lösemittel. Verwertung von 99 % der enthaltenen Lösemittel. Dies kann die Gesamt-Lösemittelkonzentration etwa um den Faktor Zehn reduzieren. Auch Harze und Pigmente können verwertet werden. Gleichzeitig können Geruchs- und VOC-Emissionen reduziert werden, die in den Sümpfen gebildet werden.

Medienübergreifende Auswirkungen
Der erzeugte feste Rückstand sollte behandelt werden. VOC werden in die Luft emittiert und werden vor der Freisetzung behandelt.

Betriebsdaten
Um solche Verfahren zu betreiben, ist Energie (Wärme und Strom) erforderlich. Es gibt Anlagen zur Behandlung von bis zu 4000 Tonnen Destillationsrückständen pro Jahr. Daraus ist es möglich, 1500 bis 2000 Tonnen Lösemittel pro Jahr zu gewinnen. Die spezifische Energie[26] beträgt bis zu 0,1 kWh/kg. Die Trennung von Heiz- und Kühlzonen erleichtert eine wirksame Kontrolle der Produkttemperatur.

Anwendbarkeit
Das Verfahren benötigt nicht viel Fläche und ist leicht mit bestehenden Anlagen anwendbar. Es ist anwendbar auf Destillationsrückstände von Farblösemittel, Polymeren, Elastomeren, pharmazeutischen Produkten und Lebensmittelerzeugnissen. VOCs fallen bei einem breiten Spektrum von Abfallarten an. Offensichtliche Beispiele sind Altöl und Lösemittel. Z.B. kann der Schlamm eines Destillationssumpfs signifikante Lösemittelkonzentrationen aufweisen, welcher, wenn das Material flüssig vorliegt, zur Verwertung geeignet sein kann.

Wirtschaftlichkeit
Investitionskosten von 1,2 Millionen EUR. Die Betriebskosten schwanken zwischen 100 und 150 EUR pro Tonne behandelten Reststoffs.

Treibende Kraft für die Anwendung
Verbesserung der Verwertung von Lösemitteln und Abfallminimierung

Beispielanlagen
Weltweit setzen mindestens sechs Anlagen dieses Verfahren ein. Mindestens vier befinden sich in der EU. Trocknungstechniken werden in GB bei der Destillation von Sumpfschlämmen verwendet.

Literatur
[50, Scori, 2002], [55, UK EA, 2001], [66, TWG, 2003], [150, TWG, 2004]

[26] Anm.d.Übers.: Im Originaltext wird von „kneading energy“ gesprochen.

4.4.2.5 Vollständige Automatisierung der Reststoffverbrennung

Beschreibung
In einer Lösemittel-Destillationsanlage wird das Ablassen des Destillationsschlamms optimiert. Aus Arbeits- und Umweltschutzgründen ist dieser Vorgang des Ablassens jetzt voll automatisiert. Wegen seines hohen Heizwerts wird der Schlamm einer betriebsinternen Verbrennungsanlage zugeführt; der Transport des Schlamms ist voll automatisiert.

Erreichter Nutzen für die Umwelt
Behandlung der Reststoffe aus der Behandlung von Lösemittelabfällen.

Anwendbarkeit
Diese Technik des quasi-trockenen Ablassens muss nicht notwendigerweise die angemessene Lösung sein, wenn das Verfahren als Ganzes optimiert wird.

Beispielanlagen
Eine Lösemittel-Destillationsanlage in Münster (Deutschland).

Literatur
[150, TWG, 2004]

4.4.3 Altkatalysatoren

4.4.3.1 Allgemeine Techniken, die bei der Behandlung von Altkatalysatoren angewendet werden

Beschreibung
Zu den Techniken gehören:

a. Anwendung von Wärmerückgewinnung in Form von Energieproduktion oder -rückgewinnung. Zu diesem Zweck können regenerative Brenner, Wärmetauscher sowie Heizkessel eingesetzt werden, um Wärme zurückzugewinnen. Dampf oder Elektrizität kann erzeugt werden, um im Betrieb oder außerhalb des Betriebs genutzt zu werden, z.B. zum Vorheizen von Prozess- oder Brennstoffgasen.
b. Nutzung von Sauerstoff oder sauerstoffangereicherter Luft oder Sauerstoff[27] in den Brennern
c. Vorwärmen der in den Brennern eingesetzten Verbrennungsluft
d. Vorwärmen des Materials, das zur Feuerungsanlage abgeleitet wird
e. Automatische Kontrolle des Extraktionspunktes unter Verwendung von Drosselkappen und Steuerung der Ventilatoren, so dass die Verfahren angewendet werden können, wo und wann sie benötigt werden, zum Beispiel während der Beschickung oder während des „Abfahrens“ des Konverters.

Erreichter Nutzen für die Umwelt
Rückgewinnung von Wärme und Energie, was wegen des hohen Anteils der Energiekosten an den Gesamtkosten in dieser Branche ein wichtiger Faktor ist.

Der Einsatz von sauerstoffangereicherter Luft oder Sauerstoff in den Brennern senkt den Gesamtenergieverbrauch, indem eine vollständige Verbrennung des kohlenstoffhaltigem Material ermöglicht wird. Gleichzeitig wird das Abgasvolumen signifikant reduziert, was den Einsatz kleinerer Ventilatoren usw. ermöglicht.

Der Vorteil des Vorwärmens der in Brennern eingesetzten Verbrennungsluft ist gut dokumentiert. Wird die Luft auf 400 °C vorgeheizt, steigt die Flammentemperatur um 200 °C an; wenn sie auf 500 °C vorgeheizt wird, steigt die Flammentemperatur um 300 °C. Der Anstieg der Flammentemperatur führt zu einer höheren Effizienz und einer Reduzierung des Gesamtenergieverbrauchs. Eine Alternative zum Vorheizen der Verbrennungsluft ist das Vorheizen des Materials, mit dem die Feuerungsanlage beladen wird. Aus der Theorie geht hervor, dass eine Energieeinsparung von 8 % erzielt wird für jede 100 °C die vorgeheizt werden, und in der Praxis wird behauptet, dass ein Vorheizen von 400 °C zu 25 % Energieeinsparung führt, während ein Vorheizen auf 500 °C zu 30 % Energieeinsparung führt.

[27] Anm.d.Übers.: Doppelung des Begriffs „Sauerstoff“ in der Aufzählung im Originaltext.

Anwendbarkeit
Die eingesetzte Technik zur Wärmerückgewinnung variiert von Anlage zu Anlage und hängt von einer Anzahl von Faktoren ab, wie etwa von den Nutzungsmöglichkeiten für Wärme und Energie am Standort oder in der Nähe des Standorts, der Größe des Betriebs und dem Potenzial der Gase oder deren Inhaltsstoffen, Verschmutzungen oder Ablagerungen an Wärmetauschern zu erzeugen.

Einige Techniken mit dem Ziel der Energierückgewinnung lassen sich relativ leicht nachrüsten, gelegentlich können jedoch Probleme durch die Ablagerung von Metallverbindungen in Wärmetauschern auftauchen. Eine gute Auslegung basiert auf einer fundierten Kenntnis über freigesetzte Verbindungen und ihr Verhalten bei verschiedenen Temperaturen. Ebenso werden Reinigungsmechanismen für Wärmetauscher eingesetzt, um ihre thermische Effizienz aufrechtzuerhalten.

Literatur
[125, Ruiz, 2002]

4.4.3.2 Verbesserung der Verfahrenskontrolle

Beschreibung
Zu den Techniken gehören:

a. Anpassung der Temperaturhöhen und Verweilzeit des Katalysators in der Einheit, um die erwünschten Konzentrationen an Kohlenstoff und Schwefel zu erreichen
b. Einsatz einer Kühlung vor der Gewebefilteranlage
c. Nutzung abgedichteter Feuerungsanlagen, wodurch eine effiziente Rückhaltung der Dämpfe ermöglicht wird
d. Nutzung von Leitungen und Ventilatoren, die gesammelte Gase zu Abluftreinigungs- oder Behandlungsanlagen befördern. Ventilatoren mit variabler Geschwindigkeit werden verwendet, um Abluftleistungen zu erreichen, die geeignet sind, bei veränderten Bedingungen wie etwa bei Veränderungen des Gasvolumens, einen minimalen Energieverbrauch zu erzielen.
e. Vorhandensein einer guten Temperaturkontrolle während des Regenerationsprozesses
f. Auslegung der Verweilzeit in der Vorbehandlungsanlage auf eine sehr kurze Zeitspanne (im Bereich von ein paar Minuten), um Abnutzungen zu minimieren, die normalerweise mit Wirbelschichtverfahren verbunden sind
g. Anwendung einer Sichtungstechnologie (z.B. Längenklassierung) nach der Regeneration. Die Technologie der Längenklassierung entfernt kurze Katalysatorpartikel (in der Regel solche mit Längen von 1-2 maligem Durchmesser), die durch konventionelle Siebung nicht entfernt werden können. In einem Beispiel wurde eine Längenklassierung durchgeführt, in der nur relativ kleine Schnitte akzeptiert wurden, um so die Durchschnittslänge um 0,1 – 0,2 mm zu erhöhen ohne dabei zu viel Material zu verwerfen.

Erreichter Nutzen für die Umwelt
Verbessert die Prozesskontrolle und die Effizienz der Abluftreinigungstechniken. Der Wirkungsgrad der Erfassung hängt von der Effizienz der Abzugshauben, dem intakten Zustand der Leitungen und dem Einsatz eines guten Kontrollsystems für den Druck/Durchfluss ab.

Betriebsdaten
Die Anwendung einer Kühlung vor der Gewebefilteranlage ist eine wichtige Technik, da sie den Filter vor hohen Temperaturen schützt und eine größere Gewebeauswahl ermöglicht. Manchmal ist es möglich, auf dieser Stufe Wärme zurückzugewinnen. Die Temperatur der Gase nach diesem Wärmetauscher kann zwischen 200 und 450 ºC liegen. Der zweite Wärmetauscher senkt die Gastemperatur auf 130 ºC vor dem Gewebefilter. Den Wärmetauschern folgt normalerweise ein Zyklon, der größere Partikel entfernt und Funken einfängt.

Treibende Kraft für die Anwendung
Anforderungen an das Produkt.

Literatur
[125, Ruiz, 2002]

4.4.3.3 Genutzte Minderungstechniken im Sektor der Regeneration von Altkatalysatoren

Minderungsstechnik	Ort der Anwendung	Abschnitt dieses Dokuments, in dem die Minderungstechnik untersucht wird
Gewebefilter	Ausgang der Öfen	4.6.5
Nasse Gaswäsche	Ausgang der Öfen	4.6.11

Tabelle 4.39: Minderungstechniken angewandt in Regenerationsanlagen für Altkatalysatoren [125, Ruiz, 2002]

4.4.4 Aktivkohle

4.4.4.1 Wahl der Feuerung zur Regeneration verbrauchter Aktivkohle

Beschreibung
Mögliche Optionen sind "Etagenöfen", "direkt befeuerte Drehrohröfen" und "indirekt beheizte Öfen" (in denen kein Kontakt zwischen dem Ofeninhalt und den von einem Brenner erzeugten Abgasen stattfindet).

Erreichter Nutzen für die Umwelt
Der Etagenofen hat gegenüber den anderen Ofenarten unter dem Gesichtspunkt der Regenerationseffizienz signifikante Vorteile, da die Temperatur jedes Ofens unabhängig voneinander kontrolliert werden kann. Die austretenden Gase können entweder im Gleichstrom oder im Gegenstrom zum Fluss des Kohlenstoffs geführt werden. Bei manchen Konstruktionen kann der Nachbrenner im Ofen des "untersten" Levels eingebaut sein. Der Etagenofen zeigt bessere Massenübergangs- und Temperaturkontrolleigenschaften als Drehrohröfen. Die Kohlenstoffverweilzeit liegt in der Regel zwischen ein bis zwei Stunden. Die Kohlenstoffverluste können bis zu 10 Gew.-% betragen.

Direkt befeuerte Drehrohröfen können mit zur Verbrennungsluft im Gleichstrom oder im Gegenstrom fließenden Kohlenstoff betrieben werden. Im Gegenstrombetrieb besitzen die aus dem Ofen austretenden Gase eine höhere Temperatur als im Gleichstrombetrieb, womit potenziell ermöglicht wird, den Nachbrenner nach weniger strengen Kriterien auszulegen und dennoch gasförmige Schadstoffe zu zerstören.

Indirekt beheizte Öfen bieten den Vorteil, dass Brennerabgase nicht mit Prozessgasen gemischt werden. Das geringere Gasvolumen führt zu Energieeinsparungen und kleineren Abluftreinigungsanlagen. Abgase aus dem Brenner, die den Ofen indirekt beheizen, werden daraufhin zur Basis des Schornsteins geleitet, wo sie mit den Ofenabgasen gemischt werden können, um die Sichtbarkeit der emittierten Rauchfahne zu reduzieren. Diese Methode kann den Vorteil bieten, dass man es sich leisten kann, höhere Dampfpartialdrücke im Ofen zu fahren, um somit wahrscheinlich die Bildung von Stickoxiden zu mindern. Auch wird die Bildung von Halogeniden wahrscheinlich eher gefördert als die von elementaren Halogenen, wobei die Halogenide in den folgenden Gaswäschern leichter entfernt werden können.

Betriebsdaten
Drehrohröfen können wegen der Absenz von ungeschützten Metalloberflächen, normalerweise bei höheren Temperaturen arbeiten als Etagenöfen. Die Kohlenstoffverluste in Drehrohröfen können im Bereich von 5 – 15 Gew.-% liegen. Aufmerksamkeit muss auf die Verschlüsse zwischen dem rotierenden Ofen und den Endplatten gelegt werden, um etwaige Leckagen von Gasen und partikelförmigen Stoffe zu vermeiden. Flüchtige Emissionen aus diesem Bereich werden normalerweise vermieden, indem man den Ofen bei leichtem Unterdruck betreibt.
Indirekte Feuerungsanlagen werden normalerweise mit einem Metallrohr konstruiert und sind wegen Korrosionsproblemen, die während der Behandlung bestimmter Aktivkohlen aus der Industrie auftauchen können, nicht so gut für Industrieanwendungen geeignet.

Anwendbarkeit
Die Anwendung von indirekt befeuerten Öfen wird aber im Allgemeinen zur Behandlung von Aktivkohlen aus der Industrie eingesetzt, wobei hier strengere Temperaturkriterien bei der Nachverbrennung gelten.

Beispielanlagen
Das Konzept des indirekt befeuerten Ofens breitet sich immer mehr aus. Infrarotfeuerungen sind relativ neu in der Anwendung und befinden sich vorrangig in den Vereinigten Staaten. Bei der Feuerungsmethode werden Infrarotelemente und eine indirekte Beheizung der Aktivkohle genutzt. Als Resultat wird die Produktion ein brennbaren Gas vermieden, was dazu führen kann, dass kleinere Abgasvolumen produziert werden, die behandelt werden müssen. Ihre Kapazität ist allerdings auf maximal etwa 1000 Mg/a begrenzt.

Der einzige bekannte indirekt befeuerte Drehrohrofen in Europa stand in GB und ist wahrscheinlich nicht mehr in Betrieb.
Eine Anlage zur Regeneration von Aktivkohle, die sich an einem Standort zur Trinkwasseraufbereitung befindet, verwendet einen Etagenofen: Die Anlage besteht aus Silos für gebrauchte und reaktivierte Aktivkohle, separate Wassertransportsysteme um verbrauchte und reaktivierte Aktivkohle aus den Silos zum Ofen sowie vom Ofen weg zu transportieren. Die Einheit besitzt zudem eine Einrichtung zum direkten Transport zum Wasserwerk, zur Behandlung des Kohlenstoffs dieser speziellen Anlage. Verbrauchte und reaktivierte Kohle von anderen Standorten wird mit Tankfahrzeugen transportiert.

Literatur
[29, UK Environment Agency, 1996], [41, UK, 1991], [42, UK, 1995], [150, TWG, 2004]

4.4.4.2 Abgasbehandlung

Beschreibung
Zu den Techniken gehören:

a. Nutzung eines Nachbrenners für Gase, die aus der Feuerungsanlage oder dem Ofen austreten. Der Nachbrenner muss immer im Betrieb sein, wenn Kohlenstoff im Ofen vorhanden ist
b. Konstruktion des Regenerators sowie der dazugehörigen Rohrleitungen und Geräte für den Betrieb unter Unterdruck, um das Entweichen von Gasen aus dem Regenerator in die Luft zu verhindern
c. Anwendung von Wärmerückgewinnung. In der Regel beinhaltet dies Gas/Gas-Wärmeaustauscher, um das Vorheizen von Verbrennungsluft und das Wiederaufheizen von Abgas zu ermöglichen. Es kann auch ein Abwärmekessel vorhanden sein, mit dessen Hilfe Dampf erzeugt wird, welcher wiederum zur Reaktivierung der Kohlenstoffs genutzt wird
d. Kühlung der Abgase durch einen Quensch oder Venturiwäscher
e. Nutzung einer wässrigen oder alkalischen Gaswäsche. Auch Sprühabsorptionstechniken können eingesetzt werden. Es ist notwendig, eine pH-Wert Kontrolle für die Waschflüssigkeit durchzuführen
f. Ableitung der Abgase zum Schornstein mittels induzierten Abzugs und partieller Aufwärmung der Abgase
g. Nutzung nasser oder trockener elektrostatischer Abscheider, Venturiwäscher oder Gewebefilter. Wenn Trägheitsabscheider, z.B. Zyklone, allein eingesetzt werden, ist die Einhaltung niedriger Emissionswerte unwahrscheinlich.

Erreichter Nutzen für die Umwelt
Reduziert die Emissionen aus dem erzeugten Abgas. Ein Sprühtrockner mit anschließenden Gewebe- oder Keramikfiltern bietet den zusätzlichen Vorteil, weitere Neutralisationsreaktionen zwischen den abgeschiedenen festen Rückständen und dem Abgasstrom zu ermöglichen. Dies kann zu einer Reduktion des Bedarfs an Alkalien eines Sprühtrockners führen, die 10 –15 % im Vergleich zu einer nassen Gaswäsche beträgt.

Tabelle 4.40 zeigt die erreichbaren Konzentrationen für Schlüsselsubstanzen im Kontext der berücksichtigten Verfahren.

Stoff	Erreichbare Konzentrationen (mg/Nm^3)
Gesamtstaub	20
Chlorwasserstoff	30
Schwefeldioxid (als SO_2)	50
Stickoxide (als NO_2)	350
Kohlenmonoxid (gemessen nach letztem Einblasen von Luft)	50
VOC (als C) (außer Staub)	20
Dioxine und Furane (Internationale Toxizitätsäquivalente – ITEQ)	1 ng/m^3
Anmerkungen: Die obigen Konzentrationen gelten für nicht kontinuierliche Überwachung	

Tabelle 4.40: Benchmarks für die Emissionen in die Luft
[29, UK Environment Agency, 1996]

Medienübergreifende Auswirkungen
Bei Technik f im Abschnitt "Beschreibung" erfordert ein Wiederaufheizen des Abgases.

Betriebsdaten
Der Regenerator enthält eine Nachbrennkammer, die so ausgerüstet und betrieben wird, dass das Abgas aus der Regeneration des Kohlenstoffs nach dem letzten Einblasen von Luft in einer kontrollierten, homogenen Form, auch unter Betrachtung der höchst ungünstigsten Bedingungen, auf eine Temperatur von mindestens 850 ºC aufgeheizt wird. Dies wird an der Innenwand der Verbrennungskammer gemessen und muss für mindestens zwei Sekunden, in Anwesenheit von mindestens 6 Vol-% Sauerstoff im trockenen Gas gehalten werden. Gemessen wird am Ausgang des Nachbrenners. Für Kohlenstoff aus industriellen Anwendungen, in denen wahrscheinlich halogenierte oder andere thermoresistente Stoffe (z.B. zu mehr als einem bestimmten kleinen Prozentsatz) enthalten sind, wird die Temperatur in der Regel auf mindestens 1100 ºC erhöht. Wobei die Verweilzeit, die Einhaltung der Mindesttemperatur und der Sauerstoffgehalt der Abgase verifiziert werden müssen. Allerdings kann es unter manchen Umständen, die nicht in der TWG spezifiziert wurden, möglich sein, eine gleichwertige Wirkung unter weniger strengen Bedingungen zu erzielen (einige allgemeine Informationen zu diesem Thema befinden sich im BVT-Merkblatt „Abfallverbrennung").

Anwendbarkeit
Abgase aus Etagen- oder Drehrohröfen durchlaufen in der Regel einen ähnlichen Pfad der Behandlung. Im Fall von im Gleichstrom befeuerten Drehrohröfen kann es möglich sein, gleiche Bedingungen ohne einen Nachbrenner zu erfüllen.

Die Abgasreinigung hängt von der vorhergehenden Anwendung des Kohlenstoffs und von der Beschaffenheit des Brennstoffs ab, der zum Befeuern des Ofens und Nachbrenners eingesetzt wird. Die oben beschriebene Ausstattung kann in der Regel für Kohlenstoff eingesetzt werden, der zur Trinkwasseraufbereitung und für lebensmitteltaugliche Anwendungen eingesetzt wurde. Für Kohlestoff aus industriellen Anwendungen können umfangreichere Minderungsmaßnahmen erforderlich sein.

Die Abgasreinigungsanlagen können sich je nach der vorherigen Anwendung des Kohlenstoffs unterscheiden. Strengere Anforderungen können für Kohlenstoff aus industriellen Anwendungen notwendig sein. In diesen Fällen kann eine zusätzliche chemische Gaswäsche erforderlich sein, um die erwünschten Emissionswerte zu erreichen. Es kann auch erforderlich sein, den Kohlenstoff nach der Regenerationsstufe für zwei Sekunden Verweilzeit bei Temperaturen von mindestens 1100 ºC unter Anwesenheit von mindestens 6 Vol.-% Sauerstoff im trockenen Gas zu halten, um eine vollständige Oxidation bestimmter hitzebeständiger Verbindungen sicherzustellen.

Treibende Kraft für die Anwendung
Unter bestimmten örtlichen Gegebenheiten und aus visuellen Gründen (z.B. Unterdrückung der sichtbaren Rauchfahne) verlangen bestimmte Behörden manchmal die Techniken c und f aus dem obigen Abschnitt „Beschreibung".

Literatur
[29, UK Environment Agency, 1996], [41, UK, 1991], [42, UK, 1995], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.4.4.3 Abwasserbehandlungsanlagen

Beschreibung
Diese Verfahren benötigen eine Anlage zur Behandlung des in der Abgasreinigungsanlage erzeugten Abwassers. Zu den Techniken gehören:

a. Anwendung einer zweistufigen Hydroxidfällung bei verschiedenen pH-Werten
b. Einsatz einer Sulfidfällung zur Entfernung von Metallen
c. Einsatz der Flockung, des Absetzens, der Filtration oder von Zentrifugen zur Abtrennung der suspendierten Materialien. Eine chemische oder physikalische Vorbehandlungsstufe kann zusätzlich erforderlich sein, um die suspendierten Feststoffe zu konditionieren und die Abtrennung zu verbessern
d. Einstellung des pH-Werts, um die Fällung spezifischer Chemikalien zu fördern und ein einleitfähiges Abwasser zu erreichen
e. Nutzung von natürlichen Zeolithen, Ionenaustauscherharzen, Aktivkohle- und Umkehrosmosetechniken zur Entfernung schädlicher Verunreinigungen (z. B. Pestizide). Das Aufkonzentrieren durch Eindampfen ist auch eine Möglichkeit
f. Anwendung einer biologischen Behandlung zum Abbau von BSB, Phenolen, Cyaniden und Ammoniak.

Erreichter Nutzen für die Umwelt
Tabelle 4.41 zeigt die erreichbaren Emissionswerte für Schlüsselsubstanzen der berücksichtigten Verfahren.

Stoff	Erreichbar [1]	Einheiten
CSB		
Suspendierte Feststoffe	50 [2]	mg/l
Cadmium	5 [3]	µg/l
Quecksilber	1 – 10	µg/l
Andere Schwermetalle	<0,5	mg/l
Dioxine und Furane, PAHs und andere organische Stoffe		
Simazin	1 [4]	µg/l
Atrazin	1 [4]	µg/l

Anmerkungen:
[1] Bei den zitierten Werten handelt es sich um nach dem Durchfluss gewichtete monatliche Durchschnittskonzentrationen
[2] Durch Sedimentation oder Absetzen. Abhängig vom eingehenden Wasser und dem Ausmaß der Kontamination mit anderen Schadstoffen können niedrigere Freisetzungen, wenn notwendig, durch Filtration erreicht werden
[3] Durch Fällung und Filtration, wobei 70 % Reduktion erwartet werden können. Eine anschließende Behandlung in der biologischen Behandlungsanlage eines Klärwerks senkt den Wert unter die Nachweisgrenze
[4] Bei Aktivkohlen zur Abwasserbehandlung können aus granulierter Aktivkohle Spuren von Pestiziden ins Abwasser ausgewaschen werden, bevor es in die Kanalisation eingeleitet wird. Viele Regenerationsanlagen für granulierte Aktivkohle installieren als Vorsichtsmaßnahme kleine Filter aus granulierter Aktivkohle am Auslass zur Kanalisation

Tabelle 4.41: Erreichbare Werte für die Emissionen ins Wasser
[29, UK Environment Agency, 1996], [150, TWG, 2004]

Anwendbarkeit
Angewandt bei Abwasser aus dem Quensch oder der Gaswäsche.

Beispielanlagen
In der Branche gibt es viele Beispiele.

Literatur
[29, UK Environment Agency, 1996], [150, TWG, 2004]

4.4.4.4 Bei der Regeneration von Aktivkohle anwendbare Umweltschutztechniken

Umweltschutztechniken zur Bekämpfung von Partikeln und sauren Gasen	Anwendbarkeit auf die Regenerierung von Aktivkohle
Primärmaßnahmen zur Abscheidung von Partikeln	Ofentemperatur Drehfrequenz des Rotationsofens Art des Brennstoffs
Sekundärmaßnahmen zur Abscheidung von Partikeln und sauren Gasen	Mechanische Abscheider Nasse Gaswäsche Trockene Gaswäsche Elektrostatische Abscheider Gewebefilter
Primärmaßnahmen zur NO_x – Minderung	Senkung der Ofen- und Verbrennungstemperaturen Verringerung überschüssiger Luft und folglich Senkung der Konzentration von atomarem Sauerstoff in Hochtemperaturzonen Senkung der Verweilzeit in allen Bereichen höherer Temperatur Kontrolle der Wärmefreisetzung des Ofens und Ausschalten bei Temperaturspitzen Abgasrückführung Luftdosierung Brennstoffdosierung Wärmeisolierung des Ofens Niedriger Eintritt der (kalten) Sekundärluft Niedrigeres Luft-Brennstoff-Verhältnis
Sekundärmaßnahmen zur NO_x – Minderung	Selektive katalytische Reduktion (SCR) Selektive nicht-katalytische Reduction (SNCR) DESONOX-Verfahren SNOX-Verfahren EDTA-Chelat-Verfahren SO_x NO_x RO_x BOX

Tabelle 4.42: Anwendbarkeit von Abluftbehandlungstechniken bei der Regeneration von Aktivkohle [41, UK, 1991], [150, TWG, 2004]

4.4.5 Regeneration von Harzen

4.4.5.1 Techniken zur Regeneration von Harzen

Beschreibung
Zu den Techniken gehören:

a. Anwendung eines pH-Wert Ausgleichssystems
b. Anwendung der Regeneration mit heißem Wasser.

Erreichter Nutzen für die Umwelt
Erhöht die Regenerationsquote für Harze. Die alternative Verwendung von Wärme (d. h. heißem Wasser) zur Regeneration von Harzen, führt potenziell zu kleineren Abwasservolumen und benötigt weniger Energie, insbesondere wenn eine Wärmerückgewinnung aus der regenerierten Flüssigkeit durchgeführt wird.

Anwendbarkeit
Die Regeneration mit heißem Wasser ist nur für thermisch stabile Harze möglich.

Wirtschaftlichkeit
Die Haupttechnik, die zur Reduzierung der Emissionen in das Wasser eingesetzt wird, ist ein pH-Wert Ausgleichssystem. Die Kosten eines solchen Verfahrens liegen in der Größenordnung von 30000 bis 40000 GBP. Zum Vergleich: Die Kosten einer gesamten Anlage liegen in der Größenordnung von 250000 GBP ohne Baumaßnahmen. Durch den Einsatz der Regeneration mit heißem Wasser werden die Betriebskosten gesenkt.

Literatur
[41, UK, 1991], [42, UK, 1995]

4.4.5.2 Für Aktivkohle- und Harzregeneration anwendbare Umweltschutztechniken

Hier kann dieselbe Art von Techniken wie für die Regeneration von Aktivkohle eingesetzt werden. Es sei also auf Abschnitt 4.4.4.4 verwiesen.

4.5 Bei der Aufbereitung von Abfall zur Nutzung als Brennstoff zu berücksichtigende Techniken

In diesem Abschnitt werden Techniken aufgeführt, die aus Sicht der Umwelt ein günstiges Betriebsverhalten besitzen (z.B. Verwendung eines guten Energiesystems) oder die zu einer günstigen Umweltperformance führen können (z.B. Umweltmanagementsysteme). Dieser Abschnitt enthält diejenigen Techniken, die bei der Aufbereitung von Abfall zur Nutzung als Brennstoff von Bedeutung sind.

4.5.1 Vertiefung des Wissens über den hergestellten Brennstoff aus Abfall

Beschreibung
Diese Technik steht im Zusammenhang mit der Technik die im Abschnitt 4.1.1.1 beschrieben wird, und in Zusammenhang mit Qualitätsmanagementsystemen (QMS). Das Mixen und Vermischen (siehe Abschnitt 4.1.5) spielt bei diesem Thema auch eine wichtige Rolle. Die Qualitätssicherung bei der Aufbereitung von Abfall zur Nutzung als Brennstoff wird von der Notwendigkeit getragen, die Anforderungen der annehmenden Anlage zu erfüllen. Zu den Techniken gehören:

a. Übergabe eines Berichts an den Kunden, der die wichtigsten physikalischen und chemischen Eigenschaften des Brennstoffs aus Abfall umfasst, insbesondere:
   - Herkunft und Abfallschlüsselnummer nach EAV
   - unterer Heizwert
   - Aschegehalt
   - Wassergehalt
   - Gehalt an flüchtigen Bestandteilen
   - Biomassegehalt
   - chemische Zusammensetzung (insbesondere C, H, O, N, S, P, Cl, F, Al, K, Na, Schwermetalle).
b. Limitieren der Menge von relevanten Parametern bei allen Abfällen, die als Brennstoff in Anlagen zur Mitverbrennung eingesetzt werden sollen (z.B. Chrom(VI), Gesamtchrom, Blei, Cadmium, Quecksilber, Thallium, PCB, Schwefel und Gesamthalogengehalt für die Nutzung in Zementöfen).

Erreichter Nutzen für die Umwelt
Liefert dem Brennstoffnutzer Kenntnisse über mögliche Emissionen und Probleme in der Betriebsführung, die durch den Einsatz des Materials als Brennstoff verursacht werden können. Der Nutzer des Brennstoffs aus Abfall muss ausreichende Anforderungskriterien für den Brennstoff bereitstellen, um mögliche Auswirkungen gering zu halten, wie etwa auf die Emissionen, die Qualität der in seiner Anlage erzeugten Reststoffe, das Korrosionsverhalten und die Qualität der Produkte.

Betriebsdaten
Laborarbeit ist erforderlich (Analysen).

Anwendbarkeit
Die tatsächliche Mischung von Lösemittelabfällen im Einzelnen, richtet sich nach der guten Kenntnis der Bestandteile, um Heizwerte zu erreichen und Grenzwerte für Schadstoffe, zum Beispiel für Chlor und Schwermetalle, einzuhalten.

Treibende Kraft für die Anwendung
CEN/TC 343 “solid recovered fuels” und WG 2 ‘Specifications and classes’. Die Nutzung von Brennstoffen aus Abfall und die Verlagerung von Schadstoffen in Reststoffe oder Produkte wird ein immer bedeutenderes Thema. Deshalb muss die Nutzung einiger Brennstoffe aus Abfall in Abhängigkeit von ihrer nachfolgenden Behandlung eingeschränkt werden. Neue Diskussionen oder Vorschriften zur Begrenzung von Chrom(VI) in Zement aus Gesundheits- und Sicherheitsgründen auf höchstens 2 ppm könnten die Nutzung einiger chromhaltiger Abfälle einschränken. Einige Hinweise sind verfügbar (z.B. von Nordrhein-Westfalen in Deutschland).

Literatur
[14, Ministry for the Environment, 2000], [55, UK EA, 2001], [74, ENDS, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.5.2 Herstellung verschiedener Arten von Brennstoff aus Abfall

Beschreibung
Bei der Herstellung verschiedener Typen von Brennstoff aus Abfall müssen die technischen Eigenschaften der Verbrennungsverfahren, in denen sie eingesetzt werden sollen, berücksichtigt werden (z.B. Zementwerk, Kalkwerk, Kraftwerk (Steinkohle, Braunkohle), spezifische Verbrennungsanlage für Brennstoffe aus Abfall). Diese Verbrennungsverfahren haben verschiedene technische Eigenschaften.

Das Ausmaß der Abfallbehandlung hängt von der Verwendung des Brennstoffs aus Abfall ab. Einige Beispiele dafür sind:

a. Art des Abfalls, aus dem der Brennstoff hergestellt wird
b. eingesetzte Techniken für die Lagerung des Brennstoffs aus Abfall
c. Art der Ofenbeschickung (stückiges Material, Einblasen)
d. Eingesetzte Brennstoffmischung im Verbrennungsverfahren
e. Art des Verbrennungsverfahrens, Rostfeuerung mit Durchmesser <150 mm oder Pyrolyse mit Durchmesser <150 mm mit einer hohen Toleranz für Metalle und schwere Partikel
f. Art der Beschickung mit dem Brennstoff aus Abfall: Einblasen in einen Hochofen bei d <20 mm (Zementofen, Braunkohlekraftwerk) nur für Teilchen mit einer Geschwindigkeit von weniger als 2 oder 3 m/s
g. Toleranz gegenüber einigen Inhaltsstoffen: z.B. ein Chlorgehalt von <0,3 % der auch abhängig von der Brennstoffmischung ist (Zementwerk), im Gegensatz zu z.B. <5 % wie er in manchen Brennstoffen aus Abfall vorkommt.

Die Typen an festem Brennstoff aus Abfall, die aus nicht gefährlichem Abfall hergestellt werden können, entstammen in der Regel einer der folgenden Kategorien:

- aus Siedlungsabfall (hauptsächlich Hausmüll)
- aus gemischtem hausmüllähnlichen Gewerbeabfall und anderem Abfall
- aus trockenen sortenreinen Abfällen oder ausgewählten homogenen Abfallströmen
- aus Filterkuchen, Schlämmen und anderen nassen Abfällen.

Die angewandte Behandlung hat einen Einfluss auf die physikalisch-chemischen Eigenschaften des hergestellten Brennstoffs aus Abfall. Z.B. kann eine Zerkleinerung bis hin zur erforderlichen Korngröße des festen Brennstoffs aus Abfall durchgeführt werden. Ein anderes Beispiel zeigt, dass bei der Aufbereitung unerwünschte Bestandteile und Fremdstoffe mittels einer mechanischen Aufbereitung und Zerkleinerung abgetrennt werden können. Das heißt, dass es möglich ist, eine Brennstoffausbeute von 100 bis x % einer Brennstoffqualität, durch Zunahme des Wasser- und Aschegehaltes, zu erlangen.

Erreichter Nutzen für die Umwelt
Bereitstellung der geforderten physikalisch-chemischen Eigenschaften des Brennstoffs aus Abfall für den Nutzer.

Betriebsdaten
Die Technologie, die zur Herstellung eines bestimmten Brennstoffs aus Abfall eingesetzt wird, hängt von den Eigenschaften des Input-Materials und den Anforderungen der Nutzer ab und wird in diesem Abschnitt nicht behandelt. Z.B. hängt das Ausmaß der mechanischen und biologischen Aufarbeitung von der Herkunft des Abfalls ab. Eine Abfallart, aus unterschiedlichen Herkünften, kann unterschiedliche Zusammensetzungen/Eigenschaften aufweisen. Z.B. haben alle folgenden Papier/Pappeabfälle unterschiedliche Zusammensetzungen: Papier und Pappe für das Recycling aus der Papierproduktion 03 03 08, Verpackungsmaterial 15 01 01, mechanische Aufbereitung 19 12 01, mechanische Aufbereitung (einschließlich Mischungen) 19 12 12, und Siedlungsabfall 20 01 01.[28] Ein anderes Beispiel sind Windeln a) als Produktionsrückstand b) als Fraktion mit hohem Heizwert aus Siedlungsabfall (der zu etwa 15 – 20 Gew.-% aus Windeln besteht).

Auch muss der Einfluss der Abfallsammlung (und im Fall von Konsumgüterabfall die nationalen und regionalen Konsumgewohnheiten) auf die Eigenschaften der Abfallströme berücksichtigt werden.

[28] Anm.d.Übers.: Abweichung vom Originaltext, in dem eine falsche Zuordnung der Abfallschlüsselnummern erfolgte.

Treibende Kraft für die Anwendung
Einige Hinweise sind verfügbar (z.B. Nordrhein-Westfalen in Deutschland).

Literatur
[150, TWG, 2004], [152, TWG, 2004]

4.5.3 Techniken zur Herstellung von festen Brennstoffen aus Abfall

Dieser Abschnitt enthält Techniken, die bei der Herstellung von festen Brennstoffen aus gefährlichen und nicht gefährlichen Abfällen eingesetzt werden. Die Abschnitte „Anwendbarkeit“ für diese Techniken geben weitere Orientierung darüber, wann diese Techniken angewendet werden. Allerdings sind die Techniken in den Abschnitten 4.5.3.1 bis 4.5.3.5 für alle Abfallarten von Bedeutung. Die Techniken in den Abschnitten 4.5.3.6 bis 4.5.3.12 sind hauptsächlich auf nicht gefährliche Abfälle anwendbar. Nur eine Technik, die sich speziell auf gefährliche Abfälle bezieht, wurde aufgenommen und befindet sich in Abschnitt 4.5.3.13.

4.5.3.1 Auswahl der Techniken für die Herstellung von festen Brennstoffen aus Abfall

Beschreibung
Zu den Techniken gehören:

a. Klassieren von festen Abfällen (z.B. Hausmüll) und Zerkleinern der Sperrmüllfraktion vor dem Sortiervorgang
b. Anwendung eines Magnetscheiders
c. Durchführung der Misch- und Siebvorgänge in eingehausten Bereichen
d. Nutzung von Stickstoff-Mischvorrichtungen, um die Atmosphäre inert zu machen, wenn Explosionsrisiken bestehen.

Erreichter Nutzen für die Umwelt
Klassier- und Zerkleinerungsvorgänge sind essentiell, um zufriedenstellende Sortierergebnisse zu erzielen sowie eine nachfolgende thermische Behandlung zu ermöglichen. Andere Gründe liegen darin, dass der Einsatz dieser Techniken indirekt auch flüchtige Emissionen von Staub und VOC vermeiden kann.

Betriebsdaten
Eine Zerkleinerung benötigt viel Energie zu hohen Kosten, aber ist bei sperrigem Material unvermeidbar.

Anwendbarkeit
Gefährliche und nicht gefährliche Abfälle. Technik a aus dem obigen Abschnitt „Beschreibung“ ist nicht an die Herstellung von Brennstoff aus gefährlichem Abfall angepasst. Diese Technik kann von Vorteil sein, es gibt aber auch andere Strategien, die ebenso gut funktionieren. Technik d wird bei gefährlichen Abfällen mit Explosionsrisiko angewendet.

Bei der Aufbereitung einiger spezifischer nicht gefährlicher Abfälle sind spezielle oben erwähnte Techniken nicht notwendig. Einige Beispiele dafür sind Anlagen, in denen Brennstoffe aus an der Quelle getrennt gehaltenen Abfallströmen erzeugt werden, z. B. aus Verschnittabfällen aus der Kunststoffherstellung oder aus Abfällen aus der Altpapieraufbereitung. Allerdings sind diese Ausnahmen von den Erfahrungen abhängig, die der Betreiber der Abfallbehandlungsanlage mit dem speziellen Abfall gemacht hat. Das heißt, dass der Betreiber der Abfallbehandlungsanlage den/die Kunden, die Zusammensetzung des aufbereiteten Abfalls und die Art, wie der Kunde den Abfall sammelt, sehr gut kennen sollte. Nur auf dieser Art kann vermieden werden, dass der Abfall Bestandteile enthält, die zu Problemen in der Abfallbehandlungsanlage oder bei der Qualität des erzeugten Brennstoffs führen.

Treibende Kraft für die Anwendung
Technik d aus dem obigen Abschnitt “Beschreibung” wird im Allgemeinen durch die Gesetzgebung zur Unfallverhütung geregelt.

Beispielanlagen
Die Sicherheit einer Mischvorrichtung kann durch die Zugabe von Stickstoff gewährleistet werden, indem eine Inertisierung erreicht wird. Durch die Zugabe von Stickstoff zur Inertisierung der Atmosphäre kommt es zu einer Verringerung des Sauerstoffgehalts (Arbeitsbedingungen zwischen 6 und 8 % Sauerstoffgehalt). Z.B. ermöglicht eine solche Technik, Abfall mit einem Flammpunkt von unter 0 °C zu mischen.

Literatur
[122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [152, TWG, 2004]

4.5.3.2 Trocknung des festen Brennstoffs aus Abfall

Beschreibung
Abhängig vom Wassergehalt und von den physikalischen Eigenschaften der Abfälle kann als erster Schritt eine Entwässerung durchgeführt werden. Sie kann aus einem der folgenden Verfahren bestehen: Eindickung durch Schwerkraft, Zentrifugieren, Flotation, Entwässerung und Drehtrommel-Eindickung. Zu den Techniken gehören:

- Nutzung einer thermischen Trocknung des Materials. In (direkten oder adiabatischen) Konvektionstrocknern besteht ein direkter Kontakt zwischen dem Heizmedium und dem zu trocknenden Produkt. Durch das Heizmedium wird die Feuchtigkeit aus dem Brennstoff entfernt. In Kontakttrocknern besteht kein direkter Kontakt zwischen Heizmedium und Produkt. Der Wärmeübergang findet durch beheizte Oberflächen statt. Die Feuchtigkeit wird durch das Trägergas entfernt, welches etwa 10 % der Menge beträgt wie sie im Kontaktverfahren genutzt wird. Daher können Kontakttrockner möglicherweise für staubige oder geruchsintensive Abfälle präferiert werden.
- Nutzung eines biologischen Abbau-/Trocknungsverfahrens. Je nach eingesetztem Verfahren ist der Abbau mehr oder weniger ausgeprägt, manchmal liegt der Schwerpunkt auf der Trocknung. Abhängig vom eingesetzten Verfahren muss Prozesswasser, das während des biologischen Abbaus entsteht, gereinigt werden, bevor es in den Vorfluter eingeleitet wird. Um die biologische Aktivität aufrechtzuerhalten, wird das System belüftet. Die Abluft wird erfasst und muss ebenfalls gereinigt werden.

Erreichter Nutzen für die Umwelt
Erhöht den Heizwert des festen Abfalls und führt in manchen Fällen zu zufriedenstellenden Sortierergebnissen.

Medienübergreifende Auswirkungen
Im Fall einer thermischen Trocknung ist Wärme erforderlich. Eine Studie zeigt, dass im Fall der Klärschlammtrocknung die energetische Nutzung im Falle der thermischen Trocknung höher ist. Die Gründe dafür liegen darin, dass bei einer biologischen Trocknung mehr Energie (die durch das organische Material im Klärschlamm bereitgestellt wird) erforderlich ist und der Heizwert des Brennstoffs aus Abfall tendenziell niedriger ist.

Anwendbarkeit
Strahlungstrockner werden zur Trocknung von festen Abfällen nicht eingesetzt. Anwendbar für die Entwässerung und Trocknung von Schlämmen.

Die biologische Trocknung ist eher auf nicht gefährliche Abfälle anwendbar.

Literatur
[64, EIPPCB, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.3 Magnetabscheidung von Eisenmetallen

Beschreibung
Zu den Techniken gehören:

a. Einbau eines Überband-Magnetabscheiders, der längs über den Förderbändern direkt über der Flugkurve des Materials angebracht ist
b. Sortierung des Materials mit einem magnetischen Trommelabscheider oder mittels magnetischer Rolle, da kleine eisenhaltige Partikel immer noch unter einer nicht magnetischen Schicht verblieben sein können
c. Erhöhung der Geschwindigkeit des Förderbands, womit man eine geringe Schütthöhe des Materials erzielt
d. Nutzung einer abwerfenden Beschickungskonstruktion für magnetische Trommelabscheider.

Erreichter Nutzen für die Umwelt
Magnetabscheider können eingesetzt werden, um Eisen und Stahl als Ressource auszusortieren, z.B. Weißblechdosen aus Leichtverpackungen. Sie können auch eingesetzt werden, um durch die erforderliche Entfernung aller Eisenmetalle aus dem Abfall Betriebsprobleme in den folgenden Behandlungsschritten zu vermeiden und die Produktqualität zu verbessern, so werden z.B. Magnetabscheider in Kabelrecyclingverfahren verwendet, um Metalle zu entfernen, um die Messer von Rotationsquerschneidern vor dem Abstumpfen oder Zerbrechen zu schützen und um anschließend das Kupferprodukt zu reinigen.

Die Anbringung in Laufrichtung (Längsanordnung) zum Band wird bevorzugt, da sie dabei hilft, das gelockerte Material aus der Flugkurve effektiv abzutrennen. Wenn der Magnet quer zum Material ausgerichtet ist (d.h. quer über dem Förderband aufgehängt ist), muss die Stärke des Magneten ein vielfaches höher sein als bei einer Längsanordnung, da sich manchmal nicht magnetische Gegenstände über eisenhaltigen Teilen befinden und der Magnet dann durch sie hindurch wirken muss.

Wenn Überband-Magnetabscheider Siedlungsabfall mit einem bestimmten Gehalt an Kunststoffen mit großer Oberfläche sortieren, ist es nicht zu vermeiden, dass sie diese Kunststoffe zusammen mit den eisenhaltigen Teilen aussortieren. Um diesen Effekt zu minimieren, wird empfohlen, die Bandgeschwindigkeit zu erhöhen. Im Allgemeinen erzielen Überband-Magnetabscheider sehr gute Ergebnisse von bis zu 98 Gew.-% des Eisen-Inputs.

Der Vorteil der abwerfenden Anordnung bei magnetischen Trommelabscheidern ist, dass eisenhaltige Teile direkt in Kontakt mit dem stärksten Magnetfeld gebracht werden und folglich feinkörnige und schwach magnetisierbare Teile gut abgetrennt werden können.

Betriebsdaten
Die Betriebsart, mit der magnetische Trommelabscheider mit Material beschickt werden können, ist entweder über eine abwerfende Anordnung oder eine aushebende Anordnung. Bei einer abwerfenden Anordnung wird das Material unter Verwendung einer Schwingrinne direkt über dem Scheitelpunkt der Trommel beladen. In diesem Fall werden nur magnetisierbare Teile an der Trommelhülle festgehalten, bis sie die Grenze des magnetischen Felds erreichen, an der das Material von der Trommel fällt und hinter einer nicht magnetisierbaren Trennplatte gesammelt wird.

Bei der aushebenden Anordnung werden die Eisenmetalle durch den Luftspalt von der Trommelhülle angezogen und werden dann – ähnlich wie beim Überband-Magnetabscheider – fallen gelassen, jedoch nicht vor dem Verlassen des Magnetfelds. Für eine homogene Beschickung ist der Einsatz von Schwingrinnen unerlässlich.

Anwendbarkeit
Genutzt, wenn Eisenmetalle im Abfall vorhanden sind. Üblicherweise können Magnetabscheider rostfreien Stahl nicht abscheiden, weil dieser nicht oder nur schwach magnetisierbar ist.

Normalerweise ist der aushebende Betrieb nur für bestimmte Anwendungen in der Abfallverarbeitung von Bedeutung, z.B. für die Aufarbeitung von Schredderschrott. Der Anzugspol dieser Trommel erzeugt ein starkes und weitreichendes Magnetfeld, um den geschredderten und verdichteten Schrott sicher abzuscheiden. Der Transport der eisenhaltigen Materialien zur Falllinie wird durch zusätzliche schwache Pole erzielt. Wegen des starken Abriebs während der Schrottsortierung wird die Trommelhülle aus einer 8 mm dicken Platte aus hartem Manganstahl hergestellt.

Treibende Kraft für die Anwendung
Die Anwendung der Magnetscheidung hängt von der Art des verarbeiteten Abfalls und den Anforderungen an den Brennstoff aus Abfall ab. Beispiele dafür sind:

- Nutzung der Abtrennung eisenhaltiger (oder nicht eisenhaltiger) Metalle, um den Abrieb zu verringern, wenn die Produktanforderungen eine Feinzerkleinerung durch Schneiden erforderlich machen
- die Abtrennung eisenhaltiger oder nicht eisenhaltiger Metalle und/oder die Abtrennung der Feinfraktion durch Sieben ist hilfreich, wenn der Aschegehalt begrenzt ist
- Anreicherung mittels eines Windsichters ist notwendig, wenn die Feuerungstechnologie nur Partikel mit einer niedrigen Absetzgeschwindigkeit im festen Brennstoff aus Abfall zulässt.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.4 Abscheidung von NE-Metallen

Beschreibung
Zu den Techniken gehören:

a. Konditionierung der Korngröße der Nichteisenmetall-Bestandteile des Abfalls auf 3 bis 150 mm vor der Abtrennung durch einen Wirbelstromabscheider
b. Nutzung eines hochfrequenten alternierenden magnetischen Feldes, um die Abtrennung feinkörniger NE-Metalle zu verbessern
c. exzentrische Positionierung der Magnetpole
d. Nutzung von Schwingrinnen, um einzelne Kornschichten zu erzeugen, um gute Sortierungsergebnisse zu erzielen
e. Separieren der feinkörnigen eisenhaltigen Partikel durch magnetische Trommel mit abwerfender Anordnung vor Beschicken des Wirbelstroms.

Ereichter Nutzen für die Umwelt
Wirbelstromabscheider können Nichteisenmetall-Partikel mit einer Korngröße zwischen 3 und 150 mm aussortieren. Somit kann eine Vorsortierung von Vorteil sein, um die Abtrennung von NE-Metallen aus dem Abfall zu verbessern.

Die magnetischen Pole werden entweder exzentrisch oder zentrisch positioniert. Anlagen mit zentrischen Polen haben Probleme mit kleinen Eisenpartikeln, die zwischen das Förderband und die Trommelhülle gelangen können. Diese Partikel werden entlang des gesamten Umfangs der Trommel angezogen, werden heiß und können zur Beschädigung der Kunststofftrommel führen. Zusätzlich können in exzentrischen Systemen die magnetischen Pole variabel positioniert werden, so dass das stärkste Feld zur Abstoßzone dirigiert werden kann.

Betriebsdaten
Es ist schwierig, längliche und flächige Abfallbestandteile wie Aluminiumfolie und Kupferdrähte abzutrennen, weil in diesen Materialien nur ein schwacher Wirbelstrom erzeugt wird.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.5 Allmetallabscheider

Beschreibung
Bei der Herstellung von festem Brennstoff aus Abfall werden Allmetallabscheider hauptsächlich für die Aufbereitung von Kunststoffen eingesetzt. Hohe Durchsätze können erzielt werden, wenn das Material vor der automatischen Erkennung diversifiziert wird. Normalerweise arbeiten Allmetallabscheider mittels Detektionsspule, die diagonal zur Transportrichtung angebracht ist und in Einzelsegmente aufgeteilt ist. Wenn ein Metallpartikel das hochfrequente alternierende magnetische Feld der Spule passiert, beeinflusst es das Feld. Diese Veränderung wird durch einen elektronisch kontrollierten Mikroprozessor erfasst, der in der Lage ist, das Spulensegment in der Nähe des Metallpartikels zu identifizieren. Dieses Partikel wird durch eine oder mehrere Druckluftdüsen, die in der Nähe der Detektionsspulen angebracht sind, abgetrennt. Die Metalle werden durch eine Teilungsplatte abgetrennt.

Erreichter Nutzen für die Umwelt
Verbessert die Abtrennung von Metallen aus Abfall.

Anwendbarkeit
Detektionsspulen sind in der Lage, Metallpartikel ab einer Größe von ca. 1 mm zu erkennen. Die Form sowie Masse sind für den Abtrennungsprozess nicht von Bedeutung.

Treibende Kraft für die Anwendung
Allmetallabscheider werden zur automatischen Abtrennung von eisenhaltigen und nicht eisenhaltigen Metallen eingesetzt. Diese Aggregate werden eingesetzt, wenn der Metallgehalt im Einsatzmaterial niedrig ist, wenn andere Metallabtrennungsverfahren wegen sehr hoher Anforderungen an die Produktqualität nicht effizient genug arbeiten oder wenn nachfolgende Aggregate, z.B. Rotationsquerschneider, geschützt werden müssen.

Beispielanlagen
Bei der Aufbereitung von Kunststoff angewendet.

Literatur
[126, Pretz, et al., 2003]

4.5.3.6 Positiv- und Negativsortierung

Beschreibung
Es gibt zwei verschiedene Verarbeitungsstrategien: Positiv- und Negativsortierung:

a. Positivsortierung bedeutet, dass nur die erwünschten Materialien mit hohen Heizwerten und niedrigen Gehalten an schädlichen Stoffen aus dem Materialfluss aussortiert werden. Diese Strategie führt zu einem höheren Aufkommen an zu deponierendem Material und oft zu einer höheren Qualität des erzeugten Brennstoffs aus Abfall
b. bei der Negativsortierung werden nur die Materialien abgetrennt, die im Produkt unerwünscht sind (z.B. wenn es erforderlich ist, den Chlorgehalt im Abfallstrom zu reduzieren, weil er bei der Verbrennung oder Mitverbrennung Probleme verursacht, kann die Reduzierung des PVC-Gehalts im Abfallstrom eine Möglichkeit darstellen). Bei dieser Strategie kann das Aufkommen an zu deponierendem Material geringer sein, da andere Materialien, die einen höheren Gehalt an schädlichen Substanzen enthalten können, in das Produkt eingehen.

Erreichter Nutzen für die Umwelt
Verbesserung der Qualität des abgetrennten Abfalls oder Vermeidung von Problemen bei der weiteren Behandlung bestimmter Abfallströme.

Medienübergreifende Auswirkungen
Einige Verunreinigungen können nicht aussortiert werden, weil sie zurückgehalten werden oder im Material versteckt sind, so dass die Erfassungsgeräte sie nicht erkennen können.

Anwendbarkeit
Angewendet bei der Herstellung von festem Brennstoff aus Siedlungsabfall. Abhängig von der erforderlichen Qualität kann eine Negativ- oder eine Positivsortierung zum Einsatz kommen. Wenn ein hochwertiger Materialstrom nachgefragt wird, ist eine Negativsortierung angebracht; die Vergütung des Produkts ist höher, wobei die erzeugte Produktmenge jedoch kleiner ist als bei einer Positivsortierung.

Wirtschaftlichkeit
Im Hinblick auf die ökonomischen Aspekte der Positiv- und Negativsortierung ist es nicht möglich, eine allgemeingültige Aussage zu machen.

Treibende Kraft für die Anwendung
Abhängig vom Ausmaß der Aufarbeitung und von der erwünschten Qualität des festen Brennstoffs aus Abfall kann die Menge der Materialien, die zur Deponie verbracht werden, stark schwanken.

Beispielanlagen
Einige Abfallstrategien trennen nur das Inertmaterial und die Metallfraktion ab und senken zusätzlich den Organik- und Wassergehalt. Der Rest gelangt in das Produkt, wodurch automatisch die Menge des Materials reduziert wird, das zur Deponie geht.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.7 Nutzung von Druckluft zur Größenreduzierung

Beschreibung
Verwendung von Druckluft zur Verarbeitung von Materials aus der Zerkleinerung (Größenreduzierung).

Erreichter Nutzen für die Umwelt
Einige Vorteile sind:

- der unerwünschte Gehalt an extrem feinkörnigem Material im Endprodukt wird gesenkt
- die Rotoren einschließlich der Messer und des Gehäuses werden abgekühlt
- der Energiebedarf wird gesenkt
- der Transport des Materials wird erleichtert.

Anwendbarkeit
Angewendet bei Tätigkeiten zur Verringerung der Größe.

Literatur
[126, Pretz, et al., 2003]

4.5.3.8 Trommelsiebe

Beschreibung
Je nach Geschwindigkeit der Trommel können verschiedene Betriebsvarianten eingesetzt werden: Kaskade oder Katarakt. Abbildung 4.9 zeigt diese Varianten.

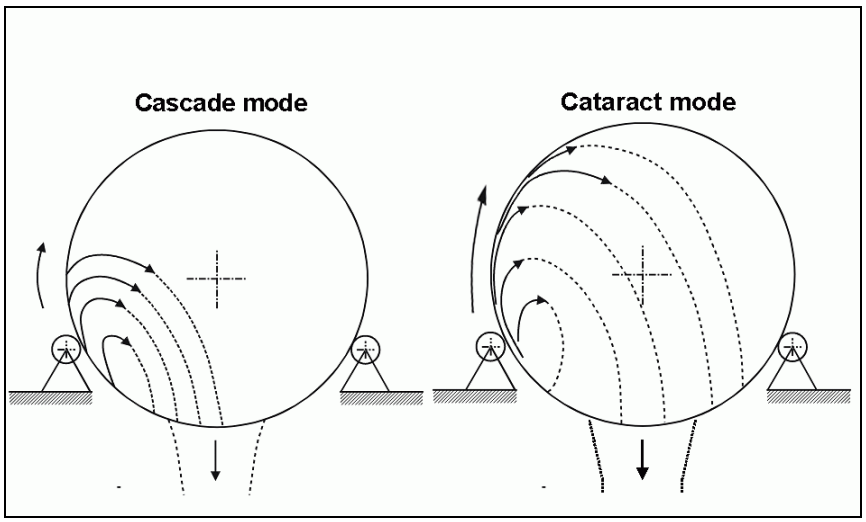


Abbildung 4.9: Trommelsiebe
[126, Pretz, et al., 2003], [150, TWG, 2004]

Das Trommelsieb weist in der Kataraktmethode bei einer Drehgeschwindigkeit von 70 % der kritischen Drehzahl die besten Ergebnisse auf. Der Nachteil der Kaskadenmethode ist, dass bei der Siebung Klumpen erzeugt und feine Partikel nicht gut freigesetzt werden.

Um die Effizienz zu erhöhen, sind Greifer im Sieb befestigt, mit denen das Material aufgehoben und höher befördert wird, so dass es in einen freien Bereich fällt. Einsatzmaterialien mit einem hohen Gehalt an groben Partikeln (ca. 100 – 250 mm) verursachen oft Probleme durch Blockieren des Siebs, was dann zu einer Verringerung der Effizienz und einem hohen Gehalt an feinen Partikeln im Überlauf führt.

Erreichter Nutzen für die Umwelt
Erhöht die Abtrennungsquote. Vorteile liegen darin, dass der Betrieb keine Vibrationen benötigt, eine große Homogenisierung ist möglich. Eine Reinigung der Oberflächen von anhaftenden kleinen Partikeln, die oft einen hohen Gehalt an Schwermetallen aufweisen, ist möglich.

Um das Sieb gegen Blockieren zu schützen, haben sich Rohrhülsen, die angeschweißt werden können, als wirksam erwiesen.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.9 Verbesserungen der Staubfilterung in Zyklonen von Windsichtern

Beschreibung
Wiederverwendung der Luft, die für den Windsichter und das Abblasen verwendet wurde. Etwa 30 % der im Kreislauf geführten Luft werden auf der Druckseite des Ventilators abgelassen und durch einen Staubfilter gereinigt.

Erreichter Nutzen für die Umwelt
Dieses Verfahren bietet die folgenden Vorteile:

- Der Filter zur Abscheidung des Staubs kann viel kleiner ausgelegt werden, da das zu reinigende Luftvolumen weniger als 1/3 des Volumens bei konventionellem Betrieb beträgt.
- Es wird keine staubbeladene Luft an den Öffnungen für das Beschickungsband oder des Schwergutaustrags abgeleitet
- In der zirkulierenden Luft werden weder Staubpartikel noch Feuchtigkeit aufkonzentriert
- Die Luftgeschwindigkeit in der Trennzone kann durch Drosselklappen genau eingestellt werden.

Betriebsdaten
Die Menge der von den Windsichtern benötigten Luft hängt von den Abmessungen der Sichterkanäle ab.

Anwendbarkeit
Nicht alle erhältlichen Windsichter können in Recyclingverfahren verwendet werden. In den meisten Fällen müssen sie speziell darauf ausgelegt werden, große Partikel zu behandeln.

Die Luftgeschwindigkeit für trockene Papiere, dünnwandige Kunststoffe und Kunststofffolien liegt zum Beispiel bei ca. 11 - 12 m/s. Die Mindest-Rückgewinnungsquote für dieses hochkalorische Leichtmaterial liegt etwa bei 70 %. Der Durchsatz von Windsichtern ist durch die spezifische Beladung begrenzt, bei einer maximalen Kapazität von 0,35 kg Feststoffen /(m³ Luft · h).

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.10 Nah-Infrarotspektroskopie

Beschreibung
Materialien, die getrennt werden müssen, werden oft auf ein Förderband aufgegeben. Das Band arbeitet normalerweise bei schnellen Geschwindigkeiten, so dass seine Arbeitsweise geradezu wie eine Trennvorrichtung wirkt. Oberhalb des Förderbands sind Halogenlampen und der Detektor angebracht. Der Detektor besteht aus einem Nah-Infrarotspektrometrie(NIR)-Sensor, der die gesamte Breite des Förderbands abtastet und die charakteristischen Spektren der verschiedenen Materialien an eine Datenverarbeitung übermittelt. Die Signale werden mit einer Datenbank verglichen. Die Analyse berücksichtigt die Berechnung der aktuellen Position auf dem Förderband sowie die Messergebnisse im Bruchteil einer Sekunde. Die Sortierung erfolgt dann mit Hilfe eines Luftdüsensystems, das vor dem Austrittsende angebracht ist. Das Druckluftsystem ist mit verschiedenen einzelnen Luftdüsen in einem Abstand von etwa 30 mm ausgestattet. Jede einzelne Düse verfügt über ein Druckluftreservoir und wird über ein Magnetventil gesteuert. Der Datenprozessor übermittelt ein Signal, wenn ein Partikel positiv detektiert worden ist und die Luftdüse bläst es heraus. Hierbei können eine oder mehrere Luftdüsen aktiviert werden. Die Druckstöße blasen das Partikel heraus, das dann durch eine Trennungsplatte aus dem Materialfluss abgetrennt wird.

Erreichter Nutzen für die Umwelt
Die Anwendung dieses Verfahrens liegt in der selektiven Abtrennung von Getränkekartons, Papier, Pappe und gemischten Kunststoffen wie Polyethylen (PE), Polypropylen (PP), Polystyrol (PS), Polyethylenterephthalat (PET) und Polyvinylchlorid (PVC). Eine ca. 80 bis 90 %ige Abtrennung ist möglich, doch hängt die tatsächliche Rückgewinnung potenziell recycelbarer Materialien von den Abfalleigenschaften ab. Die erreichbaren Produktqualitäten liegen bei 90 bis 97 %. Durch das Verfahren wird auch der Schwermetallgehalt (z. B. Sb, Cd, Pb) und Cl-Gehalt des Abfallstroms gesenkt, weil Abfall, der diese Bestandteile enthält, spezifisch abgetrennt werden kann.

Medienübergreifende Auswirkungen
Die Anwendung dieser Technik erzeugt einen Abfallstrom mit einem höheren Gehalt an Chlor und Metallen, der behandelt werden muss.

Betriebsdaten
Die Abtrennung von dunkelbraunen und schwarzen Materialien ist unmöglich, da das NIR-Licht fast vollständig absorbiert wird und folglich keine Abstrahlung zum Sensor reflektiert wird.

Anwendbarkeit
Automatische Erkennungsgeräte können Partikel, die zwischen ca. 30 und 300 mm groß sind, sortieren. Die Betriebsbreite der Förderbänder liegt zwischen 500 und 1400 mm. Der Durchsatz von vorsortierten Leichtverpackungen mit Partikelgrößen zwischen 50 und 200 mm liegt zwischen 1 und 6 t/h.

Diese Technik wird eingesetzt, um den Gehalt von einigen Verbindungen im Brennstoff aus Abfall zu reduzieren und um Qualitäten zu erzielen, die im hergestellten Brennstoff aus Abfall erforderlich sind.

Treibende Kraft für die Anwendung
Senkung des Schwermetall- und Chlorgehalts des festen Brennstoffs aus Abfall. Einige Standards werden zur Zeit durch die CEN TC 343 WG 2 erarbeitet. Chlor ist einer der Parameter, die zur Definition von Klassen von Sekundärbrennstoffen verwendet werden. Der momentan diskutierte Chlorgehalt liegt bei etwa 3 %, was bedeutet, dass Kunststoffe, die organisch gebundenes Chlor enthalten, d.h. im wesentlichen PVC, zu einem begrenzten Anteil akzeptiert werden.

Beispielanlagen
In Deutschland gibt es verschiedene Beispiele für den Einsatz von NIR zur Herstellung von festem Brennstoff aus Abfall.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004], [153, TWG, 2005]

4.5.3.11 Automatische Klaubung

Beschreibung
Das Material passiert eine Schwingrinne, die ein Förderband speist. Ein Metalldetektor ist unter dem Förderband angebracht, der spezifische Daten von jedem Partikel zu einem Computer sendet. Zusätzlich verarbeitet eine Farbkamera, die oberhalb des Förderbands angebracht ist, Informationen über die Partikel und sendet sie an die Computereinheit. Beide Informationslinien werden durch eine spezielle Software analysiert, bevor der Computer Impulse übermittelt und Düsen anweist, einzelne Partikel auszublasen oder passieren zu lassen (Positiv- oder Negativsortierung). Sowohl die angenommenen als auch die zurückgewiesenen Produkte werden dann durch einzelne Bänder zur weiteren Behandlung oder zur Lagerung transportiert.

Erreichter Nutzen für die Umwelt
Steigert die Effizienz der Klassierung der verschiedenen Materialien des Abfalls.

Anwendbarkeit
Bei einer Bandbreite von 1200 mm und abhängig vom Einsatzmaterial ist es möglich, einen Durchsatz von 2 – 8 t/h bei einer Korngröße von 3 – 250 mm zu behandeln.

Beispielanlagen
Die automatische Sortierung gewinnt im Abfallbehandlungssektor immer mehr Beachtung, insbesondere wenn ein Produkt mit bestimmten Eigenschaften gefordert wird.

Literatur
[126, Pretz, et al., 2003]

4.5.3.12 Pelletierung und Agglomerierung

Beschreibung
Scheibenagglomeratoren bestehen aus einem Metallgehäuse, in dem eine oder mehrere Scheiben angebracht sind. Die Innenseite des Reaktors wird diskontinuierlich mit Material befüllt. Die Scheiben, welche Überbauten haben, um das Material besser zu rühren, fangen an zu rotieren und wandeln die Reibungsenergie in Reibungswärme um. Das Material wird durch Rühren homogenisiert und beginnt dann, mit der steigenden Reibungswärme, zu schmelzen. In dem Moment, in dem das Material zu plastifizieren anfängt, steigt der Energieverbrauch, wodurch das Signal zur Entleerung des Reaktors ausgelöst wird. Nach dem Prozess muss das Material abgekühlt werden.

Erreichter Nutzen für die Umwelt
Erhöht die Dichte der Produkte.

Medienübergreifende Auswirkungen
Wegen des vollständigen Schmelzens ist der Energieverbrauch für dieses Verfahren sehr viel höher als für die Pelletierung.

Betriebsdaten
Abhängig von den Austraggeräten kann das Material granuliert werden.

Anwendbarkeit
Da solche Verfahren vom Schmelzen der Abfallbestandteile abhängen, können sie nur angewendet werden, wenn solche Bestandteile (z.B. Kunststoffe) verfügbar sind.

Literatur
[126, Pretz, et al., 2003], [150, TWG, 2004]

4.5.3.13 Kryogenes Mahlen

Beschreibung
Kryogenes Mahlen ist eine Behandlung zur Zerkleinerung und zum Sieben von tiefgekühlten vollen und leeren Verpackungen unter inerter Atmosphäre. Ziel ist es, Farben sowie Druckfarben und ähnliche Stoffe von gebrauchten Verpackungen in Fraktionen zu trennen z.B. zur Nutzung als Brennstoff, als Sekundärmetall und –kunststoff bei Minderung der Emissionen von VOC und flüchtigen Verbindungen auf Grund der niedrigen Temperaturen.
Der erste Arbeitsschritt besteht in der Trennung der flüssigen von der festen Fraktion. Die feste Fraktion wird weiter bearbeitet durch Mahlen, Sieben und Abtrennung der Metalle bei Temperaturen von -100 °C bis -196 °C (in der Regel mit flüssigem Stickstoff). Bei diesen Temperaturen wird das Material spröde und eine einfache Trennung unter Verwendung klassischer Verfahren ist möglich.

Die kryogene Behandlung gebrauchter Verpackungen, die Farbe sowie ähnliche Materialien beinhalten, enthält folgende Schritte:

a. Zerkleinerung in einem Schredder und Zugabe von Stickstoff zur Inertisierung der Atmosphäre. Die flüssige Fraktion (z. B. Farbschlamm) wird durch Sieben abgetrennt
b. Kryogene (Tiefkühl-) Behandlung mit flüssigem Stickstoff (-196 ºC). Durch diese Behandlung wird das Material härter und auf Grund der unterschiedlichen Expansionskoeffizienten der Bestandteile verringern sich die Bindungen.
c. Trennung von Verpackung (z.B. Metall und Kunststoff) und Inhalt (z.B. Farbschlamm) durch eine Hammermühle und ein Schwingsieb
d. Sammlung der Metallfraktion durch Magnetabscheidung mit dem Ziel der Wiederverwendung
e. Zugabe von Sägemehl als Adsorbens zum Schlamm, um ihn zu verfestigen. Die Kunststofffraktion und der Schlamm werden zur Aufbereitung als Brennstoff weitergeleitet.

Erreichter Nutzen für die Umwelt
Auf Grund der inerten Atmosphäre während des Mahlens wird das Explosionsrisiko auf ein Minimum beschränkt. Die Schlammfraktion wird zur Nutzung als Brennstoff aufbereitet.
Im Vergleich zur direkten Verbrennung solcher Abfälle wird so mehr Energie zurückgewonnen, weil Metalle vor der Verbrennung entfernt werden. Die Abtrennung anderer Materialien, z.B. von Metallen und Kunststoffen, ermöglicht ihre Nutzung.

Medienübergreifende Auswirkungen
Für den kryogenen Prozess und zur Stickstofferzeugung ist Elektrizität erforderlich. Emissionen in die Luft, z.B. von VOCs und flüchtigen Kohlenwasserstoffen, können erzeugt werden. Zur Reduzierung der VOC-Emissionen werden die Abgase erfasst und mittels eines Aktivkohlefilters gereinigt. Die Abgase werden durch einen Aktivkohlefilter von flüchtigen Kohlenwasserstoffen gereinigt. Die verbleibenden Emissionen werden auf 0,06 kg/t eingesetzten Verpackungsabfalls geschätzt.

Betriebsdaten
Die Endprodukte des Verfahrens sind pulverförmiger organischer Abfall, Nichteisen- und Eisenmetalle und Kunststoffe. Der Stromverbrauch durch den kryogenen Prozess liegt bei etwa 31 kWh/t eingesetzten Verpackungsabfalls. Der Betrag an verbrauchtem Stickstoff liegt bei etwa 0,67 t/t eingesetzten Verpackungsabfalls. Als Adsorbens für den Schlamm wird Sägemehl verwendet. Die verbrauchte Menge liegt bei 170 kg/t Abfall. Das verwendete Sägemehl ist ein Abfallstoff, was heißt, dass Primärmaterialien eingespart werden.

Anwendbarkeit
Ein Beispiel ist die Erzeugung von festem Brennstoff aus Abfall, der sich aus gebrauchten Verpackungen, die Farbe und ähnlichen Stoffe beinhalten, zusammensetzt. Diese technischen Einrichtungen werden häufig zur Verarbeitung von Metall- und Kunststoffverpackungen verwendet, die mit Farben, Druckfarbe, Ölschlamm, Lack, Klebstoff, Harz usw. gefüllt sind, sowie bei gummibasierten Abfällen (z.B. Reifen). Verpackungen mit anderen gefährlichen Abfällen, z.B. mit Pestiziden, halogenierten Chemikalien und Laborchemikalien können nicht mit diesem Verfahren behandelt werden, da ein Risiko der Ausbreitung von giftigen Substanzen besteht.

Beispielanlagen
In den Niederlanden gibt es eine Beispielanlage, mit einer Kapazität von 17 500 Tonnen pro Jahr.

Literatur
[122, Eucopro, 2003], [150, TWG, 2004], [156, VROM, 2004]

4.5.4 Techniken zur Erzeugung flüssiger Brennstoffe aus Abfall

4.5.4.1 Allgemeine Techniken zur Erzeugung von flüssigem Brennstoff aus Abfall

Beschreibung
Zu den Techniken gehören:

a. Verwendung von Wärmetauschern außerhalb des Behälters. Dort wird Wasserdampf ausgetrieben und das eingesetzte Öl kann auf 90 °C aufgeheizt werden, womit ein Großteil des suspendierten (gegenteilig von gelöstem) Wassers abgetrennt wird. Dies erfolgt durch Verringerung der Viskosität der Ölphase (was durch Erhöhung der Temperatur verursacht wird). Mittels Schwerkrafttrennung erreicht man das erwünschte Ergebnis, da das Wasser zum Tankboden sinkt.
b. Nutzung von Aktivkohleadsorption oder Kondensation zur Vermeidung von VOC-Emissionen. Bei Nutzung der Kondensation kann die gesammelte organische Fraktion in den Kessel eingespeist werden.
c. Entfernung des hohen Feststoffgehalts aus flüssigem Abfall, der als Brennstoff genutzt wird. Dafür wird in der Regel warmes Öl aus Heizbehältern über offene Filter geleitet, um Feststoffe zu entfernen. Diese befinden sich entweder auf offenen Plätzen oder in Gebäuden. VOCs werden emittiert, wenn warmes Öl zur Entfernung der Feststoffe die Filter durchläuft. Bei den verwendeten Filtern handelt es sich in der Regel um vibrierende Metallmaschentypen, die häufiger im Zusammenhang mit Mineralaggregaten eingesetzt werden. Bei offenen Filtern müssen Hauben angebracht sein, um eine Absaugung des Dampfes aus der Filtration zu ermöglichen. Auch Zentrifugen können zum Zwecke der Trennung von Feststoffen aus Öl verwendet werden, mit dem Vorteil minimaler Emissionen.
d. Eine Entfernung von Öl aus Abwasser vor der Einleitung in Abwasserkanäle oder andere Gewässer wird normalerweise durch Öl-Wasser-Abscheider, Schrägplattenabscheider und/oder Filtrationstechniken mit anschließender Nutzung des Öls als Brennstoff durchgeführt
e. Sicherstellung, dass in einem Mehrkammer-Ölabscheider jede einzelne Kammer groß genug ist, um sechs Minuten Verweilzeit bei maximal vorhersehbarer Durchflussrate zu ermöglichen
f. Verwendung eines Vertikalrührers, bei dem sich die Gleitlager nicht innerhalb des Tanks befinden.

Erreichter Nutzen für die Umwelt
Reinigt und mindert Emissionen aus der Behandlung von flüssigen Abfällen. Für den Verkauf flüssiger Brennstoffe aus Abfall ist entscheidend, dass der hohe Feststoffgehalt, falls im warmen Öl enthalten, entfernt wird.

Medienübergreifende Auswirkungen
VOC-Emissionen können signifikant sein, wenn Öl aus dem Prozesstank in Kanäle geleitet wird und auch, wenn warmes Öl über den Schrägplattenabscheider geleitet wird.

Betriebsdaten
Die Aktivkohleadsorption kann durch die Anwesenheit von Wasserdampf beeinträchtigt werden. Der Vorgang der Feststoffentfernung ist aggressiv, weshalb die eingesetzten Filter robust sein müssen, um mit den Feststoffen und dem warmen Öl umgehen zu können. Ölabscheider können wassermischbare Stoffe nicht abtrennen.

Schrägplattenabscheider (Technik d im obigen Abschnitt "Beschreibung") benötigen sehr viel niedrigere Verweilzeiten. Öl/Wasser-Abscheider werden auf der Grundlage ihrer Bauart, ihrer maximalen vorhersehbaren Durchflussrate und der geforderten Emissionswerte ausgelegt.

Anwendbarkeit
Anwendbar auf die Ölaufarbeitung: Das vorrangige Ziel ist die Herstellung eines Brennstoffs aus dem Altöl. Zwei Mischtechniken sind geeignet, um den flüssigen Brennstoff zu homogenisieren:

- Ein langer Mixer, der auf dem Dach des Tanks angebracht ist
- Ein Pumpsystem, dass den oberen und unteren Teil des Tanks mittels Kreislaufströmung mischt.

Bei Trocknungs- und Heizvorgängen müssen die Emissionen und die Risiken der Entflammbarkeit berücksichtigt werden.

Literatur
[55, UK EA, 2001], [122, Eucopro, 2003], [152, TWG, 2004]

4.5.4.2 Thermisches Cracken von Altöl

Beschreibung
Siehe Abschnitt 2.5.2.4.4.

Erreichter Nutzen für die Umwelt
Der Einsatz des thermischen Crackens in einer Raffinerie verringert die CO_2-Emissionen, da es den Rohölverbrauch der Raffinerie senkt.

Wirtschaftlichkeit
Thermisches Cracken ist kapitalintensiv: Die Investitionskosten und die fixen Betriebskosten machen etwa 80 % der Gesamtkosten aus (Altölkauf ist nicht enthalten). Die Kosten für eine thermische Crackanlage liegen etwa bei einem Drittel bis der Hälfte der Kosten einer Regenerationsanlage gleicher Größe (obwohl dieser Vergleich nicht notwendigerweise relevant ist, da die erzeugten Outputs verschieden sind). Experten sind sich einig, dass Anlagen für das thermische Cracken mit ihren geringeren Investitionskosten ab einer Kapazität von 30 kt/a wirtschaftlich sind. Subventionen sind nicht notwendig.

Parameter	Kapazität A	Kapazität B	Kapazität C	Einheiten
Kapazität	40	50	80	kt/a
Investitionskosten	11	13	20	Millionen EUR
Spezifische Kosten	135	123	112	EUR/Tonne Altöl
Kosten der internen Finanzrendite (1)	50	46	44	
Einkünfte	144	144	144	EUR/Tonne Altöl
Altöl-Annahmegebühr	-10	-21	-32	
(1) auf der Grundlage einer 15 % angepassten Risikorate der Finanzrendite (in der Kostenaufstellung enthalten).				

Tabelle 4.43: Kosten und Altöl-Annahmegebühren für drei einfache thermische Crackanlagen unterschiedlicher Kapazität
[7, Monier and Labouze, 2001], [150, TWG, 2004]

Die Investitionskosten für die Nutzung von Altöl als Brennstoff bei einer kompletten Wiederaufbereitung liegen bei 12 Millionen USD (1995) bei einer Behandlung von 54 kt/a (Voraussetzungen: Lagerung: 15 Tage, Betriebsmittel: 15 Tage). Die Investitionskosten für Texaco Trailblazer, der Dieselöle für die Schifffahrt produziert, liegen bei 11 Millionen USD (1994) für eine Behandlung von 54 kt/a (unter denselben Voraussetzungen wie oben).

Aus anderen Informationen geht hervor, dass der ungefähre Wert von gebrauchtem Mineralöl, bei einer kompletten Wiederaufbereitung (der Wert am Anlagentor (1994) setzt einen internen Zinsfuß von 15 % nach Steuern und Betriebsmittel von 15 Tagen voraus) ohne Berücksichtigung der Sammelkosten, bei 47 USD /t und einschließlich der Sammelkosten bei – 63 USD /t liegt (die durchschnittlichen Sammelkosten innerhalb von Europa wurden mit 110 USD/t bewertet).

Literatur
[5, Concawe, 1996], [6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001]

4.5.4.3 Membranfiltration zur schonenden Wiederaufarbeitung von Altölen

Beschreibung
Vorbehandlung zum Schutz der Membrananlage.

Erreichter Nutzen für die Umwelt
Bessere Qualität der Altöle und Schutz der Membranen.

Anwendbarkeit
Übliches Verfahren bei der Behandlung von Altöl durch Membranfiltration.

Wirtschaftlichkeit
Signifikante zusätzliche Kosten. In der Regel ist der Wert der erforderlichen Anlage, einschließlich des Verfahrensschritts zum Schutz der Membran, im Vergleich zum Wertzuwachs des Produkts hoch.

Beispielanlagen
Betriebserfahrungen liegen vor.

Literatur
[150, TWG, 2004]

4.5.5 Erzeugung von gasförmigem Brennstoff aus Abfall

Beschreibung
Vergasung und Pyrolyse sind Wege zur Herstellung eines gasförmigen Brennstoffs. Für Informationen über die Umwandlung organischen Abfalls in ein Gas, das als Brennstoff oder Synthesegas verwendet werden kann, siehe das BVT-Merkblatt „Abfallverbrennung“.

Erreichter Nutzen für die Umwelt
Erzeugt einen sauberen gasförmigen Brennstoff, wobei die Verunreinigungen im Laufe des Verfahrens in verschiedenen Fraktionen zurückgehalten werden.

Betriebsdaten
Die Vergasung bietet den Vorteil, dass gemischte Abfälle angenommen werden können, z.B. Altöle und Kunststoffe. Dies ist besonders für den Fall erheblich, dass Altöle in ihre Originalbehälter zurückgeführt wurden.

Anwendbarkeit

Wirtschaftlichkeit
Weil in der Regel große Anlagen notwendig sind, um eine Kostendeckung zu erreichen, können nur existierende Anlagen zur Behandlung von Abfällen verwendet werden. Dennoch haben jüngste Entwicklungen gezeigt, dass kleine Anlagen, die 10 – 15 t/Tag behandeln, kosteneffizient sein können.

Treibende Kraft für die Einführung
Solche Anlagen sind viel größer, als es zur Beseitigung von gebrauchtem Öl erforderlich wäre, deshalb werden sie normalerweise nicht speziell für diesen Zweck gebaut. Wo dennoch solche Anlagen zu anderen Zwecken gebaut werden, würden sie einen sicheren Beseitigungsweg für gebrauchtes Öl unter Bewahrung seines Energiegehalts bereitstellen.

Beispielanlagen
In Europa existieren einige Anwendungsbeispiele.

Literatur
[5, Concawe, 1996], [58, CEFIC, 2002], [150, TWG, 2004]

4.5.6 Vermeidungs- und Minderungstechniken, die bei der Erzeugung von Brennstoff aus gefährlichen Abfällen eingesetzt werden

Technik	Verweis in diesem Dokument	Anwendbarkeit
Vermeidungsmaßnahmen gegen Staub		
Errichtung aller Annahme-, Produktions- und Lagerbereiche in geschlossenen Gebäuden mit Unterdruck	4.6.1	
Das Anlegen eines Überdrucks an die Arbeitsplätze (Kontrollraum, Fahrzeugkabine usw.) stellt sicher, dass kein Staub zu den Arbeitern gelangt	4.6.1	Kann in bestehenden Anlagen ohne eine vollständige Neukonzeption der Anlage angewendet werden
Sicherstellung, dass Aufbereitungs- und Mischvorgänge in eingehausten Bereichen unter Erfassung der Abluft durchgeführt werden	4.6.1	
Umgang mit staubigen Abfällen in geschlossenen Bereichen	4.6.1	Kann in bestehenden Anlagen ohne eine vollständige Neukonzeption der Anlage angewendet werden
Verwendung geschlossener Behälter/Mischer/Filter/Siebe/Magnetscheider/Homogenisierungsgeräte	4.6.1	Kann in bestehenden Anlagen ohne eine vollständige Neukonzeption der Anlage angewendet werden
Einsatz von Sprüh-/Zerstäuber verfahren zur Befeuchtung von Umgebungsluft und gefasster Luft, um Staubemissionen zu vermeiden	4.6.1	
Sicherstellung, dass Ladungen von frischem Sägemehl, staubigem Abfall oder festem Brennstoff aus Abfall vor dem Transport wirksam bedeckt werden	4.1.4.1	Kann in bestehenden Anlagen ohne eine vollständige Neukonzeption der Anlage angewendet werden
Verwendung eines Staubrückhaltenetzes	4.6.5	Kann in bestehenden Anlagen ohne eine vollständige Neukonzeption der Anlage angewendet werden
Minderungsstechniken für Staub		
Nasse Gaswäsche	4.6.11	In bestehenden Anlagen zur Erzeugung von Brennstoff aus Abfall nicht eingesetzt, weil einige Stäube hydrophob sind und der nasse Rückstand nicht leicht in der Produktion von Brennstoff aus Abfall wiederverwendet werden kann
Zyklone	4.6.3	Im Sektor nicht weit verbreitet. Diese Technik kann nur in Verbindung mit einem Beutelfilter genutzt werden
Gewebefilter	4.6.5	Im Sektor weit verbreitet
Elektrostatischer Abscheider	4.6.4	
Abwasserbehandlung		
Behandlung mit Aktivkohle	4.7	Schwach verunreinigte Abwässer
Thermische Behandlung	4.7	Stark verunreinigte Abwässer

Tabelle 4.44: Vermeidungs- und Minderungstechniken bei der Herstellung von Brennstoff aus gefährlichen Abfällen [122, Eucopro, 2003], [152, TWG, 2004]

4.6 Abgasbehandlung

Dieser Abschnitt führt Techniken auf, die im Abfallbehandlungssektor zur Reduzierung, Verminderung oder Kontrolle der Emissionen in die Luft angewendet werden. Der Schwerpunkt liegt auf der Vermeidung der Erzeugung und Verlagerung von Schadstoffen.

Punktuelle Emissionsquellen entstehen durch diejenigen Emissionen, die aus der Sammlung von Abluft aus einem Behälter oder Bereich resultieren und die, entweder über eine Minderung oder direkt, zu einem Schornstein oder einer Abluftanlage weitergeleitet werden.

Dieser Abschnitt enthält nur diejenigen Techniken, die für den Abfallbehandlungssektor von Relevanz sind. Im Allgemeinen wurden die meisten Techniken bereits in anderen BVT-Merkblättern beschrieben und untersucht (insbesondere in den BVT-Merkblättern „Abwasser- und Abgasbehandlung“ und „Abfallverbrennung“). Deswegen ist in diesem Abschnitt nicht beabsichtigt, eine vollständige Untersuchung jeder der verschiedenen Techniken vorzulegen. Stattdessen konzentriert sich dieser Abschnitt nur auf Themen, die für den Abfallbehandlungssektor von Bedeutung sind, einschließlich der Diskussionen darüber, was gut erreichbare Emissionswerte sind. Vermeidungstechniken sind im vorhergehenden Abschnitt enthalten, da sie insbesondere von der Art des durchgeführten Verfahrens/Aktivität abhängig sind.

4.6.1 Allgemeine Vermeidungstechniken

Beschreibung
Zu den Techniken gehören:

a. Verwendung eines geschlossenen oder auf Unterdruck basierenden Absaugsystems, zu einer geeigneten Abgasreinigungsanlage, insbesondere bei Prozessen, in denen flüchtige Flüssigkeiten geleitet oder Abfälle, die VOC-Emissionen erzeugen, verarbeitet werden, einschließlich Be- und Entladung von Tankwagen.
b. Verwendung eines angemessen dimensionierten Absaugsystems, das die befüllten Behältnisse, Vorbehandlungsbereiche, Lagertanks, Misch- und Reaktionstanks und die Filterpressenbereiche abdeckt oder Vorhaltung eines getrennten Systems zur Behandlung von Gasen aus der Entlüftung spezieller Tanks (z.B. Aktivkohlefilter für Tanks, in denen mit Lösemitteln verunreinigte Abfälle gelagert werden)
c. Vollständige Einhausung des gesamten Standorts (z.B. in einer Halle).
d. Benutzung künstlicher Bodenabdeckungen. Die künstliche Abdeckung kann aus einer dünnen (0,1 – 0,15 mm) Kunststoffplane oder aus einer relativ dicken (0,75 – 1 mm) Kunststoffplane oder aus Geotextilien bestehen. Die Widerstandsfähigkeit verschiedener Polymere gegenüber Chemikalien, der Witterung sowie ihre Gasdurchlässigkeit und Reißfestigkeit sind dokumentiert. In der Regel ist das Material zum Aufbau einer Barriere in großen Rollen erhältlich und kann auch schnell bei großen Bodenanhäufungen angewendet werden. Die künstliche Abdeckung muss gegen Wind abgesichert werden
e. Benutzung von Windbarrieren

Erreichter Nutzen für die Umwelt
Verringert flüchtige Emissionen in die Luft (z.B. VOC und Gerüche). Die Wirksamkeit von Bodenabdeckungen ist abhängig von der Stärke der Abdeckung sowie vom prozentualen Anteil des verunreinigten Bodens der bedeckt werden kann. Gemessene Emissionsraten können wesentlich durch die Zugabe von verdichtetem Boden reduziert werden (z.B. um >95 %); dennoch kann eine laterale Freisetzung von VOCs immer noch vorkommen.

Wenn es gerechtfertigt ist, kann auch eine vollständige Einhausung des Aushebungsgeländes durchgeführt werden, um flüchtige Emissionen zu minimieren. Die Einhausung dient dazu, alle Emissionen zu sammeln, welche dann mittels des Abluftsystems zu einer Art Kontrolleinrichtung, die für punktuelle Quellen geeignet ist, geleitet werden. Die Einhausung kann entweder luftgestützt oder selbsttragend sein. Wenn sie richtig geplant und ausgeführt wird, kann die Einhausung flüchtige Emissionen auf ein vernachlässigbares Niveau reduzieren.

Für kleinere Arbeitsbereiche können diffuse Emissionen (z.B. VOC) durch den Einsatz von Windbarrieren verringert werden, indem die effektive Windgeschwindigkeit an der Bodenoberfläche gesenkt wird. Handelsübliches, poriges Zaunmaterial, das normalerweise zur Kontrolle von Staubentwicklungen verwendet wird, hat sich als effektiver herausgestellt als massives Zaunmaterial.

Anlagen, die Gerüche und Staub emittieren, können eingehaust werden, um Emissionen zu vermeiden und die Menge an verunreinigter Luft zu reduzieren, die anschließend gereinigt werden muss. Ein gut funktionierendes Abluftsammelsystem stellt sicher, dass nur ein Minimum an Keimen, Pilzen, Sporen, Gerüchen und Staubpartikeln emittiert wird. Dies kann positive Auswirkungen auf die Gesundheit der Beschäftigten haben und verringert krankheitsbedingte Abwesenheiten.

Medienübergreifende Auswirkungen
Ein positiver Nebeneffekt der Einhausung ist die Lärmminderung für die Beschäftigten und die Nachbarschaft.

Künstliche Abdeckungen können unbegrenzt am Platz gelassen werden, obwohl die physikalische Zersetzung und die Photodegradation des Kunststoffs die wirksame Lebensdauer bei dünnen Abdichtungen tendenziell auf einige Wochen reduzieren kann.

Abdeckungen aus Boden sind über längere Zeitperioden weniger effektiv, und ihre Verwendung erhöht tendenziell das Gesamtvolumen sowie die Masse des Materials, das behandelt werden muss.

Betriebsdaten
Die am weitesten verbreitete Methode zur VOC-Emissionskontrolle bei Flächenquellen, z.B. während einer Auskofferung, ist die Verwendung von Abdeckungen zur Schaffung einer physikalischen Barriere gegen den Gasaustritt. Die einfachste Barriere ist die Verwendung von relativ sauberem Boden als Abdeckung für kontaminierte Böden. Die Bodenschicht verlängert die notwendige Transportstrecke der Gasdiffusion und senkt dadurch zumindest zeitweilig die Emissionsrate in hohem Maße. Die Effektivität der Abdeckung hängt von der Permeabilität des Bodens hinsichtlich der vorhandenen Dämpfe und dem prozentualen Anteil des angemessen bedeckten Bodenhaufens ab. Labormessungen einer 0,5-mm-PVC-Plane zeigten eine relativ schlechte Leistung bei der Begrenzung der Gasdiffusion. Selbsttragende Hallen sind praktisch, wenn Lastwagen oder andere schwere Geräte regelmäßig in die Konstruktion ein- und ausfahren müssen. Im Hinblick auf die Notwendigkeit der Staubentfernung in biologischen Behandlungsanlagen spielen vorgelagerte Prozesse eine entscheidende Rolle. Im feuchten Abgas aus dem biologischen Verfahren werden potenzielle Staubemissionen wirksam entfernt. Alle mechanischen Schritte zur Aufbereitung von trockenen Materialien führen unvermeidlich zu Staubemissionen. In diesem Fall ist die Einkapselung der betreffenden Aggregate notwendig. Bei diesen mechanischen Schritten muss die Abluft einer wirksamen Staubabscheidung unterzogen werden. Werte von weniger als 10 mg/Nm^3 können durch verschiedene Techniken erreicht werden. Techniken zur Vermeidung der Bildung von Bioaerosolen und Stäuben in biologischen Behandlungsanlagen umfassen:

a. Sicherstellung, dass der optimale Feuchtigkeitsgehalt während des aeroben Prozesses aufrechterhalten wird
b. Sicherstellung, dass das biologisch abgebaute Material regelmäßig umgesetzt wird
c. Aufrechterhaltung einer guten Betriebsführung (siehe Abschnitt 4.1.2.5)
d. Errichten eines Dammes/Bepflanzungen von Bäumen um den Standort herum.

Anwendbarkeit
Künstliche Abdeckungen werden in der Regel zur Kontrolle von VOC-Emissionen aus ausgehobenem Boden verwendet, der kurzfristig als Miete gelagert wird. Künstliche Abdeckungen sind auch weit verbreitet, um VOC-Emissionen während des Transports per Bahn oder Straße zu begrenzen.

Es gibt Einschränkungen, die die Verwendung vollständiger Einhausungen auf Standorte begrenzen, wo andere Möglichkeiten nicht akzeptabel sind. Die Lufttemperaturen innerhalb der Konstruktion können so hoch sein, dass die Produktivität und Sicherheit der Beschäftigten beeinträchtigt wird. Zusätzliche Sicherheitsanforderungen, in Verbindung mit zusätzlich benötigter Zeit für die Ein- und Ausfahrt von Lastwagen, verlängern wahrscheinlich die zur Fertigstellung der Aushebung benötigte Zeit und erhöhen dadurch die Kosten.

Für große Arbeitsbereiche ist eine Einzäunung weniger praktisch. Eine Minimierung von VOC- (und Staub-) Emissionen aus einer gelagerten Bodenmiete ist möglich, indem Platzierung und Form der Miete überprüft werden. Wenn machbar, können die Mieten so platziert werden, dass sie von üblichen Winden am Standort abgeschirmt sind. Die Oberfläche des Bodens kann auf ein bestimmtes Volumen minimiert werden, indem die Miete geformt wird. Die Ausrichtung der Bodenmiete beeinflusst die Windgeschwindigkeit über der Miete, die niedrigste Windgeschwindigkeit tritt auf, wenn die längere Seite der Bodenmiete senkrecht zur vorherrschenden Windrichtung steht.
Die Wahl der anzuwendenden Abluftreinigungstechnik für VOC hängt vor allem von den Bestandteilen der VOC ab. Darüber hinaus sind diese Methoden hinsichtlich der Durchflussraten und der Konzentration besonders sensibel.

Wirtschaftlichkeit
Die Investitionskosten für die Konstruktion einer vollständigen Einhausung sind relativ hoch. Auch die Betriebskosten können sehr hoch sein, wenn große Luftvolumina behandelt und abgesaugt werden müssen, um die Schadstoffkonzentrationen in der Halle auf einem Niveau zu halten, welches die Gesundheit der Beschäftigten sicherstellt.

Technik zur Emissionskontrolle	Materialkosten (USD/m^2, wenn nicht anders angegeben)	Anmerkungen
Ton	4,15	Abdeckungen, Matte und Membran
Boden	1,33	Voraussetzung: 15 cm dick; Bodentransport nicht enthalten
Holzschnitzel, Kunststoffnetz	0,50	Schnitzelkosten je nach Standort unterschiedlich
Synthetische Abdeckung	4,40	Voraussetzung: 1,14 mm Dicke
Kurzzeitschaum	0,04	Voraussetzung: 6 cm dick, 0,7 USD/m^3 Schaum
Langzeitschaum	0,13	Voraussetzung: 3,8 cm dick, 3,3 USD /m^3 Schaum
Windschutz	40/m	Pro Meter

Tabelle 4.45: Zusammenfassung der Kosten der Emissionsminderung für Flächenquellen, angewandt auf die Auskofferung und Entfernung
[30, Eklund, et al., 1997]

Beispielanlagen
Die Mehrheit chemischer Anlagen verfügt über eine Luftabsaugung und eine Gaswäsche für Behälter der Hauptverfahren und für alle Vorbehandlungstätigkeiten, bei denen giftige Gase in die Luft freigesetzt werden könnten. Die meisten Abfallbehandlungsanlagen verfügen über Abgasreinigungsanlagen zur Emissionsminderung, Art und Umfang der Minderung sind jedoch sehr unterschiedlich.

Literatur
[30, Eklund, et al., 1997], [50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.6.2 Lecksuch- und Reparaturprogramm

Beschreibung
Ein Lecksuch- und Reparaturprogramm (LDAR) für Anlagen, die mit Lösemitteln und ähnlichen flüchtigen Materialien umgehen, kann enthalten:

a. Identifizierung und, wo möglich, Quantifizierung signifikanter diffuser Emissionen aller relevanter Quellen in die Luft. Abschätzung des jeweiligen Anteils an den Gesamtemissionen für jede Substanz, die den diffusen Freisetzungen zugeordnet werden können.
b. Nutzung von nicht-eingreifenden Volumenmessungen der Behälter
c. Ersetzen von Filtern an der Behälterklappe bei der Reinigung von Filtern
d. Lagerung von Filterspülwässern in abgedichteten Fässern
e. Lagerung von verunreinigten Wässern mit Geruchspotenzial in abgedeckten Behältnissen
f. Nutzung der Lagerung in Fässern (siehe Abschnitt 4.1.4.2)
g. Sicherstellung, dass Tanks regelmäßig gereinigt/entschlammt werden, dabei sollen Wartungspläne genutzt werden, um Dekontaminationstätigkeiten in großem Umfang zu vermeiden

h. Waschen der Tankfahrzeuge, wenn die Ladung dazu neigt, Gerüche zu bilden. Das Waschwasser/der wässrige Abfall aus dem Waschvorgang muss direkt in Lagereinrichtungen abgeleitet werden, bevor der Tank des Fahrzeugs geöffnet wird. Die Tanks der Fahrzeuge sollten so kurz wie möglich offen gelassen werden
i. Direkte Überwachung von Ventilen, Pumpendichtungen usw. mit einem tragbaren Analysegerät für organische Dämpfe, das der Überprüfung auf Lecks dient
j. Durchführung von Wartungsarbeiten, um entdeckte Lecks zu reparieren, z.B. Ersatz von Ventildichtungen.

Erreichter Nutzen für die Umwelt
Ermittlung von VOC-Lecks aus Ventilen, Pumpen und weiteren Leitungskomponenten.

Anwendbarkeit
Geeignet für Standorte, an denen eine große Anzahl von Leitungskomponenten (z.B. Ventile) vorhanden sind und eine signifikante Menge leichter Kohlenwasserstoffe (z.B. Lösemitteln) verarbeitet wird.

Wirtschaftlichkeit
Die Kosten einer Lecksuchüberprüfung und der dazugehörigen Reparaturen können teilweise durch Einsparungen aus einem verringerten Materialverlust in die Luft ausgeglichen werden. Die Einsparungen hängen vom Wert des verlorenen Materials ab.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004]

4.6.3 Zyklone

Beschreibung
Bei allen Arten von Zyklonen werden Zentrifugalkräfte genutzt, um feste Partikel oder flüssige Tröpfchen aus Abgasen abzuscheiden. Zyklonfilter werden eingesetzt, um schwerere Partikel zu entfernen, die “ausfallen”, wenn Abgase, vor Verlassen des Separators, in eine Rotationsbewegung gebracht werden. Es gibt zwei Formen, den Zyklon und den Multizyklon. Letzterer scheidet feinere Stäube ab.

Erreichter Nutzen für die Umwelt
Zyklone scheiden wirksam Partikel der Größen >10 µm ab. Sie sind weniger wirksam bei Partikelgrößen <10 µm, bei denen folglich zusätzliche Maßnahmen, z.B. Gewebefilter, erforderlich sind. Zu den Vorteilen der Verwendung eines Zyklons gehören:

- Wirksamkeit in einem großen Konzentrationsbereich
- Gesammelter Staub kann im Verfahren wiederverwendet werden.

Medienübergreifende Auswirkungen
Zyklone führen zu einem Druckabfall im Gasfluss, zu dessen Überwindung ein höherer Energieverbrauch erforderlich ist, was zu höheren Gesamtemissionen führt. Hoher Verschleiß durch abreibenden Staub.

Betriebsdaten
Zyklone sind relativ zuverlässig. Zu den Betriebsvoraussetzungen gehören:

- Überwachung von pH-Wert, Durchfluss und Menge der eingesetzten Waschflüssigkeiten sowie des Druckabfalls im Gaswäscher (Überwachung des Druckabfalls mit Alarm)
- Austrittkonzentrationen müssen unter verschiedenen Betriebsbedingungen periodisch überwacht werden.

Anwendbarkeit
Diese Technik kann nur in Verbindung mit einem Schlauchfilter verwendet werden. Sie ist nicht wirksam bei der Abscheidung von kleinen Partikeln.

Wirtschaftlichkeit
Zyklone sind relativ preiswert.

Beispielanlagen
Zyklone werden bei der Herstellung von Brennstoffen aus gefährlichen Abfällen verwendet, wo sie im Mischbehälter als Teil des Stabilisierungsprozesses genutzt werden. Sie werden auch zur Behandlung der Abgase von C-P-Anlagen verwendet.

Literatur
[55, UK EA, 2001], [122, Eucopro, 2003], [126, Pretz, et al., 2003]

4.6.4 Elektrostatische Abscheider

Beschreibung
Elektrostatische Abscheider nutzen hohe Spannungen, um feste Staubpartikel aus den Abgasen elektrostatisch anzuziehen und um sie so zu entfernen. Es gibt zwei verschiedene Betriebsarten: Die „trockene“, bei der zur Sammlung von Staub an den Elektroden ein elektrisches Feld angelegt wird und die „nasse“, die gleich ist, aber bei der zusätzlich die Elektroden zur Steigerung der Effizienz gereinigt werden.

Erreichter Nutzen für die Umwelt
Minderung der Staubemissionen. Hohe Abscheidegrade für sowohl große als auch kleine Partikel. Wirksam bei hohen Temperaturen und einsetzbar bei der Abscheidung von flüssigen Partikeln.

Anwendbarkeit
Diese Technik ist nicht für organische Partikel geeignet, da diese ein hohes Explosionsrisiko darstellen.

Beispielanlagen
Das Verfahren wird zur Behandlung der Abgase aus C-P-Anlagen verwendet.

Literatur
[122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.6.5 Gewebefilter

Beschreibung
Durch eine Barriere wird Staub aus den Abgasen separiert. Feste Partikel werden mittels eines gewebten Stoffs abgetrennt, während das Gas hindurchströmen kann. Die Effizienz des Filters kann erhöht werden, indem man das Filtertuch vorbeschichtet, bevor es eingesetzt wird.

Erreichter Nutzen für die Umwelt
- hohe Abscheidegrade sowohl für grobe als auch für kleine Partikel
- Einsetzbar in einem großen Konzentrationsbereich
- Abgeschiedener Staub kann im Verfahren wiederverwendet werden
- Hoher Abscheidegrad bei hohen Temperaturen, wenn spezifische Materialien, z.B. Teflon, verwendet werden.

Eigenschaften	Gewebefilter
Zuflussbereich im Input (m^3/Stunde)	1000 bis 50000
Konzentration im Input (mg/Nm^3)	100 bis 5000
Konzentration im Output (mg/Nm^3)	<10
Risiken	Explosion
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	2,5 bis 3,5
Brennstoff/Gas (Liter)	-
Reaktionsmitttel (Art und kg)	-
Reststoffe	-
Kosten (EUR/t jährlich erzeugten Brennstoffs aus Abfall)	
Investitionskosten	Bis 4
Betriebskosten	0,15
Wartungskosten	0,1

Tabelle 4.46: Staubfiltration durch einen Gewebefilter
[122, Eucopro, 2003]

Medienübergreifende Auswirkungen
Zyklone und Gewebefilter bewirken einen Druckverlust im Gasfluss, wodurch ein höherer Energieverbrauch erforderlich ist, um diese Absenkung auszugleichen, was wiederum zu höheren Gesamtemissionen führt. Eine Hauptquelle für gefährliche Abfälle in vielen Industriebranchen ist der Staub aus Abgasreinigungssystemen (z.B. aus Gewebefilter). Wie bei Abwassersystemen werden gemeinsame Staubabscheider für verschiedene Produktionsbereiche eingesetzt, was zu einer Vermischung verschiedener Arten von Staub führt, wodurch ein Recycling erschwert wird. In manchen Fällen können Modifizierungen an den Staubabscheidern vorgenommen werden, so dass Abgase aus verschiedenen Quellen in verschiedene Kammern geleitet werden, wodurch eine Vermischung unterschiedlicher Abfallarten verhindert und das Recyclingpotenzial erhöht wird.

Betriebsdaten
Eine Reinigung kann in situ mittels Luftimpulse, Gegenstrombelüftung oder mechanischen Klopfens erreicht werden. Die Zuverlässigkeit hängt stark vom Filtermaterial ab. Gewebefilter können ein Explosionsrisiko schaffen. Gewebefilter sind ausgestattet mit einem Monitoring der Druckabsenkung einschließlich Alarmvorrichtungen und oft mit Messungen von Einlass- und Ausgangskonzentrationen. Eine Druckmessung wird oft als unmittelbarer Ersatz für eine Konzentrationsanalyse eingesetzt. Allerdings wird von Zeit zu Zeit die Ausgangskonzentration in einem Labor überwacht, um die Emissionen zu quantifizieren. Um die Leistung zu überwachen, kann ein Trübungsmesser oder ein Detektor, mit dem die Partikelberührungen gemessen werden, eingesetzt werden. Es muss ein Programm zur regelmäßigen Reinigung der Gewebefilter vorhanden sein.

Anwendbarkeit
Angewandt sowohl bei diffusen Emissionen als auch bei Emissionen aus Punktquellen in die Luft. Gewebefilter werden in der Regel als sekundäre oder tertiäre Gasreinigungsanlagen in Kombination mit einem vorgeschalteten Zyklon oder einer vorgeschalteten trockenen Gaswäsche verwendet. Gewebefilter sind für feuchtigkeitsbeladene Abgasströme oder für solche mit sauren, teerigen oder klebrigen Eigenschaften nicht immer geeignet. Dies liegt an negativen Effekten durch „Verblinden“ des Gewebes und Anhaftungsproblemen.

Beispielanlagen
Schlauchfilter werden bei der Herstellung von Brennstoff aus Abfall eingesetzt. Sie werden auch bei Mischbehältern der Stabilisierungsprozesse zur Produktion von Spraydosen (z.B. zur Entfernung von Staub) und zur Abgasbehandlung in CP-Anlagen eingesetzt.

Literatur
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.6.6 Lamellenabscheider

Beschreibung
In Lamellenabscheidern fließt der Luftstrom durch mehrere parallele Platten, welche hakenförmige Erhebungen besitzen, die den Luftstrom dazu zwingen, seine Richtung zu ändern. Wegen der Trägheit der Partikel werden sie in einer Staubfalle abgeschieden und vom Luftstrom getrennt.

Erreichter Nutzen für die Umwelt
Minderung der Partikelemissionen.

Anwendbarkeit
Lamellenabscheider werden nur zur Abtrennung grober Staubpartikel verwendet.

Literatur
[126, Pretz, et al., 2003]

4.6.7 Adsorption

Beschreibung
In Adsorptionsverfahren wird der Schadstoff aus dem Abgasstrom entfernt und an ein Adsorbens spezifisch adsorbiert. Abgasreinigung durch Adsorption besteht grundsätzlich aus zwei Behandlungsschritten:

a. Schadstoffminderung durch Adsorption und Akkumulation in einem Adsorbens
b. Regeneration des Adsorbens.

Die Schadstoffe des Abgasstroms akkumulieren am Adsorber. Wenn die Beladungskapazität des Adsorbens erreicht ist, werden die adsorbierten Schadstoffe desorbiert, um eine Wiederverwendung des Adsorbens zu ermöglichen. Die Desorption wird normalerweise mittels Heißluftstromes durchgeführt, dessen Volumen bedeutend kleiner ist als der Abgasstrom. Das konzentrierte desorbierte Schadgas wird in einem weiteren Behandlungsschritt entfernt.

Die Adsorption beruht auf dem Prinzip von aktiven Bereichen in einer porösen Matrix. Verschiedene Adsorbentien können hauptsächlich durch ihre Fähigkeit der Adsorption von Wasser unterschieden werden. Folglich können sie in hydrophile und hydrophobe Adsorbentien aufgeteilt werden.

Aktuell wurden Anlagen zur Behandlung von Gasen mit geringem Lösemittelgehalt entwickelt. Diese basieren auf neuen adsorbierenden Materialien, die eine hohe chemische und mechanische Stabilität aufweisen und in der Lage sind, bei niedrigen Temperaturen zu adsorbieren und bei einer festgelegten Temperatur zu desorbieren. Die konzentrierten Lösemittel können dann ohne Zugabe von Brennstoff *in situ* verbrannt werden.

Obwohl Aktivkohle das am meisten verwendete Adsorptionsmaterial ist, gibt es Alternativen wie Silikagel, Aluminiumoxid und Zeolithe. Bei der Abgasbehandlung wird die Adsorption durch einen Aktivkohlefilter durchgeführt. Aktivkohle hat eine große Anzahl sehr kleiner Poren, durch die eine große Oberfläche entsteht. Typische Aktivkohlen haben Oberflächen von 600 bis 1200 m^2/g. Das Abgas kann durch eine Aktivkohlefüllung oder eine Zugabe von Aktivkohle in den Luftstrom mit anschließender Abscheidung durch einen Textilfilter gereinigt werden.

Erreichter Nutzen für die Umwelt
Einige Vorteile dieser Technik sind:

- Anwendbar für ein breites Spektrum von Komponenten
- die benutzte Aktivkohle kann mehrfach regeneriert oder als Brennstoff verwendet werden
- Adsorption an Aktivkohle ist ähnlich wirksam wie die thermische Oxidation, weist aber geringere Risiken für blitzartige Feuerentwicklungen auf, die während des Ladens/Entladens auf Fahrzeuge übergreifen können.

Eigenschaften	Wert
Zuflussbereich im Input (Nm^3/h)	<50000
VOC-Konzentration im Input (g/Nm^3)	<0,5
VOC-Konzentration im Output (mg/Nm^3)	40 – 110
Notwendigkeit einer vorgeschalteten Entstaubung	ja
Risiken	Schnelle Sättigung
Rückstände	
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	25 – 75
Brennstoff/Gas (kWh)	-
Andere Brennstoffe oder Biogas	
Reaktionsmittel (kg)	0,1 – 0,5 g/VOC[29] (für Aktivkohle)
Kosten	
Investitionskosten (EUR/t Kapazität)	10 – 30
Betriebskosten (EUR/t erzeugten Brennstoffs aus Abfall) Elektrizität Brennstoff/Gas Andere	 1,65 1 – 3 0
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	0,5

Tabelle 4.47: Technisch-ökonomische Daten für die Adsorption
[122, Eucopro, 2003]

VOC-Emissionen liegen bei der Abscheidung mit Aktivkohle (chlorierte Lösemittel) bei 8 – 32 mg/Nm^3 oder bei 215 kg/a, wenn Altöle gereinigt werden

Medienübergreifende Auswirkungen
Begrenzte Leistung wegen unvollständiger Erfassung einiger organischer Moleküle. Kann auch Feuer- und Explosionsrisiken aufweisen. Mit dieser Methode werden organische Verbindungen abgeschieden, aber nicht zerstört. Beladene Aktivkohlefilter benötigen eine weitere Behandlung.

Betriebsdaten
Die Abluftreinigung kann leicht überladen und folglich unwirksam werden. Der Einsatz von Aktivkohle ist wirksam für die Abscheidung der VOCs, die hauptsächlich aus Lagereinrichtungen anfallen. Die Adsorptionskapazität[30] der Aktivkohle hängt von der Art der einzelnen VOCs ab, ist aber auf ein Maximum von 300 g/kg Aktivkohle begrenzt. Folgende Punkte sind zu erwähnen:

- Einfache Bauart
- langfristige Stabilität
- Verträglichkeit bei Konzentrationsspitzen
- Bei einigen (hohen) VOC-Konzentrationen ist die Adsorption exotherm und muss kontrolliert werden, um Brände/Explosionen zu vermeiden.

Die Lebensdauer der Aktivkohle, die zur Abluftreinigung aus der Lagerung in Altölbehandlungsanlagen eingesetzt wird, wird als lang eingeschätzt. Dies ist so, weil bei dieser Anwendung eher Atmungs- als Verdrängungsverluste auftreten.

Wenn ein Aktivkohlefilter eingesetzt wird, muss die Abluft zuerst von Staub gereinigt werden, da der Staub zu Verstopfungen und zu einem ansteigenden Druckgradienten führen kann.

[29] Anm.d.Übers.: Der Originaltext nennt als Einheit „g/VOC“ was hier übernommen wurde.
[30] Anm.d.Übers.: Originaltext: „Absorption“

Die Beladungskapazität der Adsorbentien wird durch eine Anzahl von Faktoren beeinflusst:

- physikalisch-chemische Eigenschaften der Stoffe, die adsorbiert werden sollen (insbesondere Siedepunkt)
- Konzentration des Stoffs
- konkurrierende Adsorption von anderen Stoffen
- Co-Adsorption von Wasser
- Adsorptionstemperatur
- Porenstruktur und Größe der inneren Oberflächen des Adsorbens.

Anwendbarkeit
Die Adsorption an Aktivkohle wird zur Minderung von VOC, Geruch und von flüchtigen Emissionen eingesetzt. Sie wird häufig als Abluftreinigungstechnik für lokale Absaugungsstellen, z.B. an Sammel- und Probenahmestellen, verwendet. Es muss versucht werden zu vermeiden, dass der Luftstrom feucht wird, da übliche Adsorbentien wegen ihrer polaren Natur vorzugsweise Wasserdampf adsorbieren. Aus diesem Grund ist die Adsorption an Aktivkohle nicht zur Minderung von Emissionen aus einem Heizkessel zur Wiederaufbereitung von Öl geeignet.

Es gibt verschiedene Anwendungen für Aktivkohle, zum Beispiel wird Aktivkohle zur Entfernung von in Spuren vorliegenden organischen Verunreinigungen aus Flüssigkeits- und Dampfströmen verwendet.

Adsorptionsverfahren mit Aktivkohle werden oft bei der Absaugung von Bodendämpfen verwendet, aber die Implementierung kann kostspielig sein und sie ist grundsätzlich für Gasströme hoher Feuchtigkeit nicht akzeptabel. Sie sind auch üblich bei der Behandlung von Emissionen aus der Bodenwäsche, Lösemittelextraktion von Boden, von Bodenspülungen, Sprühdosenbehandlung, aus biologischen Behandlungsanlagen und C-P-Anlagen (z.B. zur Adsorption der flüchtigen Bestandteile).

Die Adsorption an Aktivkohle ist nicht geeignet für hohe Konzentrationen oder kleine Moleküle oder bei Anwesenheit von Staub. Auch kann die Adsorption an Aktivkohle an manche Moleküle nicht angepasst werden, z.B. Aceton.

Wirtschaftlichkeit
Folgende Punkte sind zu erwähnen:

- niedrige Betriebskosten bei niedrigen VOC-Konzentrationen
- zusätzliche Kosten für die Erneuerung der Aktivkohle.

Die beiden folgenden Tabellen (Tabelle 4.48 und Tabelle 4.49) zeigen Daten zu den Kosten der Adsorption.

Behandlung	**Maximaler Durchfluss (Nm^3/h)**	**Investitionskosten (USD)**
Adsorption an Aktivkohle (regenerativ)	170	20000[a]
	400	24000[a]
	800	33000[a]
	1770	12000[b]
Aktivkohlebehälter	160	700
	800	8000[c]
	1600	6000
	6400	23000[c]
	160	50000
[a] Einschließlich Gebläse, Entfeuchter, Kontrolleinrichtungen, Messgeräte, Ventile und Durchflussmesser [b] Einschließlich Gebläse, flexible Anschlussteile und Dämpfer [c] Tiefbettfilter		

Tabelle 4.48: Investitionskosten zur Emissionskontrolle für VOC aus Bodenluftabsaugungsverfahren [30, Eklund, et al., 1997]

Technische Beschreibung		
Kapazität	10000 t/a	
Ölarten	Gebrauchte Schmieröle	
Betriebsführung	Charge	
Abgasfluss	0 – 50 Nm^3/h	
Alter der Anlage	10 Jahre alt	
Alter der Abluftreinigung	2 Jahre alt	
Mögliche Techniken zur Emissionskontrolle	**Investitionskosten**	**Betriebskosten (GBP)**
Aktivkohlefässer *	Niedrig	1100
*Voraussetzung: Drei 60 kg-Fässer am Standort, die dreimal pro Jahr ersetzt werden müssen.		

Tabelle 4.49: Kosten der Emissionskontrolle für eine typische Ölrecyclinganlage [42, UK, 1995]

Beispielanlagen

Herstellung von Brennstoff aus gefährlichen Abfällen. Betriebserfahrungen aus biologischen Behandlungsanlagen (MBA) liegen zurzeit nicht vor.

Literatur

[30, Eklund, et al., 1997], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

4.6.8 Kondensation

Beschreibung

VOCs können durch Kondensation mit flüssigem Stickstoff oder anderen Kühlmitteln (z.B. Kühlwasser) entfernt werden. Der Kondensator ist ein Behälter, in dem ein Wärmetauscher installiert ist, an dem Gas gekühlt wird, um in die flüssige Phase überzugehen (d.h. zu kondensieren). VOC-Rückgewinnung wird mittels kryogener Kondensation, bei der Stickstoff eingesetzt wird, ermöglicht, indem das Lösemittel kondensiert (bei -130 ºC). Weitere Informationen zu diesem Thema befinden sich in den BVT-Merkblättern über organische Grundchemikalien und über Abwasser- und Abgasbehandlung.

Erreichter Nutzen für die Umwelt

Die kondensierten VOCs können verwertet werden. VOC-Emissionen in Höhe von 10 bis 50 g/h sind erreichbar. Wirkungsgrade von 99,3 % können erzielt werden. Chloroformemissionen können auf die niedrige Konzentration von 20 mg/Nm^3 gesenkt werden. Stickstoff ist für andere Zwecke in der Anlage wiederverwendbar.

Eigenschaften	Wert
Zuflussbereich im Input (Nm^3/h)	<100
VOC-Konzentration im Input (g/Nm^3)	2 – 500
Wirkungsgrad (%)	>95
Notwendigkeit einer vorgeschalteten Entstaubung	nein
Reststoffe	keine
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	25
Brennstoff/Gas (kWh)	-
Andere Brennstoffe oder Biogas	
Reaktionsmittel (kg)	Stickstoff
Kosten	
Investitionskosten (EUR/t Kapazität)	20 bis 60
Betriebskosten (EUR/t erzeugten Brennstoffs aus Abfall)	2 bis 6
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	<0,5

Tabelle 4.50: Daten zur Kondensation mit flüssigem Stickstoff [122, Eucopro, 2003]

Medienübergreifende Auswirkungen
Verbrauch von Stickstoff und Elektrizität. Eine direkte Ableitung von Stickstoff, der mit anderen Verbindungen verunreinigt ist, kann auftreten.

Betriebsdaten
Empfindlich bei der Anwesenheit von Wasser. Die Anwesenheit von Wasserdampf in der Luft kann die Anlage blockieren, denn der Wasserdampf gefriert, was zum Gefrieren oder Vereisen der Durchflusssysteme führen kann. Eine Abtauperiode ist dann erforderlich. Der Stickstoffverbrauch liegt bei 18 kg/Mg verwerteter Lösemittel. Die Sicherheitsrisiken sind zu eliminieren. Die Kontrolle von Temperatur und Druck ist einfach.

Anwendbarkeit
Angewendet in Fällen, in denen nur relativ kleine Volumen oder Durchflüsse behandelt werden müssen, wenn flüssiger Stickstoff zur Verfügung steht und die VOC-Konzentration sehr hoch ist. Diese Technologie ist für stabile Abgasvolumina und -zusammensetzungen verfügbar. Zu den Anwendungen gehört in der Regel die Behandlung der Emissionen aus Heizbehältern zur Wiederaufarbeitung von Öl, welche auch eine Verwertung der Ölbestandteile einbezieht. Die Kondensation kann als Vorbehandlung für die thermische Oxidation angewendet werden, was die Anforderungen an den Brennstoff und die erforderliche Gesamtgröße der Oxidationsanlage senkt. Anwendbar bei Durchflüssen von 50 - 100 Nm^3/h und Beladungen von 1 bis 10 kg/h. Es ist für bestehende Anlagen leicht anwendbar und lässt sich sehr flexibel an Veränderungen in Durchfluss und Konzentration adaptieren.

In C-P-Anlagen werden die flüchtigen Bestandteile gekühlt und für ihre Behandlung kondensiert.

Wirtschaftlichkeit
In der Regel hohe Betriebskosten. Betriebskosten von 2 EUR/Mg behandelter Lösemittel für einen Kondensator mit flüssigem Stickstoff.

Technische Beschreibung		
Kapazität	10000 Mg/a	
Ölarten	Gebrauchte Schmieröle	
Betriebsführung	Batch	
Abgasfluss	0 – 50 Nm^3/h	
Alter der Anlage	10 Jahre alt	
Alter der Abluftreinigung	2 Jahre alt	
Mögliche Kontrolltechniken	**Investitionskosten (GBP)**	**Betriebskosten (GBP)**
Kühlaggregat mit Glykol	30000	8000

Tabelle 4.51: Kosten der Emissionskontrolle für eine typische Ölrecyclinganlage [42, UK, 1995]

Treibende Kraft für die Anwendung
Sicherheitsvorschriften.

Beispielanlagen
Herstellung von Brennstoff aus gefährlichem Abfall und Rückgewinnung von Lösemitteln. In einer Beispielanlage zur Re-Raffination von Altöl nutzen die Dehydrierungs- sowie die Einheiten zum Entfernen von Brennstoffen luftgekühlte, kondensierende Wärmetauscher zur Rückgewinnung von Dampf. Zur Rückgewinnung von Dampf aus der Vakuumdestillation werden Öl- und Kühlwasserkondensatoren verwendet. Dampf und nicht kondensierbare Ströme werden dann dem Heizaggregat zugeleitet, um möglicherweise vorhandene organische Stoffe und geruchsintensive Stoffe zu zerstören. Es existieren mindestens acht Anlagen in der EU.

Literatur
[42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.6.9 Kurzzeit- und Langzeitschäume

Beschreibung
Mindestens sechs Arten von Schaumerzeugnissen stehen zur Verfügung. Die Schäume unterscheiden sich in ihrer Verträglichkeit und Effektivität für verschiedene Schadstoffklassen. Eine spezialisierte Ausrüstung steht zur Anwendung von Schäumen auf großen Flächen zur Verfügung. Der Schaum wird bis zu einer Tiefe von 15 – 76 cm, bei Bedeckungsraten von bis zu 100 m2/min, aufgebracht. Das flüssige Schaumkonzentrat wird durch eine Luft ansaugende Düse oder Rinne aufgebracht. Der Grad der Expansion (d. h. die Anzahl der aus einem Liter flüssigem Konzentrat erzeugten Liter Schaum) kann als hoch (250:1), niedrig (20:1) oder mittel eingestuft werden.

Zwei Arten von Schaum werden verwendet: Kurzzeit- oder Langzeitschäume. Kurzzeitschäume bieten eine Bedeckung für bis zu eine Stunde; in dieser Zeit werden mindestens 25 % der im Schaum beinhalteten Flüssigkeit freigesetzt. Langzeitschäume enthalten ein stabilisierendes Additiv, um die Nutzungsdauer des Schaums auf Tage oder sogar Wochen auszudehnen.

Erreichter Nutzen für die Umwelt
Minderung der VOC-Emissionen. Die Wirksamkeit der Schäume ist für die bedeckten Flächen sehr hoch. Kurzfristige Emissionsminderungen um 75 bis 95 % für Gesamtparaffin und Gesamtaromaten wurden in der Praxis jeweils über eine Zeitdauer von 20 Minuten gemessen. Beim Einsatz von stabilisierten Schäumen wurden in der Praxis Emissionsminderungen um 99 bis 100 % für Gesamt-VOCs über eine Zeitdauer von 24 Stunden gemessen.

Die beiden wichtigsten Vorteile von Schäumen sind, dass sie hochwirksam sein können und direkt auf Baggerschaufeln und den exponierten kontaminierten Boden aufgebracht werden können.

Medienübergreifende Auswirkungen
Es gibt verschiedene Nachteile von Schäumen, die zu berücksichtigen sind. Die dicken Schichten von Schaum, die zur Emissionskontrolle erforderlich sind, können wirksamer auf horizontale Oberflächen als auf vertikale Oberflächen wie etwa die Seiten einer Auskofferungsgrube aufgebracht werden. Eine unvollständige Bedeckung der emittierenden Oberflächen senkt den Wirkungsgrad der Kontrolle merklich. Da Schaumkonzentrate normalerweise zu über 90 % aus Wasser bestehen, erhöht die Zugabe des Wassers zum Boden das Gewicht des Bodens, womit er schwieriger zu behandeln ist und macht ihn weniger zugänglich für eine thermische Behandlung. Die Aufbringung des Schaums ist an windigen Tagen schwierig und bei besonderen Wetterlagen kann eine häufige Anwendung oder Wieder-Anwendung des Schaums erforderlich sein.

Anwendbarkeit
Modifizierte Feuerlöschschäume werden häufig benutzt, um VOC-Emissionen zu kontrollieren, die bei der Sanierung von Standorten mit gefährlichen Abfällen, die flüchtige giftige Verbindungen beinhalten, entstehen.

Literatur
[30, Eklund, et al., 1997]

4.6.10 Biofilter

Beschreibung
“Biofilter” ist der allgemeine Begriff, der alle biologischen Oxidationsverfahren umfasst, die in einem „gepackten System“ stattfinden. Dazu gehören konventionelle Tropfkörper, Biowäscher (Mikrobenpopulation in Waschflüssigkeit) oder das Filterbett (gepacktes System unter Verwendung von Boden, Torf und Rinde).

Der Biofilter besteht aus einer Vorrichtung, die mit abbaubarem Material wie Kompost, Rinde oder einer Mischung von Torf und Heidekraut usw. gefüllt ist. Mikroorganismen (Pilze, Bakterien, Viren und Algen) sind auf dem Material angesiedelt. Während die Abluft durch das Material strömt, zersetzen die Mikroorganismen die schädlichen Stoffe. Wasser und Luftstrom werden normalerweise im Gegenstrom geleitet. Ein Biofilter ist kein Filter im mechanischen Sinne (d.h. er führt nicht zu einer Separierung von Partikeln), sondern ein Reaktor, in dem ein bestimmter Bereich an schädlichen Stoffen in weniger schädliche Stoffe metabolisiert wird. Tabelle 4.52 gibt einen Überblick über die erwünschten Eigenschaften eines Biofilters.

Eigenschaft	Beschreibung
Filtermedium	Biologisch aktiv, aber ziemlich stabil
	Organikgehalt >60 %
	Porös und krümelig mit 75 – 90 % Hohlraum
	Beständig gegenüber Vernässung und Verdichtung
	Relativ geringer Feinstoffgehalt zur Senkung des Druckabfalls
	Relativ frei von Restgeruch
	Speziell zusammengestellte Materialmischungen können erwünscht sein, um die oben angegebenen Eigenschaften zu erreichen
Feuchtigkeitsgehalt	50 – 80 Gew.-%
	Vorkehrungen zur Zugabe von Wasser und zur Entfernung des Wassers aus der Entwässerung des Filterbetts müssen getroffen werden
Nährstoffe	Müssen in angemessenem Ausmaß vorhanden sein, um Begrenzungen zu vermeiden
	Normalerweise kein Problem bei Gasen aus aerobem Abbau wegen des hohen NH_3–Gehalts
pH-Wert	7 bis 8,5
Temperatur	Nahe der Umgebungstemperatur, 15 – 35 oder 40 °C
Gasvorbehandlung	Eine Befeuchtung könnte sich als nützlich erweisen, um nahezu 100 % Feuchtigkeit im einströmenden Gas zu erreichen
	Staub und Aerosole können entfernt werden, um ein Verstopfen der Filtermedien zu vermeiden, doch für die meisten Biofilter ist dies kein Problem (wenn sie nicht im Boden eine Gewebeschicht haben)
Abgasbeladungsrate	<100 $m^3/h\text{-}m^3$, wenn nicht die Ergebnisse von Tests höhere Beladungen unterstützen
Verweilzeit des Gases	30 - 60 Sekunden, wenn nicht die Ergebnisse von Tests eine kürzere Verweilzeit unterstützen
Tiefe des Filtermediums	>1m, <2 m
Abscheidekapazität	Abhängig von Medium und Verbindung (in der Regel im Bereich von 10 – 160 g $m^{-3}h^{-1}$)
Verteilung des Gases	Der Verteiler muss richtig ausgelegt sein, um einen gleichförmigen Gasfluss zu den Filtermedien sicherzustellen

Tabelle 4.52: Eigenschaften von Biofiltermedien
[59, Hogg, et al., 2002]

Im Gegensatz zum Biofilter sind in Biowäschern die Mikroorganismen nicht an organische Materialien fixiert. Die Biomasse schwimmt quasi frei in der Suspension, die im Gegenstrom in das Abgas gesprüht wird. Die prinzipiellen Unterschiede sind, dass die Absorption der schädlichen Stoffe lokal ist und vom Metabolismus separiert stattfindet.

In einer Spraydosenbehandlungsanlage wird die Abluft verschiedener Betriebsbereiche mit Hilfe von Ventilatoren durch eine luftdurchlässige Filterschicht geleitet. Während die Luft durch die Filterschicht fließt, werden die abbaubaren Bestandteile durch Mikroorganismen, die auf dem Filter lokalisiert sind, zersetzt. Um sicherzustellen, dass die Filterschicht luftdurchlässig bleibt, was entscheidend für die Versorgung der Mikroorganismen mit Luftsauerstoff ist, wird die Abluft vorher gereinigt, so dass Feststoffe (Stäube) entfernt werden. Gleichzeitig wird mittels der Reinigung das Abgas befeuchtet, was notwendig ist, um einem Austrocknen der Filterschicht vorzubeugen. Der Biofilter stellt folglich einen aeroben Festbettreaktor für die biochemische Zersetzung organischer Stoffe dar. Ein Biofilter z.B. mit einer Oberfläche von 1800 m^2 kann einen Abgasstrom von ungefähr 200 000 m^3/h behandeln, was zu einer spezifischen Filterbeladungsfläche von 111 $m^3/m^2/h$ führt. Unter dem Biofilter befinden sich Einspeisebereiche, die von den verschiedenen Behandlungsanlagen benutzt werden (Vorrichtung für Behandlung und Auslass). Dieser Bereich ist als Sammelschacht konstruiert. Außerdem ist eine stationäre Löscheinrichtung mit Schaum vorhanden.

Erreichter Nutzen für die Umwelt
Reduziert Gerüche und VOC-Emissionen aus natürlichen Verbindungen und aus der Synthese anorganischer Verbindungen (z.B. H_2S und NH_3), aromatischer und aliphatischer Verbindungen (z.B. Säuren, Alkohole, Kohlenwasserstoffe). Andere Verbindungen, die abgebaut werden können, sind nicht chlorierte Lösemittel, Mercaptane, Amine, Amide, Aldehyde und Ketone. Die Behandlungskapazität liegt, abhängig von der Art des Schadstoffs, zwischen 50 und 150 $Nm^3/h/m^2$.

Stoff (Gruppe)	Input-Konzentration (mg/Nm^3)	Output- Konzentration (mg/Nm^3)	Wirkungsgrad des Biofilters (%)
Aldehyde, Alkane			75
Alkohole			90
AOX, aromatische Kohlenwasserstoffe (Benzol)			40
Aromatische Kohlenwasserstoffe (Toluol, Xylol)			80
NMVOC			83
PCDD/F			40
Geruch			95 – 99
NMVOC (Werte als Gesamtkohlenstoff)	30 – 70	10 – 40	80

Tabelle 4.53: Wirksamkeit von Biofiltern bei der Behandlung von MBA-Abgas [81, VDI and Dechema, 2002]

Die Abscheideeffizienz eines Biofilters wird durch die Verweilzeit des Gases im Filtermedium bestimmt. Effektive Verweilzeiten liegen bei den meisten Anwendungen des aeroben Abbaus im Bereich von 30 bis 60 Sekunden. In Studien wurde über hohe Abscheideeffizienzen für bestimmte Verbindungen berichtet, wie für H_2S (>99 %), Methylmercaptan, Dimethyldisulfid, Dimethylsulfid (>90 %) und verschiedene Terpene (>98 %).

Zu den Umweltvorteilen gehören der geringe Energiebedarf und die Vermeidung eines potenziellen Schadstofftransfers in andere Medien. Messungen bei der praktischen Anwendung von Biofiltern in chemisch-physikalischen Behandlungsanlagen zeigten Abbauergebnisse von ca. 95 bis 98 % der organische Lösemittel, dies bei Konzentrationen in der zu reinigenden Abluft von 400 bis 1600 mg/Nm^3.

In biologischen Behandlungsanlagen werden übelriechende Gase über einen Gaswäscher geleitet (z.B. sauren nassen Gaswäscher), der den Ammoniakgehalt auf eine für den Biofilter akzeptable Konzentration senkt. Der Biofilter entfernt dann Gerüche und den verbleibenden Ammoniak. Der Filterungsvorgang erzeugt keine umweltschädlichen Verbindungen, und nach Nutzung kann der Filter durch Kompostierung behandelt werden, und zusätzlicher Abfall wird nicht erzeugt. Die Konzentrationen von Ammoniak und Gerüchen liegen nach der Behandlung entsprechend bei <1 mg/m^3 und bei 1000 – 6000 GE/m^3 (90 % Minderung).

Tabelle 4.54 und Tabelle 4.55 zeigen die Wirksamkeit von in MBA eingesetzten Biofiltern.

Parameter	Konzentration ($\mu g/m^3$) min – max	Wirkungsgrad (%) min – max	Konzentration ($\mu g/m^3$) min – max	Wirkungsgrad (%) min – max	Konzentration ($\mu g/m^3$) min – max	Wirkungsgrad (%) min – max
Acetaldeyd	2100 – 2500	78 – 89	46 – 740	89 – 96	4900 – 6100	99
n-Butylacetat	150 – 425	97 – 99	30 – 120	83 – 96	170 – 980	73 – 99
Ethylbenzol	250 – 310	12 – 42	60 – 190	27 – 61	250 – 740	16 – 43
2-Ethyltoluol	180 – 220	33 – 41	25 – 105	14 – 89	80 – 270	25 – 55
3,4-Ethyltoluol	480 – 640	23 – 45	70 – 260	38 – 96	230 – 1000	48 – 77
Limonene	1700 – 4300	29 – 40	810 – 2200	94 – 98	1300 – 3700	30 – 63
Toluol	490 – 550	16 – 39	130 – 280		460 – 1000	7 – 36
m/p-Xylol	850 – 1400	9 – 42	280 – 620	30 – 71	720 – 2000	19 – 45
o-Xylol	260 – 290	23 – 41	60 – 150	7 – 63	160 – 650	20 – 45
Aceton	2450 – 2900	99 – 100	1200 – 2800	99 – 100	4700 – 8200	93 – 97
2-Butanon	960 – 2800	99 – 100	80 – 770	94 – 99	370 – 11000	95 – 100
Ethanol	5200 – 5300	100	88 – 750	94 – 99	14000 – 18000	100
α-Pinen	370 – 700	8 – 44	280 – 790	53 – 83	560 – 930	5 – 39
β-Pinen	330 – 800	12 – 44	120 – 300	53 – 81	230 – 490	38 – 49

Tabelle 4.54: Konzentrationsbereiche für einige Abluftparameter in MBA, aus denen die Abscheidewirkung für diese Verbindungen hervorgeht [132, UBA, 2003], [150, TWG, 2004]

Biologische Abluftreinigungsverfahren sind nur in begrenztem Ausmaß in der Lage, die Abluft-/Abgasbestandteile aus Siedlungsabfallbehandlungsanlagen zu reduzieren (in der Regel bei NMVOC-Gehalten von über 300 g/Mg Abfall). Tabelle 4.55 zeigt einige Messergebnisse für gut gewartete Biofilter mit vorgeschalteten Luftbefeuchtern.

Verbindungen in der Abluft	Abscheideeffizienz (%)		
	Anlage A	Anlage B	Anlage C
Acetaldehyd	-18 bis -99	99	99
n-Butylacetat	83 – 96	73 – 99	97 – 99
Kampher	60 – 88	60 – 90	88 – 91
Dichlormethan	-53 bis -80	-300 bis -33	43 – 62
Dimethyldisulfid	44 – 78	-55 bis -89	10 – 31
2-Hexanon	75 – 80	-	80 – 82
Naphthalin	50 – 75	38 – 93	58 – 82
Phenol	-25 bis - 79	75 – 88	47 – 94
1,4-Dichlorbenzol	0 – 73	-1900 bis -89	-130 bis -13
Ethylbenzol	27 – 61	16 – 43	12 – 42
2-Ethyltoluol	14 – 89	25 – 55	33 – 41
3/4-Ethyltoluol	38 – 96	45 – 77	23 – 45
Limonene	94 – 98	30 – 63	29 – 40
Styrol	64 – 89	44 – 66	21 – 50
Toluol	29 – 50	7 – 36	16 – 39
m/p-Xylol	30 – 71	19 – 45	9 – 42
o-Xylol	7 – 63	20 – 45	23 – 41
Aceton	99 – 100	93 – 97	94 – 97
2-Butanon	94 – 99	95 – 100	99 – 100
Ethanol	94 – 99	100	100
Ethylacetat	74 – 93	82	97 – 99
α-Pinen	59 – 83	5 – 39	8 – 44
β- Pinen	53 – 81	38 – 49	12 – 44
Benzol	0 – 17	-	0 – 20
Trichlorethen	-108 bis -3	67 – 90	20 – 46
Kombinationen von Luftbefeuchtern und Biofiltern können unterschiedliche Reinigungsleistungen für organische Stoffe der ersten und zweiten Gruppe aufweisen.			

Tabelle 4.55: Abscheideeffizienz für organische Verbindungen im Biofilter [132, UBA, 2003]

Tabelle 4.56 fasst aktuelle Messergebnisse für den Biofilter einer Spraydosenbehandlungsanlage zusammen. Anzumerken ist, dass andere Teile des Abgases aus dem Behandlungsverfahren durch die betriebseigene Hochtemperaturverbrennungsanlage behandelt werden.

Bestandteil	Durchschnittskonzentration im Rohgas	Durchschnittskonzentration im gereinigten Gas
Gesamt-Kohlenstoff (FID)	206	49
CKW/FCKW	9,69	8,17
Benzol	1,07	0,35
Aromatische Verbindungen	35,4	8,07
Ester, Alkohole	80.8	0.57
Ergebnisse von 2003 und Daten in mg/m^3		

Tabelle 4.56: Rohgas und durch einen Biofilter behandeltes Gas in einer Spraydosenbehandlungsanlage [157, UBA, 2004]

Medienübergreifende Auswirkungen
N_2O- und NO-Emissionen sind in der Regel erhöht. Allerdings wurde demonstriert, dass mittels Einsatz einer sauren Gaswäsche zur Ammoniakentfernung (NH_3) vor der Biofiltration potenzielle N_2O- und NO-Emissionen reduziert werden können. Methan wird weder biologisch abgebaut noch durch den Biofilter erzeugt. Terpene werden durch den Biofilter selbst erzeugt und entstehen beim Abbau holzhaltiger Materialien im Biofiltermedium. In einigen Referenzen wird die Frage gestellt, ob Biofilter wirklich VOCs reduzieren, weil sie geltend machen, dass VOCs sogar durch den Biofilter selbst erzeugt werden.

Der Abbaugrad ist bei untersuchten Biofiltern in MBA für einzelne Verbindungen nicht so hoch wie bei einigen spezifischen Anwendungen in der Industrie (80 % oder >90 %). Für Nicht-Methan-TOC (NMTOC) erreichen sie im Durchschnitt einen Wirkungsgrad von nur 40 – 70 %. Für Methan liegt die Effizienz nahe bei 0 %. Die Abbaueffizienz für einzelne Verbindungen im Abgas von MBA zeigt gute Werte für NMTOC (z.B. Aceton, Acetaldehyd, Limonen und Ethanol), mäßige Werte für BTEX und keine Reduktion von FCKW.

Die teilweise niedrige Abbaueffizienz von NH_3, die ebenso mit einer potenziellen Hemmung des Kohlenstoffabbaus einhergeht, kann mittels Einsatz einer sauren Gaswäsche, anstelle einer neutralen Gaswäsche, verbessert werden (z.B. mit Schwefelsäure zur Absorption von Ammoniak). Die NH_3–Emissionen werden nicht nur wegen ihrer Geruchsintensivität minimiert, sondern auch, weil enge C/N-Verhältnisse in der Abluft der MBA zur Bildung von NO und N_2O im Biofilter führen können.

Betriebsdaten
Biofilter bestehen in der Regel aus einem Meter dickem porösem Material. Das im Biofilter verwendete Material ist normalerweise eine Mischung aus biogenem Kompost, der in der Regel über einer Konstruktion aufgehäuft wird. Diese Anlagen sind sehr einfach zu bauen und zu warten. Eine hohe Porosität (80 – 90 %), Feuchtigkeit (60 – 70 %), pH-Wert, Temperatur und Kontaktzeit mit den Nährstoffen müssen überwacht werden, damit der Biofilter eine gute Leistung erbringt. Die Feuchtigkeit im Biofilter kann mittels eines spezifischen Wassersystems oder durch Befeuchtung des Abgases, bevor es durch den Biofilter geleitet wird, aufrechterhalten werden.

Die Entfernung von NMVOC mit Biofiltern hängt stark von der Temperatur (z.B. den Wetterbedingungen) ab, die die Effizienz des Biofilters mindern kann.
In manchen Fällen ist es möglich, dass die im Biofiltermedium eingesetzten Materialien nicht alle Anforderungen der Mikroorganismen an essentiellen Nährstoffen für eine längere Zeit erfüllen können. In diesen Fällen kann die Bereitstellung zusätzlicher Nährstoffe die Effizienz des Biofilters bedeutend erhöhen.

Der Druckverlust liegt bei weniger als 50 mm H_2O. Die Oberflächenbeladung der Biofilter pro Flächeneinheit sollte ca. 80 Nm^3/m^2 x h nicht überschreiten.

Folgende Aspekte sind zu berücksichtigen:

- Die einströmende Luft muss eine relative Feuchtigkeit von >90 % haben (das kann den Einsatz eines Befeuchters erfordern)
- Partikel müssen entfernt werden
- Heiße Gase müssen auf eine optimale Aktivitätstemperatur von aeroben Mikroorganismen abgekühlt werden, die im Allgemeinen bei 25 bis 35 °C liegt und der potenzielle Temperaturanstieg über dem Bett von bis zu 20 °C muss berücksichtigt werden
- Die wichtigsten Betriebsparameter, wie etwa Abgastemperatur sowie Druckverhältnisse, müssen täglich überprüft werden
- Der Feuchtigkeitsgehalt in den Filtern muss regelmäßig überwacht werden
- Ein Alarm für niedrige Temperaturen muss eingebaut werden, um vor einem Gefrieren zu warnen, wodurch der Filter beschädigt und das Wachstum der Mikroben beeinträchtigt werden könnte
- das gepackte Medium muss einen schnellen, gleichmäßigen Luftstrom ohne Druckabsenkungen ermöglichen
- das Medium muss entfernt werden, wenn es Zersetzungserscheinungen aufweist und somit den Luftstrom behindert (Rinde ist weniger resistent als zum Beispiel Heidekraut)
- die Wahl des Mediums sowie der unterstützenden Systeme beeinflusst den Energiebedarf zur Aufrechterhaltung des Luftstroms. Die Energie, die zur Überwindung des Filterbettwiderstands benötigt wird, hat den höchsten Anteil an den Betriebskosten
- Betrachtungen zum Effekt des Biomasseverlusts auf Grund des Eindringens giftiger Verbindungen müssen getroffen werden und für einen solchen Vorfall müssen Maßnahmen bereit stehen.

Selbst im Fall von Optimierungen (Kombinationen mit Biowäschern anstelle einer wässrigen Gaswäsche) können keine niedrigen und verlässlichen Emissionen dauerhaft erreicht werden. Für Geruchsemissionen kann eine starke Minderung erzielt werden (wobei nur der Eigengeruch des Filters zurückbleibt), wenn das Abgas angemessen aufbereitet wird.

Im Fall der Abgasbehandlung aus dem aerobem Abbau von Gärrückstand aus anaeroben Behandlungen ist die Ammoniakkonzentration ziemlich hoch (>30 mg/Nm^3). In diesem Fall muss das Abgas chemisch vorbehandelt werden, bevor es zum Biofilter geleitet wird.

Anwendbarkeit
Biofilter werden für Abgasströme großen Volumens eingesetzt, die niedrige organische Beladungen, aber intensive Gerüche aufweisen. Für eine gute Leistung müssen die Konzentrationen der zu behandelnden Inhaltsstoffe relativ stabil sein. Filterbetten wurden auf Abfallbehandlungsstandorten zur Minderung geruchsintensiver Emissionen installiert. Anwendbar bei allen Arten von Abwasserbehandlungsanlagen.

Biofilter werden zur Abgasbehandlung in Spraydosenbehandlungsanlagen, bei der thermischen Trocknung von Schlamm durch Destillation, in biologischen Behandlungsanlagen (MBA) und C-P-Anlagen eingesetzt. In C-P-Anlagen werden Biofilter zur Adsorption flüchtiger Bestandteile an ein Kompostmaterial und zur biologischen Zersetzung der adsorbierten Komponenten durch Mikroorganismen im Kompostmaterial eingesetzt. Wenn der Biofilter in Gefahr ist auszutrocknen, muss das zu reinigende Abgas befeuchtet werden.

Biofilter sind nur für gering verschmutzte Abgasströme geeignet und werden deshalb nur zur Reinigung der Hallenabluftströme genutzt. Die Abgasreinigung durch Biofilter oder die biologische Reinigung, für Abgase die in Vergärungsanlagen erzeugt wurden, hat sich erwiesenermaßen bewährt.

Wirtschaftlichkeit
Die Biofiltration und Biowäsche hat geringere Betriebskosten als viele andere Abgasreinigungstechniken zur Behandlung von niedrigen Konzentrationen an biologisch abbaubaren organischen Schadstoffen. Biowäscher haben die höheren Wartungskosten von den beiden. Die Behandlung von Gasdurchflüssen von mehr als 1500 Nm^3/h werden als kosteneffizient eingestuft. Investitionskosten für einen Biofilter zur Behandlung von Gerüchen aus einer Abwasserbehandlungsanlage mit einem Durchfluss von 1800 Nm^3/h belaufen sich auf 550 000 EUR.

Eigenschaften	Wert
Zuflussbereich im Input (Nm^3/h)	<100 000
VOC-Konzentration im Input (g/Nm^3)	<1
Wirkungsgrad (%)	<90 %
Notwendigkeit einer vorgeschalteten Entstaubung	Nein
Risiken	Zerstörung der Mikroorganismen
Reststoffe	Ja
Verbrauch (pro erzeugter Tonne Brennstoff aus Abfall)	
Elektrizität (kWh)	15
Brennstoff/Gas (kWh)	-
Alternativer Brennstoff oder Biogas	
Reaktionsmittel (kg)	Rinden
Kosten	
Investitionskosten (EUR/t Kapazität)	10 bis 20
Betriebskosten (EUR/t erzeugten Brennstoffs aus Abfall)	<1
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	<0,25

Tabelle 4.57: Verbrauchszahlen und Kosten von Biofiltern
[122, Eucopro, 2003]

Treibende Kraft für die Anwendung
Reduzierung von Geruchsemissionen. Die deutsche und die österreichische Regierung haben für MBA Grenzwerte für Geruchsemissionen in Höhe von 500 GE/Nm³ sowie für VOC festgelegt (Österreich: 100 g/Mg behandelten Abfalls, Deutschland: 55 g/Mg behandelten Abfalls). Darüber hinaus können solche Anlagen nicht die Emissionsgrenzwerte für TOC einhalten, die von einigen deutschen Vorschriften verlangt werden (z.B. weniger als 55g TOC pro Tonne MBA-Input und eine TOC-Konzentration von weniger als 20 mg/Nm^3).

Beispielanlagen
In der Branche weit verbreitet. Eingesetzt zur Behandlung von Abgasen aus biologischen Behandlungsanlagen, aus der chemisch-physikalischen Behandlung von Abwässern und aus der Immobilisierung. Das Verfahren wird auch in anderen Industriesektoren genutzt, etwa in der chemischen Industrie, der Eisen- und Stahlindustrie, der Lebensmittelindustrie und in Abwasserbehandlungsanlagen. In der EU gibt es viele Beispiele für die Verwendung von Biofiltern.

Literatur
[52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [66, TWG, 2003], [81, VDI and Dechema, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [135, UBA, 2003], [150, TWG, 2004], [157, UBA, 2004]

4.6.11 Abgaswäsche

Beschreibung
Absorptionstechniken werden in der Regel Gaswäscher genannt. Zu den Techniken gehören:

a. Vorhandensein eines Gaswäschersystems für die wichtigsten anorganischen gasförmigen Emissionen (z.B. Cl_2, ClCN, HCl, H_2S, NH_3, NO_x), organischen Verbindungen (z.B. VOC) und für Gerüche aus Betriebseinheiten, in denen bestimmte Abfallarten behandelt werden (die diese flüchtigen Verbindungen enthalten), welche eine punktuelle Ableitung für die Emissionen aus dem Verfahren besitzen. Bei stark schwankenden Emissionen kann der Einbau einer sekundären Gaswäscheranlage in bestimmten Vorbehandlungsanlagen eine Lösung darstellen, wenn der Durchfluss inkompatibel oder zu konzentriert für die Haupt-Gaswäscher ist
b. richtiger Betrieb und richtige Wartung der Abluftreinigungsanlagen, einschließlich der Handhabung und der Beseitigung von verbrauchten Waschhilfsmitteln.

Die Wassereindüsung ist eine übliche Methode zur Kontrolle der Partikelemissionen. Die Zugabe von staubbindenden Chemikalien wie Polymeren oder Acrylen zum Wasser erhöht die Wirksamkeit des Sprühens.

Erreichter Nutzen für die Umwelt
Emissionsminderung von VOC, Säuren, Ammoniak, Partikel usw. Erhöht die Effizienz der Absorption von Schadstoffen, infolge des Kontakts zwischen Partikel und Gas (insbesondere relevant bei der Entfernung von sauren Gasen durch basische Partikel, die im Gaswäscher eingespritzt werden).

Medienübergreifende Auswirkungen
Diese Technik erzeugt Abwässer und Schlamm, die eine weitere Behandlung benötigen.

Nasse Gaswäscher erzeugen eine Dampfschwade. Freisetzungen aus der Entlüftung von nassen Gaswäschern müssen heiß genug sein, damit keine sichtbaren Abgasfahnen in der Nähe der Entlüftung entstehen. Dies soll die Kondensation oder Adsorption von umweltschädlichen Stoffen durch den kondensierenden Wasserdampf verhindern. Abgase aus einem nassen Gaswäscher können unter Nutzung von Abwärme erhitzt werden, um die Temperatur der Abgase zu erhöhen und eine sofortige Kondensation am Auslass der Entlüftung zu verhindern. Diese Vorgehensweise ist auch hilfreich für den thermischen Auftrieb der Abgasfahne.

Betriebsdaten
Normalerweise wird in einem bestimmten Umfang eine Überwachung der Abluft durchgeführt, entweder am Auslass des Gaswäschers oder an der Grundstücksgrenze. In der Regel ist die Überwachung der Abgase aus dem Gaswäscher/Filtersystem diskontinuierlich. Voraussetzung ist, dass die Abluftreinigungsanlagen für diesen Zweck geeignet sind und die Emissionen auf eine akzeptable Grundbelastung reduzieren. Austrittsstellen können vierteljährlich oder monatlich auf diejenigen sauren Gase überwacht werden, die voraussichtlich abgeschieden werden sollen.

Eine Wasserversorgung und Abwasserbeseitigungsanlagen müssen zur Verfügung stehen. Zu den Überwachungsmaßnahmen gehören:

- pH-Wert, Durchfluss und Füllstand der Waschflüssigkeiten, Druckabsenkung im Gaswäscher
- Überwachung der Druckabsenkung mit Alarmvorrichtungen
- periodische Überwachung der Auslasskonzentrationen unter verschiedenen Betriebsbedingungen.

Es muss auch ein Programm zum regelmäßigen Austausch der Absorbentien in den Absorbereinheiten vorhanden sein.

Anwendbarkeit
Geeignet für hohe Durchflüsse bei niedrigen Konzentrationen (z.B. 1 – 200 mg/Nm^3 VOC), Abgasströme mit niedriger Temperatur und chemischen reaktiven Schadstoffen (oder löslichen im Fall von VOC).

Diese Techniken werden in der Regel bei Punktquellenemissionen angewandt, also um diejenigen Emissionen zu behandeln, die aus der Sammlung von Abgas aus Behältern oder Bereichen entstammen und die entweder über eine Abluftreinigungsanlage oder direkt zu einem Schornstein oder einer Entlüftung weitergeleitet werden. Diese Technik kann auch zur Behandlung von Abgasen während der Befüllung von Lagertanks angewandt werden.

Saure Gaswäscher werden eingesetzt, um Ammoniakemissionen abzuscheiden, die während der sauren Behandlung bei der Re-Raffination von Altölen freigesetzt werden. Es werden auch Gaswäscher mit Mineralöl zur Abscheidung von VOCs und Gerüchen in Altölbehandlungsanlagen eingesetzt.

Hypochlorit oder Wasserstoffperoxid können zum Auswaschen von Cyaniden und zur Geruchsminderung verwendet werden. Ein zweistufiges Verfahren kann eingesetzt werden, z.B. ein alkalischer und oxidierender Gaswäscher in Serie. Eine Wasserversorgung sowie Beseitigungsanlagen für das Abwasser müssen zur Verfügung stehen, um diese Anlagen zu betreiben. Es muss ein Programm zum regelmäßigen Austausch des Absorptionsmittels in den Absorbern vorhanden sein.

Alkalisches Kaliumpermanganat oder Hypochlorit können als Oxidationsmittel zur Behandlung von Cyanidverbindungen verwendet werden.

Wirtschaftlichkeit
Die folgende Tabelle 4.58 zeigt eine Zusammenfassung von Kosten der Gaswäsche zur Emissionskontrolle bei Flächenquellen angewendet bei der Auskofferung und Entfernung.

Technik zur Emissionskontrolle	Materialkosten (USD/m^2)	Anmerkungen
Besprühen mit Wasser	0,001 (unterschiedlich)	Unter Voraussetzung von kommunalen Wasserkosten von 1 USD/1000 Liter. Das Wasser muss ständig erneuert werden. Miete für einen Wassertankwagen: 500 USD/Woche.
Additive:		Kosten schwanken je nach verwendeten Chemikalien
Oberflächenaktiver Stoff	0,65	
Salze[31]	2,58	
Bitumen/Haftmittel	0,02	

Tabelle 4.58: Zusammenfassung von Kosten bei der Emissionskontrolle von Flächenquellen bei Anwendung der Auskofferung und Entfernung
[30, Eklund, et al., 1997]

Beispielanlagen
Eine übliche Anwendung für die Behandlung von Luft aus Reaktionsbehältern ist die Nutzung einer Waschflüssigkeit, in der Regel basische Lösungen. Das Verfahren ist in C-P-Anlagen weit verbreitet (z.B. nasse Gaswäsche). Es wird auch als Vorbehandlung, z.B. vor Biofiltern, zur Behandlung von Abgasen aus biologischen Behandlungsanlagen eingesetzt.

Vorbehandlungsverfahren, die zu einer Freisetzung giftiger Gase tendieren, verfügen meistens über eigene Gaswäscher, deren Entlüftung in die betriebliche Haupt-Abgasreinigungsanlage führt und deren wässrige Flüssigkeiten in der Anlage behandelt werden.

Alle in GB bekannten Oxidationsanlagen verfügen über eigene lokale Gaswäscher, und die Reststoffe sowohl aus der Oxidation als auch die Gaswäscher-Lösungen werden in einer Hauptanlage behandelt. Wenn eine Anlage über eine zentrale Abgasreinigungsanlage für den Standort verfügt, wird das Abgas aus den oxidierenden Gaswäschern in der Regel über die zentrale Abgaswäsche geleitet, bevor es in die Luft abgelassen wird.

Die alkalische Gaswäsche wird zum Ausstrippen von Schwefelwasserstoff in Anlagen, in denen Altöl behandelt wird, eingesetzt.

Literatur
[30, Eklund, et al., 1997], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.6.12 Chemische Abgaswäsche

Beschreibung
Bei der chemischen Abgasbehandlung kann es sich um einstufige oder mehrstufige Wäscher handeln, wobei chemische Gaswäscher eingesetzt werden. Bis jetzt sind Anlagen dieser Art z.B. als einstufige oder mehrstufige Wäscher mit Trägermaterial zur Reinigung hergestellt worden, mit pH-Wert Kontrollen bei jedem Schritt oder mit Zugabe von Oxidantien.

Erreichter Nutzen für die Umwelt
Gaswäscher dieser Art sind gut geeignet zur Entfernung von Einzelbestandteile (z.B. Ammoniak).

Medienübergreifende Auswirkungen
Diese Gaswäsche ist erforderlich bei der Reduktion von N-Verbindungen vor der anschließenden Behandlung. Mehrstufige Abgaswäscher (sauer-alkalisch) oder eine Abgaswäsche mit H_2O_2, können auf Grund hoher Rohgaskonzentrationen, die vor allem bei Kreislaufführungen erzeugt werden, nur die Konzentrationen bestimmter Inhaltsstoffe reduzieren (z.B. VOCs).

[31] Anm.d.Übers.: Originaltext: “hygro salt”.

Anwendbarkeit
Stand der Technik in biologischen Behandlungsanlagen (MBA) ist eine Kombination von sauren Gaswäschern und thermisch-regenerativer Abgasbehandlung. Die behandelte Abluft wird über einen Schornstein freigesetzt.

Treibende Kraft für die Anwendung
Berichten zufolge können Konzentrationen im gereinigten Gas, die durch eine deutsche Rechtsvorschrift gefordert werden, nicht durch diese Verfahren allein erreicht werden.

Beispielanlagen
Zurzeit liegen keine Informationen über den Einsatz der Technik als unabhängiger Behandlungsschritt in biologischen Behandlungsanlagen (MBA) vor. Alle Informationen in diesem Absatz beziehen sich auf Erfahrungen in anderen Anlagenarten.

Literatur
[132, UBA, 2003], [150, TWG, 2004]

4.6.13 Schwach oxidative Verfahren

Beschreibung
Unter den üblichen schwach oxidativen Verfahren befinden sich die Ionisierung und die UV-Verfahren. Diese beruhen auf dem Prinzip, dass mitunter die Adsorption eines einzelnen O- oder OH-Radikals die Geruchseigenschaften eines Stoffs signifikant reduzieren kann.

Erreichter Nutzen für die Umwelt
Die Wirkung schwach oxidativer Verfahren ist sehr stoffgruppenspezifisch und kann durch Anwesenheit bestimmter schädlicher Gase stark beeinträchtigt werden (z.B. Bildung von Aminen in Anwesenheit von Ammoniak).

Medienübergreifende Auswirkungen
Diese Behandlung führt trotz allem nicht zu einem signifikanten Abbau von organisch gebundenem Kohlenstoff. Nach den bis jetzt gewonnenen Erfahrungen, finden oft nur partielle Oxidationen und kein Aufbrechen des Rings der aromatischen Kohlenwasserstoffe statt. Styrole können polymerisiert werden. Die Methankonzentration wird nur leicht gesenkt.

Betriebsdaten
Der spezifische Energiebedarf liegt normalerweise unter 1 kWh/1000 Nm^3 Luft.[32]

Anwendbarkeit
Diese Verfahren werden oft zur Neutralisation von Gerüchen auf verschiedenen Gebieten eingesetzt.

Beispielanlagen
Eingesetzt in biologischen Behandlungsanlagen, jedoch liegen keine Betriebserfahrungen vor.

Literatur
[132, UBA, 2003]

[32] Anm.d.Übers.: Im Originaltext wird hier die Einheit „kW“ aufgeführt.

4.6.14 Verbrennung

Beschreibung
Bei der thermischen Reinigung von Abgasen[33], wird das Abgas in einer Verbrennungskammer bei Temperaturen von bis zu 850 ºC bei einer minimalen Verweilzeit von 2 Sekunden behandelt. Innerhalb des Zeitraums werden die schädlichen Stoffe vollständig oxidiert und das gereinigte Gas kann dann in die Luft abgeleitet werden.

Bei biologischen Behandlungsanlagen, kann die Verbrennung differenziert werden in Nachverbrennung mit oder ohne Wärmerückgewinnung. Wie bei der thermischen Nachverbrennung werden die Kohlenwasserstoffe[34] in der Verbrennungskammer zu Kohlendioxid und Wasser oxidiert.

Erreichter Nutzen für die Umwelt
Das Verfahren wird zur VOC-Kontrolle eingesetzt und erfordert normalerweise die Zugabe von zusätzlichem Brennstoff zur Unterstützung des Verbrennungsprozesses. Der Betreiber kann die Kosten des Zusatzbrennstoffs ausgleichen, wenn anderswo auf dem Betriebsgelände ein Bedarf für die erzeugte Abwärme besteht. Mit dieser Technik können Werte von weniger als 50 g VOC pro Tonne Abfall erreicht werden.

In biologischen Behandlungsanlagen, kann mittels Einsatz spezieller Wärmetauscher eine hochwertige Wärmerückgewinnung von bis zu 98 % erreicht werden. Diese hohen Wärmerückgewinnungsquoten basieren auf dem Einsatz spezieller Keramik-Wärmetauscher, die eine hohe Masse wie auch Oberfläche in idealer Weise miteinander kombinieren.

Betriebsdaten
Normalerweise ist die Zugabe von Zusatzbrennstoff erforderlich, um den Verbrennungsprozess zu unterstützen. Der Durchfluss liegt bei 1500 Nm^3/h, und die Betriebstemperatur liegt bei 1050 – 1200 ºC. Die Spezifikation von 850 ºC bei 2 Sekunden Verweilzeit kann bei der Abfallverbrennung gerechtfertigt sein, wenn die gesamte Abgasbehandlungsanlage die vollständige Entfernung von Restschadstoffen erzielt. Die Verbrennungsbedingungen sind für die vollständige Zerstörung einiger geruchsintensiver und VOC-haltiger Inhaltsstoffe ebenso wie für Dioxin und Dioxin-Vorläufersubstanzen, extremer (z.B. 1100 ºC bei 2 Sekunden Verweilzeit).

Tabelle 4.59 zeigt den Energiebedarf der Verbrennung für verschiedene Kohlenwasserstoff-Konzentrationen im Gas.

Parameter				
Kohlenwasserstoff-Konzentration im Gas (g/Nm^3)	0,5	1,5	3	6
Verbrennung	9	8	6,2	3,2
Erforderliche Wärmeenergie in kWh zur Behandlung von 100 Nm^3[35] VOC-verunreinigtem Abgas Die behandelten Durchflüsse liegen im Bereich von 500 Nm^3/h bis 11000 Nm^3/h				

Tabelle 4.59: Energiebedarf der Verbrennung für verschiedene Kohlenwasserstoff-Konzentrationen im Gas [30, Eklund, et al., 1997]

Anwendbarkeit
Es gibt keine Anwendungsbeschränkungen.

[33] Anm.d.Übers.: Abweichung vom Originaltext, dort steht „Reinigung von thermischen Abgasen“.
[34] Anm.d.Übers.: Im Originaltext wird hier der Begriff „carbohydrates” genutzt, was mit Kohlenhydate übersetzt wird.
[35] Anm.d.Übers.: Im Originaltext wird hier die Einheit hier „Nm^3/h“ aufgeführt.

Wirtschaftlichkeit

Die folgenden beiden Tabellen (Tabelle 4.60 und Tabelle 4.61) zeigen Daten zu Verbrennungskosten.

Behandlung	Maximaler Durchfluss (Nm^3/h)	Investitionskosten (USD)
Verbrennung	110	13000[1]
	160	25000[1]
	915	44000[1]
Verbrennungsmotor	96	62000
	160	50000
[1] Die Kosten enthalten Gebläse, Probenahmeventile und Kontrolleinrichtungen. Wärmerückgewinnungsanlagen sind nicht eingeschlossen.		

Tabelle 4.60: Investionskosten zur VOC-Emissionskontrolle bei Bodenluftabsaugungsanlagen [30, Eklund, et al., 1997]

Investitionskosten (GBP)	Betriebskosten (GBP)
30000	3000
Verbrennung von 2,5 kg Heizöl/Stunde @ GBP 0,13p/Liter Kapazität: 10000 t/a Ölarten: gebrauchte Schmieröle Betriebsführung: Batch Abgasfluss: 0 – 50 Nm^3/h Alter der Anlage: 10 Jahre alt Alter der Abgasreinigung: 2 Jahre alt	

Tabelle 4.61: Kosten der Emissionskontrolle von Luft durch Verbrennung, für eine typische Ölrecyclinganlage [42, UK, 1995]

In biologischen Behandlungsanlagen wird die Kosteneffizienz des Betriebs durch die Größe des zu behandelnden Volumenstroms und durch die Schadstoffkonzentrationen bestimmt. Die idealen Bedingungen sind ein sogenannter autothermer Betrieb, indem der durch die Verbrennung der Schadstoffe freigesetzte Energiebetrag exakt mit dem Energiebedarf zur Aufrechterhaltung der Verbrennungstemperatur korrespondiert. Die notwendige Heizenergie kann in diesem Fall vollständig aus der Verbrennung der Kohlenwasserstoffe[36] gewonnen werden. Dieser Energiebedarf hängt direkt vom Grad der Wärmerückgewinnung ab. Wenn die Schadstoffkonzentrationen niedrig sind, ist eine Wärmezufuhr erforderlich, was zu höheren Betriebskosten führt.

Treibende Kraft für die Anwendung

Abfallverbrennungsrichtlinie (2000/76/EG).

Beispielanlagen

Mindestens zwei Altölbehandlungsanlagen nutzen ein solches Verfahren. Eingesetzt in biologischen Behandlungsanlagen.

Literatur

[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

[36] Anm.d.Übers.: Im Originaltext werden hier „Kohlenhydrate“ genannt.

4.6.15 Kombinierte Verbrennung

Beschreibung
In manchen Anlagen, in denen eine Verbrennung stattfindet, ist es möglich, verschmutzte Luft, die in der Werkhalle erfasst wurde, direkt in den Sekundärluftkreislauf des Brenners oder in die Primärluft des Brenners einzublasen. Dies kann eine spezifische Adaption des Verbrennungsverfahrens erforderlich machen (Modifizierung der Abgasreinigung und Stabilität der Verbrennung).

Erreichter Nutzen für die Umwelt
- Synergien mit bestehenden Verbrennungsanlagen
- Ermöglicht die Energierückgewinnung aus der Verbrennung der VOCs.

Tabelle 4.62 zeigt Daten zur VOC-Entfernung bei der kombinierten Verbrennung.

Eigenschaften	Wert
Zuflussbereich im Input (Nm^3/h)	<50000
VOC-Konzentration im Input (g/Nm^3)	~ 3 <Explosionsgrenze der Verbindungen
VOC-Konzentration im Output (mg/Nm^3)	10 – 50
Notwendigkeit einer vorgeschalteten Entstaubung	nein
Reststoffe	keine
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	*
Brennstoff/Gas (kWh)	*
Kosten	
Investitionskosten (EUR/t Kapazität)	*
Betriebskosten (EUR/t erzeugten Brennstoffs aus Abfall)	*
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	*
*abhängig vom Einzelfall	

Tabelle 4.62: VOC-Entfernung bei der kombinierten Verbrennung
[122, Eucopro, 2003]

Medienübergreifende Auswirkungen
- nicht verfügbar während der Wartung des Brenners
- Spezielle Instrumente und Ventile müssen eingebaut werden, um einen „Domino-Effekt“ zwischen den einzelnen Prozessen zu verhindern
- Schwankungen in Qualität oder Quantität der VOC können zu Problemen in der Verbrennungsanlage führen.

Anwendbarkeit
Eine vorgeschaltete Verdünnung mit Luft ist erforderlich, falls explosionsfähige Konzentrationen erreicht werden.

Wirtschaftlichkeit
Adaptionskosten können hoch sein. Der Betreiber kann die Kosten des Zusatzbrennstoffs ausgleichen, wenn anderswo auf dem Betriebsgelände ein Bedarf für die erzeugte Abwärme besteht.

Treibende Kraft für die Anwendung
Abfallverbrennungsrichtlinie (2000/76/EG).

Beispielanlagen
Eingesetzt bei der Herstellung von Brennstoff aus gefährlichem Abfall und bei der Wäsche von Altölen.

Literatur
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.6.16 Katalytische Verbrennung

Beschreibung
Bei dieser Technik wird die verschmutzte Luft verbrannt, jedoch wird die Verbrennungstemperatur durch Verwendung eines Katalysators abgesenkt. Der Katalysator ermöglicht einen gleichen Zerstörungsgrad von VOC bei niedrigerer Temperatur.

In biologischen Behandlungsanlagen, kann die katalytische Verbrennung zur Entfernung von TOC im Abgas eingesetzt werden. Die Schadstoffe werden bei Temperaturen zwischen 200 und 500 ºC oxidiert, dies unter Verwendung von Katalysatoren aus Edelmetallen oder Metalloxiden.

Erreichter Nutzen für die Umwelt
- Niedriger Brennstoffverbrauch
- Vollständige Zerstörung der VOC
- die Wirkungsgrade liegen im Bereich von 95 bis 99,9 %
- Output-Konzentrationen von 5 – 50 mg C/Nm^3 werden erreicht. Der tatsächliche Bereich ist abhängig von der Art der Verbindung und der Input-Konzentration.

Tabelle 4.63 zeigt Daten zur Entfernung von VOC durch katalytische Verbrennung.

Eigenschaften	**Wert**
Zuflussbereich im Input (Nm^3/h)	20 000 – 50 000
VOC-Konzentration im Input (g/Nm^3)	1 – 3
VOC-Konzentration im Output (mg/Nm^3)	10 – 50
Notwendigkeit einer vorgeschalteten Entstaubung	Ja
Risiken	Vergiftung des Katalysators
Reststoffe	keine
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	25 – 75
Brennstoff/Gas (kWh)	70 – 140
Reaktionsmittel (kg)	Katalysator
Kosten	
Investitionskosten (EUR/t Kapazität)	20 – 30
Betriebskosten (EUR/Tonne erzeugten Brennstoffs aus Abfall) Elektrizität Brennstoff/Gas	 1 – 3 1 – 2
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	<1

Tabelle 4.63: VOC-Entfernung durch katalytische Verbrennung
[122, Eucopro, 2003]

In biologischen Behandlungsanlagen können Reinigungsgrade von über 99 % erreicht werden.

Medienübergreifende Auswirkungen
Der Katalysator ist empfindlich gegenüber manchen Verbindungen (z.B. metallhaltigen und organischen), deren Aufbau die Effizienz fortschreitend verringern kann.

In biologischen Behandlungsanlagen sind unter den Störstoffen Katalysatorgifte, wie etwa metallorganische Verbindungen, organische Silikonverbindungen und Arsenverbindungen. Die Behandlung halogenierter Verbindungen, organischer Schwefelverbindungen und organischer Stickstoffverbindungen ist nur in einem begrenzten Umfang möglich. Methan kann nur unter bestimmten Bedingungen katalytisch zu CO_2 oxidiert[37] werden. Hohe Temperaturen von über 600 ºC sind für die katalytische Oxidation von Methan notwendig. Der Energieverbrauch einer thermischen Behandlung ohne Wärmerückgewinnung ist sehr hoch. Die katalytisch-thermische Oxidation bei der biologischen Behandlung (MBA) wird daher, sowohl unter ökonomischen als auch ökologischen Gesichtspunkten, in Frage gestellt.

[37] Anm.d.Übers.: Im Originaltext wird der Begriff „reduziert“ genutzt.

Betriebsdaten

- Benötigt in manchen Fällen eine Vorbehandlung der Abgase (z.B. elektrostatischer Abscheider, Gewebefilter und Gaswäscher)
- Benötigt eine vorgeschaltete Luftverdünnung wenn explosive Konzentrationen erreicht werden
- Der Energieverbrauch ist niedriger als bei der Verbrennung.

Tabelle 4.64 zeigt den Energiebedarf der katalytischen Verbrennung für verschiedene Kohlenwasserstoffkonzentrationen im Abgas.

Parameter				
Kohlenwasserstoffkonzentration im Abgas (g/Nm^3)	0,5	1,5	3	6
Katalytische Verbrennung	2	1,2	0	0
Erforderliche Heizenergie in kWh für die Behandlung von 100 Nm^3[38] VOC-verunreinigten Abgases. Die behandelten Durchflüsse liegen im Bereich von 500 Nm^3/h bis 11 000 Nm^3/h				

Tabelle 4.64: Energiebedarf bei der katalytischen Verbrennung für verschiedene Kohlenwasserstoffkonzentrationen im Abgas
[122, Eucopro, 2003]

In biologischen Behandlungsanlagen kann die Betriebsdauer solcher Katalysatoren abhängig von der Betriebstemperatur und den Störstoffen im Prozessgas mehr als 30000 Betriebsstunden betragen.

Anwendbarkeit

Angesichts zahlreicher Störfaktoren scheint die praktische Anwendbarkeit der katalytischen Oxidation in biologischen Behandlungsanlagen problematisch. Außerdem liegen keine Betriebserfahrungen aus biologischen Behandlungsanlagen (MBA) vor.

Wirtschaftlichkeit

Die Investitionskosten sind relativ hoch. Tabelle 4.65 zeigt Investitionskosten für die VOC-Emissionskontrolle bei Bodenluftabsaugungsanlagen.

Behandlung	**Maximaler Durchfluss (Nm^3/h)**	**Investitionskosten (USD)**
Verbrennungsmotor	96	62 000
	160	50 000
Katalytische Oxidation	160	25 000[a]
	320	31 000 – 69 000[a]
	800	44 000 – 86 000[a]
	1600	77 000[b]
	8000	140 000
[a] Einschließlich Brenner, Gebläse, Flammensperre, Messgeräte, Filter, Kondensatbehälter, Probenahmeanschlüsse, Kontrolleinrichtungen und Montage von Schiebevorrichtungen [b] Verdünnungsanlage für zusätzliche 22000 USD erhältlich.		

Tabelle 4.65: Investitionskosten für die VOC-Emissionskontrolle bei Bodenluftabsaugungsanlagen
[30, Eklund, et al., 1997]

Treibende Kraft für die Anwendung

Abfallverbrennungsrichtlinie (2000/76/EG).

Literatur

[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

[38] Anm.d.Übers.: Im Originaltext wird hier die Einheit hier „Nm^3/h“ aufgeführt.

4.6.17 Regenerative katalytische Oxidation

Beschreibung
VOCs werden in Verbrennungskammern bei Temperaturen zwischen 750 und 950 °C verbrannt. Die durch die Verbrennung der VOCs erzeugte Energie wird genutzt, um die verschmutzte Luft auf dem Keramikbett vor der Verbrennung vorzuheizen. Die Verbrennungstemperatur kann der VOC-Konzentration angepasst werden. Die verschmutzte Prozessluft wird mittels einer Heizanlage auf die notwendige Reaktionstemperatur erwärmt, und dann über einen kombinierten Katalysator und Wärme speichernden Bettreaktor geleitet. In diesem Reaktor wird die Prozessluft zu CO_2 und Wasser zersetzt. Die Wärme aus diesem Reaktor wird dann über einen zweiten kombinierten Bettreaktor geleitet und dort gespeichert. Nachdem das Speicherbett dieses Reaktors erwärmt wurde, wird der Prozessluftstrom so umgeschaltet, dass er in den zweiten Reaktor eintritt. Die Wärme aus dem zweiten Reaktor wird dann zum Vorheizen der Prozessluft genutzt, während die Oxidation der Schadstoffe im ersten Reaktor stattfindet. Während des weiteren Betriebs wird zyklisch zwischen den oben beschriebenen Stufen umgeschaltet.

Erreichter Nutzen für die Umwelt
- Hohe VOC-Zerstörungsrate (>99 %)
- Reduziert den Verbrauch von fossilen Brennstoffen oder Brennstoff aus Abfall (hohe Energieeffizienz)
- Bei hohen VOC-Konzentrationen (>3 g TOC/Nm^3) ist es möglich, im autothermen Bereich zu arbeiten. Das heißt, dass eine minimale externe Energie zugefügt werden muss, um die Reaktion aufrechtzuerhalten.

Tabelle 4.66 zeigt Daten für die Entfernung von VOC durch die regenerative katalytische Oxidation.

Eigenschaft	**Wert**
Zuflussbereich im Input (Nm^3/h)	20000 – 80000
VOC-Konzentration im Input (g/Nm^3)	2 – 4 mit Spitzen bis 10
VOC-Konzentration im Output (mg/Nm^3)	15 – 50
Wirkungsgrad (%)	>99 %
Notwendigkeit einer vorgeschalteten Entstaubung	Ja
Risiken	
Reststoffe	Keine
Verbrauch (pro Tonne erzeugten Brennstoffs aus Abfall)	
Elektrizität (kWh)	10 – 50
Brennstoff/Gas (kWh)	50 – 200*
Alternativer Brennstoff oder Biogas	Ja
Reaktionsmittel (kg)	-
Kosten	
Investitionskosten (EUR/t Kapazität)	10 – 25
Betriebskosten (EUR/t erzeugten Brennstoffs aus Abfall) Elektrizität Brennstoff/Gas	 1 – 3 2 – 6
Wartungskosten (EUR/t erzeugten Brennstoffs aus Abfall)	<1
*je nach VOC-Konzentration	

Tabelle 4.66: VOC-Entfernung durch regenerative katalytische Oxidation [122, Eucopro, 2003]

Medienübergreifende Auswirkungen
Hoher Energieverbrauch bei niedriger VOC-Konzentration.

Betriebsdaten
- VOC-Konzentrationsschwankungen werden zugelassen
- Benötigt eine vorgeschaltete Luftverdünnung, wenn explosionsfähige Konzentrationen erreicht werden
- Benötigt eine Entstaubung, wenn die Eingangsstaubkonzentration höher als 20 mg/Nm^3 ist.

Tabelle 4.67 zeigt den Energiebedarf der regenerativen katalytischen Oxidation für verschiedene Kohlenwasserstoffkonzentrationen im Abgas.

Parameter				
Kohlenwasserstoff-Konzentration im Abgas (g/Nm^3)	0,5	1,5	3	6
Regenerative katalytische Oxidation	0	0	0	0
Erforderliche Wärmeenergie in kWh für die Behandlung von 100 Nm^3[39] VOC-verunreinigten Gases. Die behandelten Durchflüsse liegen im Bereich von 500 Nm^3/h bis 11 000 Nm^3/h				

Tabelle 4.67: Energiebedarf der regenerativen katalytischen Oxidation für verschiedene Kohlenwasserstoffkonzentrationen im Abgas
[122, Eucopro, 2003]

Anwendbarkeit
Wegen seiner niedrigen Energiekosten auf niedrige bis mittlere VOC-Konzentrationen ausgelegt.

Wirtschaftlichkeit
Niedrige Betriebskosten und hohe Investitionskosten.

Treibende Kraft für die Anwendung
Abfallverbrennungsrichtlinie (2000/76/EG).

Literatur
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.6.18 Regenerative thermische Oxidation

Beschreibung
Das Ziel einer regenerativen thermischen Oxidation ist die ständige und qualitativ hochwertige Rückgewinnung eines großen Teils der Wärmeenergie, die für das Erwärmen des Abgasstroms auf die zur Behandlung erforderlichen Oxidationstemperaturen erforderlich ist.

Diese Wärmeenergie wird in Durchflusswärmetauschern gespeichert. Solche Wärmetauscher bestehen entweder aus einem Keramikfüllmaterial oder sind Lamellenwärmetauscher. Die Leistung dieses rekuperativen Verfahrens wird durch den erzielten Grad der Wärmerückgewinnung ausgedrückt, welcher wie folgt definiert ist:

$$\text{Leistung} = 1 - \frac{T_{\text{gereinigtes Gas}} - T_{\text{Rohgas}}}{T_{\text{Verbrennungskammer}}} \qquad T = \text{Temperatur}$$

Die einfließende Abluft wird im „heißen“ Wärmetauscherbett aufgeheizt. Die Luft wird, abhängig von der Wärmespeicherkapazität, auf eine Temperatur erwärmt, die einige Grad unter derjenigen der Verbrennungskammer liegt. In der Verbrennungskammer findet eine Oxidation statt. Im Fall niedriger Schadstoffkonzentrationen in der Prozessluft muss die fehlende Energie durch Primärenergiequellen eingebracht werden. Nach Durchgang der Verbrennungskammer wird das Abgas, das jetzt die Reaktionstemperatur besitzt, seine Wärme an ein „kaltes“ Wärmetauscherbett abgeben.

Infolge des hohen Energiebedarfs zum Aufheizen des Abgases und wegen des optimalen Wärmeaustauschs wird der überwiegende Teil der im „heißen“ Wärmetauscherbett gespeicherten Wärme nach ca. 120 Sekunden an das Abgas abgegeben. Umgekehrt heizt das heiße Abgas das „kalte“ Wärmetauscherbett auf.

[39] Anm.d.Übers.: Im Originaltext wird hier die Einheit hier „Nm^3/h“ aufgeführt.

Erreichter Nutzen für die Umwelt
Die realisierten Wärmerückgewinnungsquoten variieren zwischen 90 und 98 %, abhängig vom Schadstoffgehalt des Abgases. Eine zusätzliche Energieversorgung ist in diesem Fall nicht notwendig. Mit Bezug auf die erforderlichen Abgaswerte unterscheiden sich die derzeit auf dem Markt erhältlichen Anlagen in der technischen Methode, die eingesetzt wird, um diese niedrigsten Abgaswerte zu gewährleisten. Dies ist notwendig, weil, am Umkehrpunktes des Stroms, das gereinigte Gas durch Reste des Rohgases verunreinigt werden kann. Anlagen, die im Hinblick auf dieses Problem optimiert wurden, können Konzentrationen im gereinigten Gas von weniger als 10 mg/Nm^3 erreichen.

Betriebsdaten
Um einen kontinuierlichen Betrieb aufrechtzuerhalten, muss die Richtung des Abgasstroms in einer Art kontrolliert werden, dass das Wärmetauscherbett, wenn es zu entsprechender Zeit erwärmt wird, zum Aufheizen des Abgases genutzt werden kann. Dies führt zu einem abwechselnden Erwärmen und Kühlen des jeweiligen Wärmetauscherbetts.

Ebenso entscheidend für die Auslegung der Anlage ist die Höhe der Enthalpie, die in den zu oxidierenden Schadstoffen chemisch gebunden ist. Der Betrieb ist autotherm, wenn die Summe der in den Wärmetauscherbetten gespeicherten Wärme und die freigesetzte Reaktionsenthalpie ausreichen, um die erforderliche Temperatur in der Verbrennungskammer aufrechtzuerhalten.

Wenn die in den Schadstoffen gebundene Enthalpie nicht ausreicht, um die Oxidationstemperatur zu erreichen, muss dies durch externe Energieversorgung erreicht und sichergestellt werden. Einige Einzelanbieter realisieren dies durch den Einbau kontrollierter Brenner in die Verbrennungskammer, andere reichern das Abgas mit zusätzlichen Brennstoffen an, so dass der Betrieb unter „autothermen Bedingungen“ betrieben werden kann. In diesem Fall kann die Anlage flammenlos betrieben werden. In energieoptimierten Anlagen ist ein Energieverbrauch von 8 kWh Wärme-Output pro 1000 Nm^3 Abgas zu erwarten.

In der Anfahrzeit und bis zum Erreichen der Betriebstemperatur sowie während des Betriebs bei niedrigen Konzentrationen an organischen Stoffen (<2 g C/Nm^3) ist wegen der bislang unzureichenden Energiespeicherung in den Wärmetauscherbetten eine externe Energieversorgung notwendig. In der Anfahrphase von flammenlosen Anlagen wird normalerweise elektrische Energie zur Erwärmung eingesetzt, es kann aber auch Wärmeenergie durch Erdgas oder Propangasbrenner eingesetzt werden.

Beim Betrieb mit gasförmigen Brennstoffen aus Abfall wie Deponiegas oder Biogas muss berücksichtigt werden, dass diese Gase mit Schadstoffen verunreinigt sein können. Beim Anfahren des Betriebes sollten diese Gase nicht eingesetzt werden, wenn noch nicht die erforderlichen Temperaturen in der Verbrennungskammer erreicht sind. Dies kann nur mit konventionellen Brennstoffen wie Erdgas oder Propangas gemacht werden. Zusätzlich muss über die Sicherheitskette gewährleistet werden, dass im Fall jeglicher Betriebsunterbrechungen und der daraus resultierenden Absenkung der Temperatur in der Verbrennungskammer, die Versorgung mit Brennstoffen aus Abfall geregelt und folglich immer gesichert ist.

Anwendbarkeit
Im Zusammenhang mit Forschungsprojekten und im Anlagenbetrieb haben sich Kombinationen von Gaswäschern und regenerativen thermischen Oxidationsanlagen als nützlich erwiesen. Diese Verfahrenskombination hat Vorteile sowohl im Hinblick auf das Reinigungsvermögen als auch hinsichtlich der Betriebskosten.

Beispielanlagen
In der Praxis gibt es einige verschiedene Auslegungen von regenerativen thermischen Oxidationsanlagen, die sich vor allem in der Konzeption der einzelnen Wärmetauscherbetten und in der Wahl des Wärmetauschermaterials unterscheiden. Für niedrige Schadstoffkonzentrationen haben sich diese Verfahren für Nachverbrennung mit Wärmerückgewinnung weit verbreitet.

Regenerative thermische Oxidationsanlagen werden in Deutschland seit einigen Jahren zur Reinigung des Abgases von biologischen Behandlungsanlagen (MBA) eingesetzt. Auch in Österreich wurde kürzlich eine MBA errichtet, die eine derartige Anlage in Betrieb genommen hat.

Literatur
[132, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.6.19 Oxidationsbehandlungen

Die Art der Oxidationsbehandlung wurde im Zusammenhang mit den beiden folgenden Tabellen (Tabelle 4.68 und Tabelle 4.69) nicht spezifiziert. Es könnte sich um jede der vier Techniken handeln, die in den Abschnitten 4.6.14 bis 4.6.17 beschrieben wurden. Diese Tabellen zeigen Daten zu Luftemissionen nach der Behandlung.

Emissionsparameter	Wert	Einheiten
Abgastemperatur	140	ºC
PM	10 – 27	mg/Nm^3
Schwermetalle	0,03	mg/Nm^3
TOC	8	mg/Nm^3
SO_x	10	mg/Nm^3
NO_x	350	mg/Nm^3
HCl	2,3 – 10	mg/Nm^3
HF	<0,1	mg/Nm^3
HBr	<0,1	mg/Nm^3
HCN	<0,1	mg/Nm^3
P	0,019	mg/Nm^3
$CO_2/(CO+CO_2)$	<1	mg/Nm^3
CO_2	9,5	%
CO	50	mg/Nm^3
PAH	<0,1	ng/Nm^3
PCDD + PCDF	<0,01	ng/Nm^3
TCDD + TCDF	<0,01	ng/Nm^3
PCB + PCN + PCT	<1	ng/Nm^3
Die Werte beziehen sich auf 10 % O_2 -Gehalt im Abgas		

Tabelle 4.68: Emissionen in die Luft aus thermischen Abgasbehandlungsanlagen verschiedener Altölbehandlungsanlagen
[42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003]

Luftparameter	Einheiten	INPUT-Ströme		OUTPUT
		Abgas aus verfahrenstechnischen Anlagen	Abgas aus der Schutzgasschicht des Tanks	
Durchfluss	Nm^3/h	101	1400	2700[1]
Temperatur	°C	18	27	146
Staub	mg/Nm^3	58,6	1,1	28,4
H_2S	mg/Nm^3	101600	<1	<0,1
Mercaptane	mg/Nm^3	2153	1,7	0,7
SO_x	mg/Nm^3	30000	1,3	3
HCl	mg/Nm^3	308	0,9	0,8
VOC	mg/Nm^3			3
NO_x	mg/Nm^3			181
PAH	mg/Nm^3			<0,1
[1] einschließlich Verbrennungsluft				

Tabelle 4.69: Thermische Behandlung verunreinigter Luftströme
[66, TWG, 2003]

4.6.20 Nicht-thermische Plasmabehandlung

Beschreibung
Die nicht-thermische Plasmatechnik ist eines der hoch oxidativen Verfahren. Es ist ein physikalischer Prozess, der die Moleküle in einem wechselnden elektrischen Feld aktiviert und dadurch den Angriff durch eine Radikalreaktion erleichtert. Als nicht-thermisches Plasma bezeichnet man einen Zustand von Atomen und Molekülen, die durch elektrische Felder aktiviert werden und dadurch Gegenstand einer Dissipation der Elektronen oder einer Verschiebung der elektrischen Ladung zu energiereicheren Bahnen unterworfen werden. Dadurch können Energiepotenziale erreicht werden, deren Energieniveaus mit Temperaturäquivalenten von bis zu 100 000 °C mit thermisch angeregtem Plasma korrespondieren.

Erreichter Nutzen für die Umwelt
Organisch gebundener Kohlenstoff kann sehr weitgehend zersetzt werden. Der Vorteil des nicht-thermischen Plasmas ist, dass bei ausreichend hohen Feldstärken und einer genauen Energieversorgung eine Dosierung innerhalb von Sekundenbruchteilen eine Reaktion bewirken kann. Hierdurch werden erhöhte Mengen verschiedener Radikale erzeugt, die wegen ihres hohen Oxidationsvermögens fähig sind, organische Moleküle anzugreifen und Verbindungen aufzubrechen.

Medienübergreifende Auswirkungen
Infolge der Radikalreaktion im Reaktor wird Ozon in Anteilen von einigen Gramm pro Stunde freigesetzt. Die Anlage muss deshalb so konzipiert sein, dass die Eliminierung dieses Ozons sichergestellt wird. Für diese spezielle Aufgabe eignen sich Metalle, ein Katalysator oder Aktivkohle. Bei der Wahl eines Katalysators muss gewährleistet werden, dass keine sekundären Geruchsemissionen aus nicht zu Ende geführten katalytischen Prozessen auftreten. Die Gefahr der Selbstentzündung der Aktivkohle bei Reaktionen mit Ozon muss berücksichtigt werden. Außerdem muss berücksichtigt werden, dass in größerem Ausmaß N2O erzeugt wird.

Beispielanlagen
Eingesetzt in biologischen Behandlungsanlagen, es liegen jedoch keine Betriebserfahrungen vor.

Literatur
[132, UBA, 2003]

4.6.21 Entstickungstechniken

Beschreibung
Weitere Informationen befinden sich in den BVT-Merkblättern „Abwasser- und Abgasbehandlung“ und „Abfallverbrennung“. Zu den Techniken gehören:

a. gute Prozesskontrolle, mit der tatsächliche NOx-Emissionen vermieden werden
b. gute Auslegung der Verbrennungskammer
c. NOx–arme Brenner
d. SCR-Technik
e. SNCR-Technik
f. interne Abgasrückführung
g. oszillierende Verbrennung
h. chemische Gaswäsche (siehe Abschnitt 4.6.12).

Erreichter Nutzen für die Umwelt
Reduktion von NOx–Emissionen in die Luft.

Medienübergreifende Auswirkungen
Die Eindüsung von Ammoniak oder Harnstoff in den Abgasstrom beim Einsatz von SCR oder SNCR führt eher zu einem Risiko der NOx–Bildung als zu dessen Reduzierung, wenn die Temperatur zu hoch ist und überschüssiger Sauerstoff vorhanden ist.

Anwendbarkeit

Basis des Benchmarks	Tätigkeit
Nutzung einer guten Prozesskontrolle zur Vermeidung von NO_x -Emissionen	Behandlung von Abfallsäuren
Nutzung guter Auslegung der Verbrennungskammer	Verbrennungsanlage
Verwendung NO_x –armer Brenner	Verbrennungsanlagen

Wirtschaftlichkeit

SCR und SNCR weisen höhere Betriebskosten auf als andere Techniken, wie etwa eine gute Prozesssteuerung und NOx–arme Brenner.

Literatur

[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.6.22 Geruchsminderungstechniken

Weitere Informationen befinden sich im Abschnitt 4.6.23.

Beschreibung

Planung und Implementierung eines strukturierten Geruchsbekämpfungsplan. Der Plan muss enthalten:

a. [40]die Haupttätigkeiten und/oder Quellen beschreiben, bei denen Gerüche entstehen. Hierbei müssen alle durchgeführten und relevanten Umweltschutzüberwachungen sowie die technischen Möglichkeiten, die zur Kontrolle von Geruchsemissionen zur Verfügung stehen, enthalten sein
b. Einführen oder Weiterentwickeln eines Inventars der verwendeten oder erzeugten geruchsintensiven Materialien, wobei alle Quellen enthalten sein müssen bei denen beabsichtigte oder diffuse (unabsichtlich) Geruchsemissionen freigesetzt werden
c. eine detaillierte Beschreibung aller unternommenen Routineüberwachungen, um die Exposition der Rezeptoren zu bewerten
d. ein System bereithalten in dem die Ergebnisse der Überwachungen und Aufzeichnungen aller erhaltenen Beschwerden dokumentiert werden
e. die Identifizierung von Handlungen, die im Fall unbeabsichtigter Vorfälle oder von Bedingungen bei denen Gerüche oder potenzielle Geruchsprobleme auftreten, durchgeführt werden müssen
f. Wartungsanforderungen an die Eindämmmaßnahmen und des Managements des Betriebs z.B. auch innerhalb von Gebäuden
g. nachdrückliche Voruntersuchungen (siehe Abschnitt 4.1.1.2) und Zurückweisung bestimmter Abfälle z.B und besonders wenn es sich um geruchsintensive Materialien handelt, die in dafür ausgewiesene abgedichteten Bereichen vorgesehen sein, in die eine Entlüftung zur Abluftreinigungsanlage eingebaut ist
h. Betrachtung der Gaswäscher-Flüssigkeiten, um sicherzustellen, dass diese streng überwacht werden, um eine optimale Leistung zu gewährleisten, z.B. im Hinblick auf den richtigen pH-Wert, ihre rechtzeitige Auffüllung und ihren rechtzeitigen Ersatz
i. Anforderungen an Vakuumabsaugungen für Anlagen, in denen Gerüche verursacht werden
j. Anforderungen an eine Einhausung innerhalb von Gebäudebereichen, in denen VOC-Emissionen hoch sind und intensive Gerüche verursachen können.

Erreichter Nutzen für die Umwelt

Vermeidung von Gerichsemissionen, die belästigend sein können und außerhalb der Grenzen des Betriebsgeländes wahrgenommen werden können.

Anwendbarkeit

Für komplexe Anlagen, z.B. in denen mehrere relevante Geruchsquellen vorhanden sind oder in denen ein umfangreiches Programm von Verbesserungen eingeführt wird, um Gerüche unter Kontrolle zu bringen, wird in der Regel ein Geruchsmanagementplan geführt.

Literatur

[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [81, VDI and Dechema, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [120, Prantner, 2002]

[40] Anm.d.Übers.: Im Originaltext startet die Aufzählung mit „g“.

4.6.23 Geruchsmanagement in biologischen Behandlungsanlagen

Weitere Informationen befinden sich in Abschnitt 4.6.22.

Beschreibung

Ein effektives Management der Betriebsführung kann dazu beitragen, die Bildung von Gerüchen zu reduzieren. Dazu gehört:

a. Baldmöglichste Verarbeitung angelieferter Einsatzstoffe
b. Sicherstellung einer ordnungsgemäßen Stabilisierung der Biomasse innerhalb der Verweilzeit in geschlossenen Gebäuden, um sicherzustellen, dass in der offenen Nachbehandlungsstufe nur geruchlose Materialien vorhanden sind
c. Vermeidung eines frühen Aufbereitungsschrittes, in dem die Partikel zu sehr verkleinert werden, wodurch die Diffusion von Luft durch das Material verhindert würde, das seine biochemische Umwandlung noch abschließen muss (eine kleinere Partikelgröße könnte zu einem Strukturverlust beim aeroben Abbau führen und einen anaeroben Abbau wahrscheinlicher machen)
d. Verhinderung der Bildung von Sickerwasserlachen (z.B. durch Gewährleistung von ausreichendem Gefälle bei versiegelten Oberflächen)
e. Vermeidung einer externen Aufhäufung des groben Siebüberlaufs aus dem Siebprozess der Vorbehandlung, da auch diese einen bestimmten Prozentsatz an fermentierbaren Materialien enthalten
f. Entfernung der Abluft aus den geruchsintensiven Bereichen des Verfahrens (Abladen, Lagerung des Inputs an fermentierbaren Materialien in Tiefbunkern, Vorbehandlung, erste Verfahrensschritte. Manchmal kann auch der Nachbehandlungsbereich eingehaust und die Abluft behandelt werden)
g. Konstruktion des Entlüftungsverfahrens in einer Art, dass alle Abluftverluste durch Fenster, Türen usw. vermieden werden
h. Ausstattung der Anlage mit richtig dimensionierten Abluftreinigungsanlagen
i. Sicherstellung, dass eine ordnungsgemäße Wartung der Geruchsminderungstechnik durchgeführt wird
j. Verwendung von oberflächenaktiven Reagenzien
k. Bereitstellung geschlossener Tanks zur Sammlung/Lagerung von Sickerwasser, um Geruchsemissionen bei der Lagerung von Flüssigkeiten vor ihrer Wiedereinspeisung in den Kreislauf und/oder vor ihrer Beseitigung außerhalb des Betriebsgeländes zu minimieren
l. Bereitstellung einer Behandlung für das gelagerte Sickerwasser, etwa durch Belüftung, um Fäulnisbedingungen zu vermeiden, die Gerüche erzeugen
m. Bereitstellung einer Geruchsminderung, um Emissionen aus speziellen Quellen zu vermindern, wie etwa Zerstäuber zur Geruchsminderung
n. Konzipierung der geschlossenen Gebäude mit Unterdruck, um Geruchsemissionen aus Türöffnungen zu vermeiden.

Erreichter Nutzen für die Umwelt

Verhindert oder reduziert Geruchsemissionen.

Medienübergreifende Auswirkungen

Die Verwendung oberflächenaktiver Reagenzien mindert Gerüche nicht vollständig, insbesondere, wenn die Wahl des Reagenz auf einer charakteristischen Verbindung im geruchsverursachenden Aerosol beruht.

Betriebsdaten

Bei der Anwendung von Technik ‘n’ (siehe obige Beschreibung) wird die Luftzirkulation zur Aufrechterhaltung des Unterdrucks oft in stündlichen Luftaustauschraten angegeben, die notwendig sind, um die Luft innerhalb des Gebäudes auszutauschen. Der Wert muss umso größer sein, desto größer die Geruchskonzentrationen sind, die innen erreicht werden.

Anwendbarkeit

Neben der Vermeidung müssen aerobe Anlagen oft Geruchsprobleme in Form einer Behandlung der Abluft angehen, vor allem dort, wo sie sich durch hohe Kapazitäten auszeichnen und/oder dort wo die Abstände zu bewohnten Gebieten gering sind.

Beispielanlagen

Eine größere Anzahl von Anlagen setzt in Europa z.Zt. Techniken ein, die beim Betrieb von aeroben Abbauaktivitäten hilfreich sind, sogar in dicht besiedelten Gebieten. Dies ist möglich, wenn bei der Planung und beim Management der Anlage Geruchsprobleme mit der notwendigen Sorgfalt berücksichtigt werden.

Literatur

[59, Hogg, et al., 2002], [116, Irish EPA, 2003], [150, TWG, 2004]

4.6.24 Einige Beispiele der Abgasbehandlung für verschiedene Abfallbehandlungsverfahren

Tabelle 4.70 führt einige Anwendungsbeispiele für die Abgasbehandlung bei verschiedenen Abfallbehandlungsverfahren auf. In der Regel handelt es sich bei der Abgasminderung die im Einzelfall anwendbar ist, um eine Kombination von Techniken; wobei einige davon eventuell nicht unter den unten angeführten Beispielen erwähnt werden. Einige Beispiele zeigt Abschnitt 4.6.25.

Abfallbehandlungsverfahren	Angewendete Technik
Thermodesorption	Kondensation Verbrennung Adsorption an Aktivkohle Zyklone Venturiwäscher Gewebefilter HEPA-Filter Nasse Gaswäsche Trockene Gaswäsche
Luftabsaugung aus ausgehobenem Boden	Adsorption an Aktivkohle Katalytische Verbrennung Verbrennung Verbrennungsmotoren
Biologische Sanierung e*x situ*	Adsorption an Aktivkohle
Bodenwäsche	Adsorption an Aktivkohle
Extraktion mit Lösemitteln	Verbrennung
Belüftung des Bodens (Bioventing)	Aktivkohle Katalytische Oxidation Verbrennungsmotoren Biofilter
Chemisch-physikalische Behandlung von Abwässern	Nasse Gaswäsche Eindampfen Strippen Destillation
Erzeugung von Brennstoff aus Abfall	Extraktion Kondensation Adsorption an Aktivkohle Biofilter Thermische Oxidation Verbrennung Gaswäsche
Stabilisierung	Absorption Adsorption Gewebefilter Thermische Oxidation Zyklone
Altölbehandlung	Kondensation Thermische Oxidation Biologische Oxidation
Zerkleinern /Schreddern von Fässern	Adsorption Absorption Thermische Oxidation

Tabelle 4.70: Anwendbarkeit von Abgasbehandlungsverfahren
[30, Eklund, et al., 1997], [55, UK EA, 2001], [121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003], [150, TWG, 2004]

4.6.25 Einige Beispiele für kombinierte Abgasbehandlungen

Dieser Abschnitt führt einige Anwendungsbeispiele für kombinierte Abgasbehandlungen bei verschiedenen Abfallbehandlungsverfahren auf. In der Regel handelt es sich bei der Art der Abgasbehandlung, die im Einzelfall anwendbar ist, um eine Kombination von Techniken; einige davon sind eventuell nicht unter den unten angeführten Beispielen erwähnt.

Angeschlossene Betriebsanlagen	Produktionshallen, Tanklager, Fassbehandlung
Emissionsgrenzwerte	Organikgehalt nach der TA Luft
Größe des Gebäudes	940 m^2
Die Anlage besteht aus	Aktivkohle-Vorfilter (Abmilderung von Emissionsspitzen im Rohgas), doppelt[41]
	Regenerativem Hauptfilter aus Aktivkohle (doppelt)
	[42]Gaswäsche für Emissionen aus Tanklagern und Ladevorgängen, doppelt
	Strippern zur Austreibung von Lösemitteln aus Wasser (Austreibung von Gas mit Luft), doppelt
	Biologischer Wasserbehandlung für Kondensate aus der Gaswäsche[43] und der Aktivkohlefiltration
	Kühltürmen (außerhalb des Gebäudes)
Technologie	Adsorption an Aktivkohle
	Physikalische Absorption in einer Waschflüssigkeit mit Lösemittelrückgewinnung
Emissionskontrolle	Online-Analyse von Gesamt-Kohlenstoff, Perchlorethylen, Methylendichlorid, Trichlorethylen, Glykolen, BTX-Aromaten
Input-Materialien	Mit Lösemitteln verunreinigte Abluftströme (VbF, CKW und andere)
Betriebskapazität	6000 m^3/h leicht verschmutzte Abluft aus Produktionshallen
	400 m^3/h stark verschmutzte Abluft aus Tanklager und Ladevorgängen
Erreichte Emissionswerte	In Bezug auf organische Stoffe im Abgas (außer partikelförmige organische Stoffe) ist ein Gesamt-Massenstrom von <57 kg/a oder eine Gesamt-Massenkonzentration von <3,6 mg TOC/Nm^3 erreichbar (beide als Gesamt-Kohlenstoff angegeben)

Tabelle 4.71: Abgasbehandlungsanlage einer Lösemittelabfall-Behandlungsanlage

Abluftreinigung bestehend aus	a. Erfassung verunreinigter Luft mittels Leitungsnetz unter Unterdruck b. Gruppe von Zyklonen und Filtern zur Senkung der Staubkonzentration c. regenerative thermische Oxidationsanlage
Erreichter Nutzen für die Umwelt	Das regenerative thermische Oxidationsverfahren beinhaltet kein Verbrennungsverfahren und hat keine Verbrennungskammer. Folglich erzeugt es kein NO_x. Weil die Schadstoffe bei einer hohen Temperatur (950 °C) zersetzt werden, können VOC-Konzentrationen von weniger als 50 mg/Nm^3 im Auslass erreicht werden
Betriebsdaten	Zur Aufrechterhaltung der hohen Temperatur wird elektrische Energie benötigt, und zum Betrieb des Verfahren ist Erdgas notwendig
Beispielanlage	Anlage in Frankreich

Tabelle 4.72: Kombinierte Minderung von Stäuben und VOCs in einer Behandlungsanlage für gefährliche Abfälle

[41] Anm.d.Übers.: Im Originaltext wird es „two fold“ genannt.
[42] Anm.d.Übers.: Im Originaltext wird der Begriff „high scrubber“ genutzt.
[43] Anm.d.Übers.: Im Originaltext wird der Begriff „high scrubber“ genutzt.

4.6.26 Einige Beispiele für den Vergleich von Minderungstechniken bei der Erzeugung von Brennstoff aus gefährlichen Abfällen

Tabelle 4.73 und Tabelle 4.74 zeigen Vergleiche einiger Minderungsstechniken bei ihrer Anwendung bei einer speziellen Abfallbehandlung.

Kriterium	Gewebefilter	Nasse Gaswäsche
Staubabscheideleistung	+	-
Flexibilität	+	+
Verbrauch	++	-
Kosten	++	-
Risiken (Feuer, Explosion usw.)	+	++
Medienübergreifende Auswirkungen	+	-
Anmerkung: (-) schlecht, (+) annehmbar und (++) gut adaptiert		

Tabelle 4.73: Vergleich von Gewebefiltern und nassen Gaswäschern bei der Minderung von Staubemissionen

Kriterium	Stickstoff-abscheider	Biologische Behandlung	Aktivkohle	Kombinierte Verbrennung	Katalytische Verbrennung	Regenerative thermische Oxidation
Leistung für VOC	++	-	-/+	+	+	++
Verbrauch	-	++	++/ -	++	+	+
Kosten	+	++	++	++	-	+
Flexibilität	-	-	+	+	-	++
Risiken (z. B. Feuer, Explosion)	+	+	-	+	+	+
Medienübergreifende Auswirkungen	-	-	-	+	+	+
Anmerkung: (-) schlecht, (+) annehmbar und (++) gut adaptiert						

Tabelle 4.74: Vergleich von VOC-Minderungstechniken

4.7 Abwassermanagement

Dieser Abschnitt behandelt nur das Management von Abwasser, nachdem es verunreinigt worden ist. Vorsorgetechniken zur Vermeidung der Verunreinigung von Wasser oder Techniken zur Senkung des Wasserverbrauchs werden hier nicht behandelt und sind stattdessen im Abschnitt 4.1.3.6 enthalten.

In diesem Abschnitt werden nur die für die Abfallbehandlungsbranche bedeutendsten Techniken behandelt. Im Allgemeinen sind die gängigsten Techniken schon in zahlreichen anderen BVT-Merkblättern beschrieben und untersucht worden (insbesondere wird auf das Abwasser- und Abgas-BVT-Merkblatt hingewiesen). Aus diesem Grund ist es nicht die Absicht dieses Abschnitts, eine vollständige Untersuchung der verschiedenen Techniken zu liefern, stattdessen konzentriert sich dieser Abschnitt nur auf die Themen, die für den von diesem Dokument abgedeckten Industriesektor von besonderer Bedeutung sind und auf Emissionswerte, die in diesem Sektor als gut erreichbar gelten.

Der Hauptzweck der Abwasserbehandlung liegt in der Reduktion des BSB-Bedarfs im Abwasser (und folglich als Konsequenz eine damit verbundene Reduktion des CSB-Bedarfs). Zur Behandlung gehört üblicherweise eine Mischphase, die nicht nur das Abwasser homogenisiert, sondern auch folgende Vorgänge beschleunigt:

- Auflösung fester Partikel
- Desorption von Abfallfeststoffen
- Kontakt zwischen organischem Abfall und Mikroorganismen
- Oxidation des Abwassers durch Belüftung.

Die Abwasserbehandlung kombiniert chemische, physikalische und biologische Behandlungsverfahren. Normalerweise gehört dazu eine aerobe Stufe, in der das Abwasser in einem Belüftungstank belüftet wird (0,5 – 3 Tage Verweilzeit), um lösbare organische Stoffe durch Mikroorganismen (Schlamm) umzuwandeln und einen reineren Ablauf zu erzielen. Ein biologischer Abbau findet nur bei organischen Stoffen statt, die im Wasser gelöst sind, nicht aber bei suspendierten oder bei organischen Stoffen die in freien Phasen vorliegen. Im Allgemeinen ist die Behandlung und Reinigung von Abwässern aus Abfallbehandlungsanlagen ein wichtiges Element dieser Anlagen, meist wegen der potenziell hohen Verschmutzungsfrachten, die im Abwasser vorliegen können. Es kann zwischen Trennungs- und Umwandlungsprozessen unterschieden werden.

Trennungsprozesse sind zum Beispiel:

- mechanische Behandlung
- Eindampfen
- Adsorption
- Filtration
- Nano-, Ultrafiltration
- Umkehrosmose
- Zentrifugierung

Umwandlungsprozesse sind dagegen z.B.:

- nasse Oxidation mit H_2O_2
- Ozonbehandlung
- Fällung/Neutralisation
- anaerobe und aerobe biologische Behandlung von Abwässern.

4.7.1 Abwassermanagement innerhalb des Abfallbehandlungssektors

Beschreibung
Abbildung 4.10 zeigt ein Abwasserbehandlungssystem für eine Abfallbehandlungsanlage.

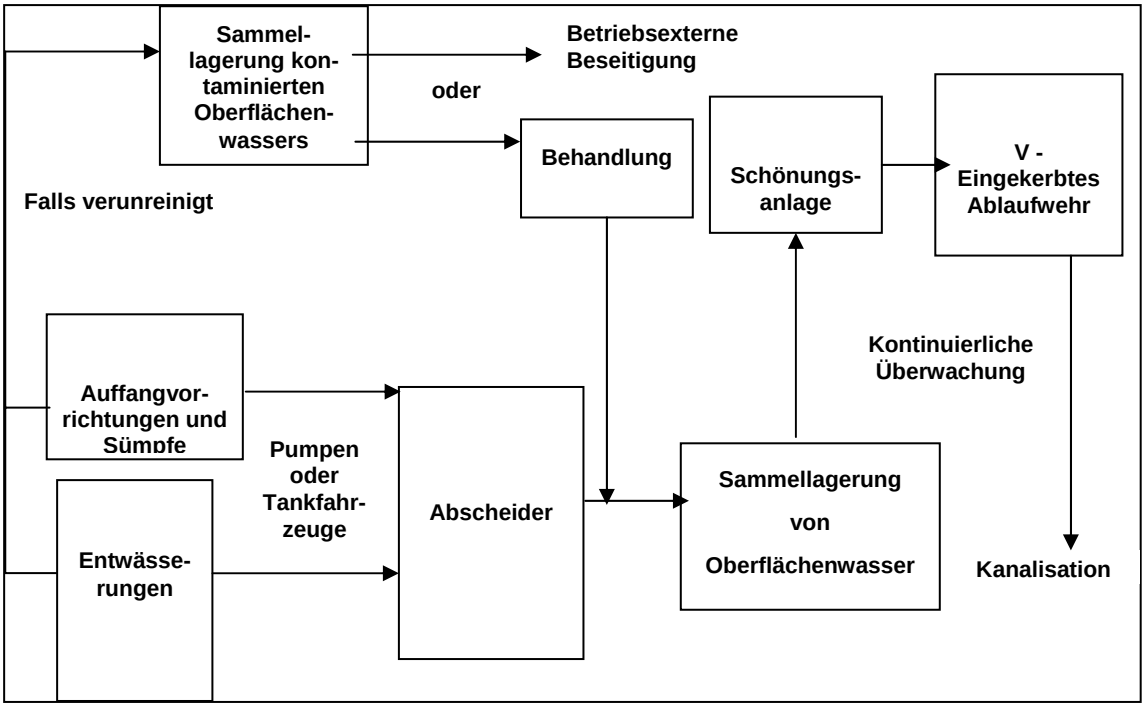


Abbildung 4.10: Abwasserbehandlung in einer Abfallbehandlungsanlage, die wie unten in Tabelle 4.75 eingestuft werden kann

Einstufung	Ziel	Techniken	Abschnitt in diesem Dokument
Selektion	Vermeidung der Einführung schädlicher und persistenter Stoffe in das System, die durch die Behandlung nicht beeinflusst werden	Voruntersuchungen und Annahmemaßnahmen	4.1.1 4.7.2
Primäre Behandlung	Entfernung oder Reduzierung von Zielsubstanzen aus Abfällen		4.7.3
Sekundäre Behandlung	Entgiftung Umwandlung löslicher Stoffe in Feststoffe	Oxidation von Cyanid oder Nitrit Reduktion von Chrom(VI) Fällung von Metallen pH-Neutralisation Reduktion des CSB Absetzen	4.7.4
Tertiäre Behandlung	Eliminierung biologisch abbaubarer organischer Verbindungen und Stickstoffverbindungen	Biologische Behandlung Absetzen Eindicken und Entwässerung	4.7.5
Endbehandlung	‘Schönung’ des Abwassers Rückgewinnung von Stoffen aus dem Abwasser	Filtration Membranen Nasse Oxidation mit Luft Adsorption	4.7.6

Tabelle 4.75: Abwasserbehandlungstechniken

Zu den Techniken für eine effiziente Abwasserbehandlung gehören:

a. Beschreibung aller betriebsexternen Behandlungen in der Gesamtbeschreibung des Abwasserbehandlungssystems (in den meisten Fällen handelt es sich um kommunale Abwasserbehandlungsanlagen, wie etwa ein Klärwerk). Wenn Abwasser betriebsextern in einer Kläranlage behandelt wird, müssen die Abwassererzeuger nachweisen, dass
   - die Behandlung in der Kläranlage genauso gut ist wie eine betriebsinterne Behandlung wäre, basierend auf der Verringerung der Fracht (nicht Konzentration) jedes Stoffs, der in den Vorfluter eingeleitet wird
   - die Wahrscheinlichkeit eines Bypasses über Sturm/Notfall-Überläufe oder an zwischengeschalteten Abwasserpumpstationen akzeptabel niedrig ist
   - Aktionspläne vorliegen, wie im Falle eines Schadensfall damit umzugehen ist, z.B. zu Wissen, wann ein Bypass auftritt, und im Falle dessen ein aufschieben oder einstellen von Tätigkeiten wie das Reinigen
   - ein geeignetes Überwachungsprogramm vorliegt, um die Emissionen, die in Abwasserleitungen gelangen zu überprüfen, dabei müssen potenzielle Hemmstoffe für nachgeschalteten biologischen Verfahren sowie Aktionspläne für solche Fälle berücksichtigt werden.
b. Auswahl der geeigneten Behandlungstechnik entsprechend der Art jeglicher Abwässer
c. Implementierung von Maßnahmen zur Steigerung der Zuverlässigkeit, mit der die erforderliche Kontroll- und Minderungsleistung erzielt wird (zum Beispiel Optimierung der Fällung von Metallen)
d. Ermittlung der wichtigsten chemischen Bestandteile des zu behandelnden Abwassers (einschließlich der Zusammensetzung des CSB) und Durchführung einer Verträglichkeitsbewertung des Verbleibs dieser Chemikalien in der Umwelt.
e. Durchführung täglicher Überprüfungen des Abwassermanagementsystems (wenn täglich Einleitungen stattfinden) und Führung eines Betriebstagebuchs für alle Überprüfungen und Vorhandensein eines Verfahrens zur Überwachung der Abwassereinleitung und Schlammqualität
f. Vorhandensein von Verfahren zur Sicherstellung, dass die Abwasserspezifikationen geeignet für das betriebsinterne Abwasserbehandlungssystem sind oder den Einleitungskriterien entsprechen
g. Vermeidung von Abwasserumgehung an den Behandlungsanlagensystemen
h. Vorhandensein und Betrieb eines geschlossenen Systems, wobei Regenwasser, das auf Betriebsflächen fällt, zusammen mit Tank-Waschwasser, gelegentlichen Verschüttungen, Behälterwaschwasser usw. gesammelt und zur Aufbereitungsanlage zurückgeführt oder in einem kombinierten Abscheider gesammelt wird
i. Sammlung des Regenwassers in einem speziellen Becken und weitere Behandlung in dem Fall, dass Kontaminationen festgestellt werden
j. Vorhandensein eines Betonbodens, der zu den betriebsinternen Entwässerungssystemen hin abfällt, welche wiederum zu Sammeltanks oder Abscheider führen, in denen Regenwasser und Verschüttungen gesammelt werden können. Abscheider mit einem Überlauf zur Kanalisation benötigen üblicherweise automatische Überwachungsverfahren, etwa für den pH-Wert, bei denen die Möglichkeit besteht, dass der Überlauf geschlossen werden kann
k. Wiederverwendung von behandeltem Abwasser und Regenwasser im Verfahren (z. B. als Kühlwasser)
l. Einleitung von gespeichertem Abwasser nur nach Abschluss aller Behandlungsmaßnahmen und einer anschließenden Enduntersuchung
m. Verwendung von Deponiesickerwasser als Input für den aeroben Abbau
n. Prozess- und Oberflächenwasser wird mit Hilfe eines geschlossenen Kreislaufsystems behandelt
o. teilweise Wiederverwendung des Wassers, das zur Herstellung von Polymerlösungen verwendet wird
p. Verdrängungsmethoden zur Behandlung VOC-haltiger chemischer Prozesswässer (ein anderes spezielles Beispiel ist kontaminiertes Grundwasser), was zu einem niedrigeren CSB-Gehalt führt.

Erreichter Nutzen für die Umwelt

Diese Techniken minimieren im Allgemeinen den Schadstoffeintrag in Wasserläufe. Sie können auch das Risiko der Kontamination von Prozess- oder Obenflächenwasser verringern und ebenso Geruchs- und VOC-Emissionen reduzieren.

Betriebsdaten

Der Betrieb ist insbesondere auf eine gute Kontrolle der Einsatzstoffe angewiesen, um sicherzustellen, dass der Abfall den (z.B. biologischen) Behandlungsprozess nicht behindert.

Anwendbarkeit
Allgemein angewendet in den meisten Abfallbehandlungsanlagen. Die Behandlungsoption ist abhängig von der Art der vorliegenden Kontamination des Abwassers. Allerdings dienen bestimmte Maßnahmen der gemeinsamen Behandlung von organischen und anorganischen Schadstoffen. In manchen Fällen, insbesondere bei kleinen Betrieben, kann die Abwasserbehandlung extern durchgeführt werden. Diese zentralen externen Abwasserbehandlungsanlagen behandeln in der Regel Abwasser aus vielen Anlagen, nicht nur aus Abfallbehandlungsanlagen.

Bei der Anwendung von Technik d (siehe obigen Abschnitt "Beschreibung") muss berücksichtigt werden, dass es nicht realistisch ist, eine Umweltverträglichkeitsbewertung für alle Variationen im Abfluss der Abfallbehandlungsanlage durchzuführen.

Die Anwendungshäufigkeit der Technik e (siehe obigen Abschnitt "Beschreibung") wird manchmal von einer Risikobewertung begleitet.

Technik k (siehe obigen Abschnitt "Beschreibung") kann wegen des Anstiegs der Konzentration einiger löslicher Inhaltsstoffe, Beschränkungen unterliegen, wenn diese mit dem Abfallbehandlungsverfahren interferieren.

Technik l (siehe obigen Abschnitt "Beschreibung") kann einen weiteren Lagertank erforderlich machen. Dies kann möglicherweise kostenintensiv sein und Platz erfordern, besonders für kontinuierliche große Durchflussvolumen.

Treibende Kraft für die Anwendung
Wassereinleitungen werden durch lokale/regionale/nationale oder internationale Vorschriften geregelt.

Beispielanlagen
Ein großer Teil der Betriebe in GB betreibt geschlossene Systeme, wobei Regenwasser, welches auf dem Betriebsgelände anfällt, gesammelt und in die verfahrenstechnische Anlage zurückgeführt wird. Es existieren einige Beispiele für die Wiederverwendung von Wasser in Immobilisierungsverfahren und in Altölbehandlungsanlagen nach einer biologischen Behandlung. Weitere Beispiele für die Wiederverwendung von Wasser liegen in Tätigkeiten zum Zwecke des Waschens und Reinigens.

Literatur
[50, Scori, 2002], [51, Inertec, et al., 2002], [52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.7.2 Zu berücksichtigende Parameter vor der Mischung von Abwässern

Beschreibung
Zu den Techniken vor der Mischung von Abwässern, die weiter behandelt werden sollen, gehören:

a. keine Mischung von Abwässern, die adsorbierbare organische Halogenverbindungen (AOX), Cyanide, Sulfide, aromatische Verbindungen, Benzol oder Kohlenwasserstoffe enthalten (gelöste, emulgierte oder ungelöste)
b. bei Metallen werden Quecksilber, Cadmium, Blei, Kupfer, Nickel und Chrom als Klassifizierungsparameter für das Abwassers eingesetzt, da sie wie Arsen und Zink alle zum Teil in gelöster Form, zum Teil als suspendierte Sulfide vorliegen und ihre Konzentration in Abwasserbehandlungsanlagen gesenkt werden muss. Diese Parameter dienen auch der Effektivitätskontrolle der Abwasserbehandlung
c. Sicherstellung, dass Maßnahmen vorliegen, um Abwässer zu separieren, falls die Analyseergebnisse der Proben darauf hinweisen, dass Anforderungen nicht erfüllt wurden. Zwischenfälle dieser Art müssen im Abwassertagebuch festgehalten werden
d. getrennte Abwassersammelsysteme für potenziell stark verschmutztes Wasser (z.B. aus der Lagerung und aus Be- und Entladebereichen) und schwach verschmutzte Wässer (z. B. Regenwasser)
e. Separierung von Drainagesystemen aus Lagerbereichen für entzündliche Abfälle, um zu verhindern, dass Brände über das Drainagesystem durch Lösemittel oder andere entzündliche Kohlenwasserstoffe verbreitet werden.

Erreichter Nutzen für die Umwelt
Verhindert Probleme bei der späteren Behandlung und Verdünnung.

Betriebsdaten
Abfälle und Abwässer enthalten oft eine Mischung von harten und weichen[44] CSB-Verbindungen, die den BSB-Bedarf beeinflussen können.

Anwendbarkeit
Technik d wird in der Regel in zwei getrennten Systemen durchgeführt. Das eine ist für Regenwasser, das in der Regel nicht behandelt wird, das andere sammelt die gesamten restlichen Abwässer, die in der Regel gemeinsam behandelt werden. In manchen Fällen kann Regenwasser, das aus Lagern oder Be- und Entladebereichen stammt, stärker verschmutzt werden.

Beispielanlagen
Die Verfahren, die in C-P-Anlagen durchgeführt werden, werden hydraulisch getrennt in solche mit verschmutztem Abwasser und solche mit unverschmutztem Regenwasser. C-P-Anlagen haben zwei getrennte technische Entwässerungssysteme.

Im Zusammenhang mit Technik e des Abschnitts “Beschreibung” hat es in GB eine Anzahl von Vorfällen gegeben, bei denen Feuer durch das Drainagesystem von einem Bereich zu einem anderen übergegriffen hat.

Literatur
[121, Schmidt and Institute for environmental and waste management, 2002], [134, UBA, 2003], [150, TWG, 2004]

4.7.3 Primäre Abwasserbehandlung

Beschreibung
Zu den Techniken gehören:

a. Sicherstellung, dass das Abwasser frei von sichtbarem Öl ist. Zu dieser Überprüfung müssen Vorgehensweisen gehören, die die richtige Konfiguration, den richtigen Betrieb und die richtige Wartung der Öl/Wasser- Abscheider sicherstellen
b. Anwendung einer Luftstrippung in Belüftungstanks von Deponiesickerwasser, bevor es mit Abwasser aus der Anlage gemischt wird.

Erreichter Nutzen für die Umwelt
Entfernt oder reduziert Zielsubstanzen aus dem Abwasser. Im Zusammenhang mit Technik b im obigen Abschnitt “Beschreibung” ist das Verfahren darauf ausgelegt, überschüssigen Ammoniak und Methan aus den Sickerwässern zu entfernen, bevor diese Emissionen direkt in die Luft übergehen oder im Kanalsystem ein Explosionsrisiko darstellen. Eine geschätzte Freisetzung von 5 t Ammoniak pro Jahr wurde von einem Standort berichtet.

Anwendbarkeit
Das Strippen mit Luft wird eingesetzt, um halogenierte und nicht halogenierte Kohlenwasserstoffe aus verdünnten wässrigen Lösungen zu entfernen, damit die restliche Lösung in der Abwasserbehandlungsanlage unter Einhaltung der Einleitungsbedingungen aufbereitet werden kann. Die Kohlenwasserstoffe werden über Aktivkohlefilter zurückgewonnen. Das Strippen mit Luft ist ideal geeignet für Abwasserströme mit niedrigen Konzentrationen (<200 ppm). Das Strippen mit Dampf ist in der Lage, VOC-Konzentrationen im Wasser auf sehr niedrige Werte zu senken (d.h. ppb-Bereich).

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

[44] Anm.d.Übers.: Im Originaltext wird von „hard“ und „soft“ CSB gesprochen. Direkte Entsprechung sind im Deutschen nicht bekannt. Möglicherweise sind hier „partikuläre“ und „gelöste“ CSB-Verbindungen gemeint.

4.7.4 Sekundäre Abwasserbehandlung

Beschreibung
Zu den Techniken gehören:

a. Vorhandensein einer betriebsinternen Abwasserbehandlungseinheit, die die Vakuumfiltration zur Entfernung kolloidaler Feststoffe einsetzt
b. Sicherstellung, dass der Gehalt an gelösten Metallen minimiert wird, normalerweise durch Einstellung des pH-Werts auf den erforderlichen Wert zur Aufrechterhaltung der minimalen Löslichkeit
c. Sicherstellung, dass die Behandlung der Cyanide (Oxidation der Cyanide) bis zur Beendigung durchgeführt wird, normalerweise durch Aufrechterhalten eines pH-Werts bei >10 und Vermeiden des Ausschleppens von NaOCl aufgrund von Überdosierungen
d. Vorhandensein eines pH-Neutralisationsverfahrens
e. Verwendung eines Flockungsverfahrens um Filterkuchen zu erzeugen, mit einer Neutralisation des Filtrats und einer Einleitung in die Abwasserleitung für den Umgang mit Abfällen aus Latexemulsion und für kontaminiertes Regenwasser des Standorts. Der Filterkuchen weist bei seiner Analyse eine Stickstoffkonzentration von ~51 mg/kg Kuchen auf.

Erreichter Nutzen für die Umwelt
Fällung und Flockung werden eingesetzt, um gelöste Stoffe in Feststoffe umzuwandeln und aufzukonzentrieren, so dass sie durch Einstellung eines geeigneten pH-Werts abgetrennt werden können.

Bei der Fällung werden gelöste anorganische und organische Stoffe durch chemische Reaktion in eine ungelöste feste Phase umgewandelt. Während der Flockung werden physikalisch-chemische Vorgänge (Destabilisierung, Erzeugung von Mikro- und Makroflocken) genutzt, um feine suspendierte oder kolloide Stoffe in einen Zustand zu bringen, in dem sie aus der flüssigen Phase durch mechanische Vorgänge abgetrennt werden können (z. B. Sedimentation, Flotation, Filtration). In der Praxis finden Fällung und Flockung oft parallel mit Adsorptionsvorgängen statt.

Betriebsdaten
Bestimmte anorganische und organische Komplexbildner im Wasser können die Fällungsreaktion unterbrechen oder behindern.

Hohe Konzentrationen an neutralen Salzen erhöhen die Restlöslichkeit bei der neutralen Fällung von Metallen. Wenn die Anforderungen an die Restmetallkonzentrationen nicht erfüllt werden, sind weitere Behandlungsschritte erforderlich, z.B. eine zusätzliche Sulfidfällung, Filtration, Ionenaustausch etc.

Um optimale Bedingungen für die Fällung und Flockung zu gewährleisten, kann eine Vorbehandlung erforderlich sein. Diese kann eine Abtrennung leichter Stoffe, eine Emulsionsspaltung, eine Zerstörung oder eine systematische Entfernung von Komplexen, eine Entgiftung oder eine Vermeidung von Stoffen, die die Reaktion oder die anschließende Abtrennung von Feststoffen unterbrechen, beinhalten. Dies kann möglicherweise auch zu der Anforderung einer getrennten Behandlung von Abfällen und ihren Abwässern führen.

Wenn das Abwasser oberflächenaktive Substanzen enthält, die zu Schäumen in den Reaktionsbehältern führen können, müssen Gegenmaßnahmen ergriffen werden.

Anwendbarkeit
Chemische Fällungen werden hautsächlich angewendet, um Metallionen aus Abwässern zu entfernen und Phosphat chemisch zu eliminieren. Abgesehen von der Abtrennung der Fällungsprodukte entfernt die Flockung auch suspendierte Feststoffe und hochmolekulare Verbindungen.

Für Fällung und Flockung können folgende Punkte von Bedeutung sein und sollten berücksichtigt werden:

- Eine chemische Fällung sollte zu Verbindungen führen die entsprechend niedrige Löslichkeitsprodukte besitzen
- Um optimalen Kontakt zwischen den Reaktionspartnern zu gewährleisten, ist ein ausreichendes Mischen im Fällungsreaktor notwendig. Eine effektive Flockung erfordert auch eine schnelle und gleichmäßige Verteilung der Flockungsmittel. Rühren ermöglicht die Bildung von Flocken, die gut sedimentieren, wobei übergroße Scherkräfte vermieden werden sollten.
- Trennung der Koagulationsphase (Kompensation des elektrischen Potenzials der Kolloide) und der Flockungsphase in zwei getrennte Schritte ist in vielen Fällen ein geeigneter Weg, um ein gutes Flockungsergebnis zu erzielen
- Die Rückführung des Kontaktschlamms verbessert die Bildung von kompakten, schweren Flocken und gewährleistet die optimale Ausnutzung der Reagenzien
- Ein mehrstufiges Fällungs- und Flockungsverfahren unterstützt das schrittweise Erreichen eines optimalen pH-Werts und die effiziente/effektive Kombination verschiedener Fällungs- und Flockungstechniken (z.B. Hydroxidfällung mit anschließender Sulfidfällung).

Literatur
[55, UK EA, 2001], [134, UBA, 2003]

4.7.5 Tertiäre Abwasserbehandlung

Beschreibung
Zur Eliminierung biologisch abbaubarer organischer Verbindungen und Stickstoffverbindungen haben sich wiederholt biologische Behandlungsverfahren als effektiv erwiesen. Im Gegensatz zu anderen Behandlungstechniken werden in biologischen Behandlungen Mikroorganismen genutzt, die entsprechend der mannigfaltigen existenziellen Grenzbedingungen reagieren können und deshalb in der Lage sind, sich optimal an die abzubauenden Verbindungen anzupassen (Adaptation). Unter anaeroben Bedingungen entwickeln sich verschiedene Bakterienpopulationen, was den Abbau eines breiten Spektrums von Stoffen ermöglicht. Im optimalen Fall schreitet der Abbau bis zu dem Punkt fort, an dem anorganische Stoffe wie CO_2 und H_2O gebildet werden (Mineralisation). Zu den tertiären Techniken gehören:

a. a. Anwendung der biologischen Behandlung für Abwasser mit hohem BSB-Gehalt. Schädliche und persistente Stoffe, die einen wesentlichen Anteil an der CSB-Fracht ausmachen, wie etwa Lösemittel, Pestizide, organische Halogene und andere organische Stoffe können an Partikel und Kolloide adsorbiert und anschließend als fester Rückstand entfernt werden. Das Behandlungsverfahren entscheidet aber nicht über die Effizienz und die Entfernung ist sehr variabel. Als „Daumenregel“ sollte, um Biodegradation zu ermöglichen, das CSB/BSB-Verhältnis im Abwasser bei der Einleitung in die Abwasserleitung in der Regel nicht über 10:1 liegen
b. Absetzen
c. Eindicken und Entwässern
d. nasse Oxidation mit Luft

Erreichter Nutzen für die Umwelt
Senkt den BSB und folglich die CSB-Fracht des Abwassers. Gleichzeitig können Stickstoff und einige Mikroelemente (z.B. Zn) durch die biologische Behandlung abgefangen werden. Den Abbau von organischen Verbindungen wird von Mikroorganismen durchgeführt, deren Aktivität stark von ihren Umweltbedingungen abhängt, was zu einer gewissen Schwankung im Wirkungsgrad des Verfahrens führt.

Parameter	Zufluss (Primärabwasser)		Abwasser nach der biologischen Behandlung (Sequential-Batch-Reaktor)	
	Minimum (mg/l)	Maximum (mg/l)	Minimum (mg/l)	Maximum (mg/l)
CSB	2500	12000	600	1500
NH_4-N [1)]	25	16000	<1	150
Nitrit	10	300	<1	<1
Nitrat	10	1000	<1	<1
Phenole	10	500	<2	<2
Ölgehalt	--	--	<0,5	--
[1)] Abwasser nach der biologischen Behandlung: Oft um 20 mg/l				

Tabelle 4.76: Konzentrationen im Abwasser einer C-P-Anlage vor und nach der tertiären Abwasserbehandlung

Medienübergreifende Auswirkungen
Mineralisierung organischer Substanzen und Produktion von Biomasse. Durch Adsorptionsprozesse und Bioakkumulation können anorganische und nicht abbaubare organische Verbindungen in der Biomasse angereichert werden.

Betriebsdaten
Bestimmte organische und anorganische Inhaltsstoffe des Abwassers können einen toxischen Effekt auf die Bakterienpopulation haben. Auf Grund des Nährstoffbedarfs, den biologische Prozesse benötigen, können niedrige Phosphorkonzentrationen ein limitierender Faktor für die Vitalität der Bakterien werden (dieses Problem kann möglicherweise durch eine systematische Zugabe von Nährstoffen gelöst werden). Für alle z.Zt. eingesetzten biologischen Behandlungsverfahren muss eine Anzahl von spezifischen Eigenschaften und Grenzbedingungen berücksichtigt werden:

- Für den biologischen Abbau werden Nährstoffe (Stickstoff, Phosphor) und Spurenelemente (Metalle etc.) benötigt
- Optimale pH-Bereiche (üblicherweise pH-Wert 6,5 – 8,5) müssen im Reaktor aufrechtgehalten werden
- Damit der Prozess aufrechterhalten wird, sind Sauerstoffgehalte über 1 mg/l notwendig
- Die Aktivität der Mikroorganismen steigt mit ansteigender Temperatur, bis zu einem Optimum bei etwa 30 – 35 °C. Unter 10 °C verlangsamen sich die Reaktionen üblicherweise drastisch
- Für die Funktion des Verfahrens ist die Rückhaltung von Biomasse von besonderer Bedeutung.

Biologische Anlagen sollten mit einer ausreichenden Verweilzeit ausgelegt werden, um einen geeigneten Abbau der im Abwasser vorliegenden komplexeren Verbindungen zu erzielen.

Die Schlammalterung ist auch von Bedeutung. Optimale Betriebstemperaturen können den Abbau fördern. Zurzeit sind einige aerobe Anlagen geplant, die bei Temperaturen um 30 °C arbeiten sollen.

Anwendbarkeit
Die biologische Behandlung ist eine sehr wirksame Technik zur Eliminierung von:

- einer großen Anzahl biologisch abbaubarer organischer Kohlenstoffverbindungen. Selbst wenn die Analyse des Abwassers eine niedrige biologische Abbaubarkeit aufweist (BSB5/CSB-Verhältnis <0,1), können immer noch 40 – 50 % des CSB entfernt werden (bei nur geringer Erzeugung von Biomasse)
- Stickstoffverbindungen. Organischer Stickstoff und Ammonium können über Nitrit zu Nitrat umgewandelt werden. Emissionswerte unter 10 mg NH4+-N/l können leicht erreicht werden, Werte <1 mg NH4+-N/l sind üblich. Nitrat oder Nitrit kann in elementaren Stickstoff umgewandelt werden.

Beispielanlagen
Im Sektor weit verbreitet.

Literatur
[55, UK EA, 2001], [134, UBA, 2003], [150, TWG, 2004]

4.7.6 Endbehandlung des Abwassers

Beschreibung
Die Endbehandlung bezieht sich auf jedes Verfahren, das als „Schönungsphase“ betrachtet wird, die in der Regel nach der tertiären Behandlung, falls vorhanden, durchgeführt wird und auch eine Rückgewinnung bestimmter Substanzen enthalten kann. Die folgende Tabelle 4.77 zählt einige solche Techniken auf:

Technik	Beschreibung
Makrofiltration	Sandfiltration, gemischte Filtermedien (zum Beispiel Sand/Anthrazit-Mischungen) oder spezialisiertere Arten von Filtrationsmedien wie granulierte Aktivkohle
Starke Reduktion	
Nasse Oxidation mit Luft	Die nasse Oxidation mit Luft ist eine Schadstoff zerstörende physikalisch-chemische Behandlungsmethode, die eingesetzt wird, um Abwässer mit hohen CSB-Gehalt zu behandeln, die sich nicht für eine direkte Einleitung in eine Abwasserbehandlungsanlage eignen, deren Verbrennung jedoch zu teuer ist
Starke Reduktion mit Hydrazin	
Ionenaustausch	Entfernung von Nitrat und Metallen, Aufkonzentrierung von Metallen

Tabelle 4.77: Endbehandlungen für Abwasser

Erreichter Nutzen für die Umwelt
Der Nutzen dieser Technik besteht in der abschließenden „Schönung“ des Abwassers und der Rückgewinnung von Stoffen aus dem Abwasser, bevor es wiederverwendet oder in die Kanalisation, Oberflächenwasser usw. eingeleitet wird.

Der Anwendungsbereich diese Filtrationstechniken (einschließlich Sandfilter) kann in der Entfernung von Partikeln aus dem Abwasser bestehen, wodurch sich eine Möglichkeit zur Senkung der Konzentration von suspendierten Feststoffen im Abwasser bietet.

Bei der Makrofiltration werden suspendierte Feststoffe, bestimmte Chemikalien, Geschmack und Gerüche entfernt.

Medienübergreifende Auswirkungen
Bei der Makrofiltration mit granulierter Aktivkohle ist eine Regeneration erforderlich, diese wird üblicherweise mittels Verbrennung durchgeführt.

Betriebsdaten
Bei Filtrationsvorgängen ist Druck erforderlich. In manchen Fällen werden sehr hohe Drücke benötigt (z.B. bei der Umkehrosmose).

Bei Versuchen des Einsatzes der nassen Oxidation mit Luft für manche Abfallbehandlungen zeigten sich Probleme im Zusammenhang mit heterogenen und schwankenden Abfall-Einsatzstoffen, folglich werden sie derzeit in der Abfallbehandlung nicht angewandt. Sie werden jedoch in anderen Sektoren angewendet, falls sie für ausgewählte Prozesse mit spezifischen Abfallströmen an dem Standort geeignet sind.

Anwendbarkeit
Die Adsorption ist ein einfaches und zuverlässiges Verfahren, ein Chargenbetrieb ist möglich.

Treibende Kraft für die Einführung
Die Notwendigkeit dieser Behandlungen wird von drei potenziellen Faktoren bestimmt:

- Anforderung zur Einhaltung der in der Genehmigung gelegten Einleitungsbedingungen
- Ermöglichung der Aufbereitung von Abwasser zu Prozess- oder Waschwasser
- Erleichterung der Rückgewinnung, d.h. von Öl aus ölverunreingtem Wasser, z.B. durch Ultrafiltration.

Filtrationsverfahren werden z.Zt. von einigen Wasserbetrieben bei der Einleitung aus Abwasserbehandlungsanlagen eingesetzt, vor allem zur Reduzierung von Pathogenen im Abwasser.

Hydrazin ist ein gefährlicher Stoff, der Berichten zufolge in mindestens einem Mitgliedsstaat verboten ist.

Beispielanlagen
Es existiert eine Beispielanlage in der 90 % der Hg-Emissionen aus Kontaminationen des Bodens entstammen, welche dann in die Leitungssysteme gelangen. Bei der Firma Akzo Nobel in Bohus (Schweden), einer quecksilberbasierten Chlor-Alkali-Anlage, besteht das Verfahren zur Entfernung von Quecksilber aus dem Abwasser aus einem Mischbehälter, in dem Hydrazin zum Abwasser gegeben wird, zwei Sedimentationstanks, Sandfiltern, Aktivkohlefiltern und Ionenaustauschern. Der Durchfluss des behandelten Abwassers lag im Jahr 1997 bei 7 m3/h bei einem Quecksilbergehalt von 3000 - 5000 µg/l und einer Endkonzentration von Quecksilber im Abwasser von 5 - 8 µg/l, entsprechend einer Emission von 0,005 g Hg/Tonne Chlorkapazität. Am Standort lag die Gesamt-Quecksilberemission in das Wasser bei etwa 0,045 g Hg/Tonne Chlorkapazität, was bedeutete, dass etwa 10 % der Quecksilberemissionen aus dem Verfahren selbst stammten, während die anderen 90 % indirekte Emissionen aus abgelagertem Quecksilber waren, die ins Oberflächenwasser gelangten.

Literatur
[41, UK, 1991], [42, UK, 1995], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.7.6.1 Eindampfung

Beschreibung
Das Ziel der Behandlung ist die Aufkonzentrierung von Abwasserbestandteilen in besser handhabbare Volumina.

Indem das Eindampfen in mehrere kleinere Schritte aufgeteilt und Vakuum genutzt wird, um die Siedetemperatur zu senken, kann der Energieverbrauch optimiert werden.

Abhängig von der Temperatur findet das Eindampfen üblicherweise ohne chemische Umwandlung von Stoffen statt. Während des Aufkonzentrierens können Phasen gebildet werden, die eine weitere Trennung begünstigen (z.B. eine Kristallisation).

Erreichter Nutzen für die Umwelt
Senkt die Abwassermenge, die behandelt werden muss.

Medienübergreifende Auswirkungen
Der Energieverbrauch steigt an. Wenn die Materialien nicht für eine Verwertung geeignet sind, können die Eindampfrückstände abhängig von ihren Inhaltsstoffen nach einer geeigneten Nachbehandlung (wie etwa Trocknung, Entwässerung, Konditionierung) deponiert werden. Da das Eindampfen im Idealfall zu einem leicht verschmutzten Dampfkondensat führt, muss das Kondensat üblicherweise, abhängig von seinen Inhaltstoffen, einer Nachbehandlung und Reinigung unterzogen werden.

Betriebsdaten
Grenzen der Behandlung:

- Für die Auswahl des Inputmaterials für die Eindampfanlage müssen die Inhaltsstoffe des Abwassers berücksichtigt werden
- Wenn das Abwasser oberflächenaktive Substanzen enthält, die zu Schäumen während des Eindampfprozesses führen könnten, müssen Maßnahmen zur Schaumreduzierung getroffen werden. Nebem dem Einsatz von Separatoren kann der Einsatz von Entschäumern notwendig sein.

Einrichtungen zur mechanischen Entfernung von “Krusten” oder zur Ableitung fester Substanzen, die während des Eindampfens akkumulieren, müssen zur Verfügung stehen.

Anwendbarkeit
Die Behandlung ist für stark verschmutzte Abwässer geeignet, aus denen alle nicht flüchtigen anorganischen und organischen Bestandteile eliminiert werden müssen. Das Eindampfen ist z.B. geeignet, Abwässer, die bereits durch Umkehrosmose oder Ultrafiltration eingedickt wurden, noch weiter zu konzentrieren.

Beispielanlagen
Chemisch-physikalische Behandlung von Abwässern.

Literatur
[134, UBA, 2003], [150, TWG, 2004]

4.7.6.2 Adsorption

Beschreibung
Die Adsorption an Aktivkohle wird hauptsächlich zur Abtrennung organischer Stoffe aus Abwässern angewendet. Z.Zt. werden zwei verschiedene Methoden genutzt:

- Zugabe von meist pulverförmiger Aktivkohle zum zu behandelnden Abwasser
- Leiten des Abwassers über mehrere Adsorptionssäulen, die in Serie geschaltet und mit granulierter Aktivkohle befüllt sind.

Erreichter Nutzen für die Umwelt
Reduzierung von organischen Stoffen im Abwasser.

Medienübergreifende Auswirkungen
Beim Einsatz von pulverförmiger Kohle muss die Kohle nach ihrem Einsatz vom Abwasser getrennt werden. Abhängig von den adsorbierten Stoffen kann sie verbrannt oder auf geeigneten Deponien abgelagert werden. Granulierte Aktivkohle wird üblicherweise in externen Anlagen regeneriert.

Anwendbarkeit
Dieses Behandlungsverfahren eignet sich vor allem für die Entfernung organischer Stoffe aus Abwässern. Wenn einzelne Schadstoffe oder Schadstoffgruppen (z.B. AOX) selektiv entfernt werden müssen, kann das Verfahren durch Betrachtung der spezifischen Eigenschaften des Abwassers (Art und Menge der enthaltenen Stoffe) optimiert werden und somit kann die Adsorption an einzelne Fälle adaptiert werden (Form und Eigenschaften der Kohle, Adsotptionszeit, Säulengröße und -anordnung usw.).

Da Feststoffe die Oberfläche der Aktivkohle belegen und dadurch die Poren blockieren können, müssen sie vor der Behandlung mit Aktivkohle entfernt werden.

Beispielanlagen
Die Adsorption an Aktivkohle wird häufig dazu genutzt, um Betreibern zu ermöglichen, den genehmigten Höchstwert von AOX ≤ 1 mg/l einzuhalten. Die Adsorption an Aktivkohle trennt allerdings nicht selektiv die AOX-bildenden Materialien ab, sondern eher eine hohe Anzahl von anderen organischen Stoffen.

Literatur
[134, UBA, 2003]

4.7.6.3 Membranfiltration

Beschreibung
Die Trennung von Stoffen in Membranverfahren wird durch unterschiedlichen Durchlässigkeiten der Membran für unterschiedliche chemische Bestandteile bewirkt. Mindestens ein Bestandteil der Stoffmischung, die getrennt werden soll – üblicherweise das Lösemittel – muss in der Lage, die Membran ohne Widerstand zu passieren, während die anderen Bestandteile in einem stärkeren oder geringerem Maße zurückgehalten werden. Die zurückgehaltene Fraktion ist das Konzentrat; das Material, das die Membran passiert, nennt man Permeat.

Folgende Behandlungsverfahren, gruppiert nach ihren Porengrößen, werden z.Zt. technisch genutzt:

- Mikrofiltration (MF) (>0,6 µm, >500000 g/mol)
- Ultrafiltration (UF) (0,1 – 0,01 µm, 1000 – 500000 g/mol)
- Nanofiltration (NF) (0,01 – 0,001 µm, 100 – 1000 g/mol)
- Umkehrosmose (<0,001 µm, <100 g/mol)

Folgende Punkte müssen berücksichtigt werden:

a. Der pH-Wert im zu behandelnden Abwasser kann verschoben werden, um Reaktionen zu beschleunigen und/oder Beladungswerte zu verbessern
b. Ein Feinfilter kann vor dem Aktivkohlefilter angeschlossen werden, um schädliche Feststoffe zurückzuhalten
c. Eine Befeuchtung der Aktivkohle, die Verwendung feiner Granulate anstelle von Pulvern und die Zugabe in den Reaktor/Becken unterhalb des Wasserspiegels kann dazu beitragen, Probleme der Staubbildung beim Rühren zu beherrschen.

Erreichter Nutzen für die Umwelt
Durch den Einsatz von Membrantechniken können Abwässer mit organischen und anorganischen Schadstoffen ohne bedeutende Zugabe von Chemikalien behandelt werden.

Medienübergreifende Auswirkungen
Durch eine Prozessoptimierung sollte das Permeat einer Membrananlage üblicherweise genügend gereinigt sein, um in das industrielle Verfahren zurückgeführt zu werden oder die Mindestqualitätsanforderungen für die Einleitung in Gewässer zu erfüllen. Das Konzentrat wird üblicherweise einer weiteren Behandlung unterzogen, wie etwa:

- Wiederverwendung
- Beseitigung
- Eindampfung
- Immobilisierung.

Anwendbarkeit
Membrantechniken, die zur Stofftrennung und Aufkonzentration eingesetzt werden, haben sich zu einer Schlüsseltechnologie der Wasser- und Abwasserbehandlung entwickelt, weil keine Chemikalien erforderlich sind – bis auf die Reinigung der Membran - da es sich ausschließlich um eine technische Art der Trennung handelt. Folglich sind die getrennten Bestandteile weder chemisch noch thermisch verunreinigt. Infolge dieser Faktoren ist die Behandlung selbst in kleineren Anlagen kosteneffizient, und eine dezentralisierte Behandlung der Abwässer am Ort ihrer Entstehung ist auch möglich.

Die Anwendbarkeit der Membrantechniken wird sowohl durch die Konstruktion als auch durch die Auslegung der Module/Membrananlagen und durch eine Anzahl zusätzlicher limitierender Faktoren beeinflusst.

Dazu gehören:

- Beschädigungsfaktoren: Freies Chlor, organische Lösemittel, starke Oxidantien
- Verstopfungsfaktoren
- Verschmutzungen (Metallhydroxide, Kolloide, biologische Stoffe, organische Stoffe)
- Kesselsteinbildung (Ausfällung von Salzen geringer Löslichkeit)
- leistungsmindernde Faktoren
- osmotischer Druck, Viskosität.

Allerdings gelten diese Faktoren üblicherweise nicht ausschließlich für Membrantechniken. Dennoch erfordern sie im Allgemeinen eine ausführliche Vorbewertung des zu behandelnden Wassers im Hinblick auf:

- Wahl der Membran (Polymer oder Keramik)
- Wahl des Materials (Kunststoff, Stahl)
- notwendige Vorbehandlung (Filtration, Hemmung, Biozide etc.)
- Reinigungsprogramm (sauer, alkalisch).

Beispielanlagen

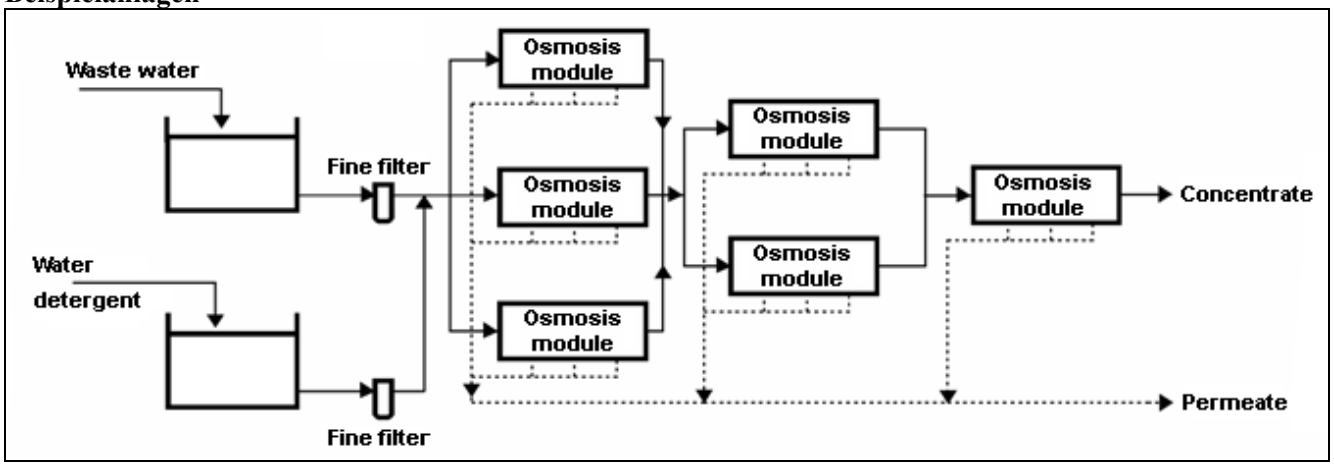


Abbildung 4.11: Beispieldiagramm einer dreistufigen Umkehrosmoseanlage
[150, TWG, 2004]

Literatur
[134, UBA, 2003], [150, TWG, 2004]

4.7.6.4 Ozon/UV-Behandlung

Beschreibung
Stark verschmutzte Abwässer können mit Ozon allein oder mit Ozon und UV-Licht in Verbindung mit biologischen Behandlungsverfahren behandelt werden.

Die Ozonreaktion ist eine nasse chemische Reaktion. Bei pH-Werten unter 9 reagiert Ozon durch die Zersetzung ionisierend, wobei ein aktives Sauerstoffatom oder ein Radikal durch Adsorption des gesamten Moleküls an organische Kohlenstoffdoppelbindungen entsteht, diese werden bei pH-Werten über 9 wieder aufgebrochen. Unter Einwirkung von UV-Licht können aus Ozon auch Sauerstoffradikale oder Hydroxylradikale gebildet werden. Diese Radikale sind sogar noch reaktiver als Ozon.

Außerdem können Stickstoffverbindungen durch eine Kombination der Ozonbehandlung mit biologischen Verfahren abgebaut werden. Dabei wird das Abwasser von der Zulaufpumpe zum Denitrifikationsbehälter transportiert. Dem Zulauf wird Phosphorsäure zugegeben. Bevor die Flüssigkeit in den Denitrifikationsbehälter eintritt, wird der Rücklauf aus der Nitrifikation hinzugegeben.

In Ozonreaktoren kann das Ozon mit den im Abwasser enthaltenen oxidierbaren Stoffen reagieren. In nachgeschalteten UV-Reaktoren wird das noch im Wasser verbliebene Ozon zerstört oder in Radikale umgewandelt, die dann ebenfalls mit organischen Stoffen reagieren können.

Der verbliebene Sauerstoff wird von aeroben Bakterien zur Nitrifikation genutzt.

Nach der Behandlung mit Ozon und UV-Licht wird ein Teil des im Kreislauf geführten Wassers als gereinigtes Abwasser in den Auslauf eingeleitet.

Erreichter Nutzen für die Umwelt
Die nasse chemische Oxidation mit Ozon allein oder mit Ozon in Kombination mit UV-Licht senkt die Konzentrationen von:

- gelösten organischen Kohlenwasserstoffen (DOC)
- halogenierten Kohlenwasserstoffen
- polyzyklischen aromatischen Kohlenwasserstoffe[45] (PAK)
- Pestiziden
- Dioxinen
- (pathogenen) Mikroorganismen.

Das Ziel der nassen chemischen Oxidation ist die direkte Zersetzung von Schadstoffen bei niedrigem Druck und niedriger Temperatur. Ozon reagiert mit allen organischen Stoffen, die Kohlenstoffdoppelbindungen besitzen.

Einige kurzkettige aliphatische Verbindungen und Kohlenstoff-Halogen-Verbindungen reagieren träge mit Ozon. Die Bindungen dieser Moleküle können einfacher zerstört werden, wenn Ozon und UV-Licht in Kombination angewendet werden.

Abhängig von den Grenzbedingungen (Art der Abwasserbestandteile, Ozoneintrag, Reaktionszeit) kann die Reaktion Kohlendioxid am Punkt vollständiger Oxidation, biologisch abbaubare Stoffe (Anstieg des BSB5) oder Stoffe, die schwach biologisch abbaubar sind, erzeugen.

Medienübergreifende Auswirkungen
Wenn eine Ozon/UV-Behandlung mit einem biologischen Schritt kombiniert wird, werden durch die biologische Behandlung Schlämme erzeugt, die dann einer weiteren Behandlung unterzogen werden müssen.

Anwendbarkeit
Folgende Punkte müssen beachtet werden:

- Längerkettige aliphatische Verbindungen ohne Doppelbindungen werden durch Ozon/UV-Behandlung nicht verändert
- Bei gefärbtem oder dickflüssigem Abwasser ist eine Behandlung nur möglich, wenn eine UV-Behandlung zur Zersetzung der Inhaltsstoffe nicht notwendig ist
- Anorganische Stoffe im Abwasser werden nicht verändert, und hohe Salzkonzentrationen können zu einer Unterbrechung des Prozesses führen.

Beispielanlagen

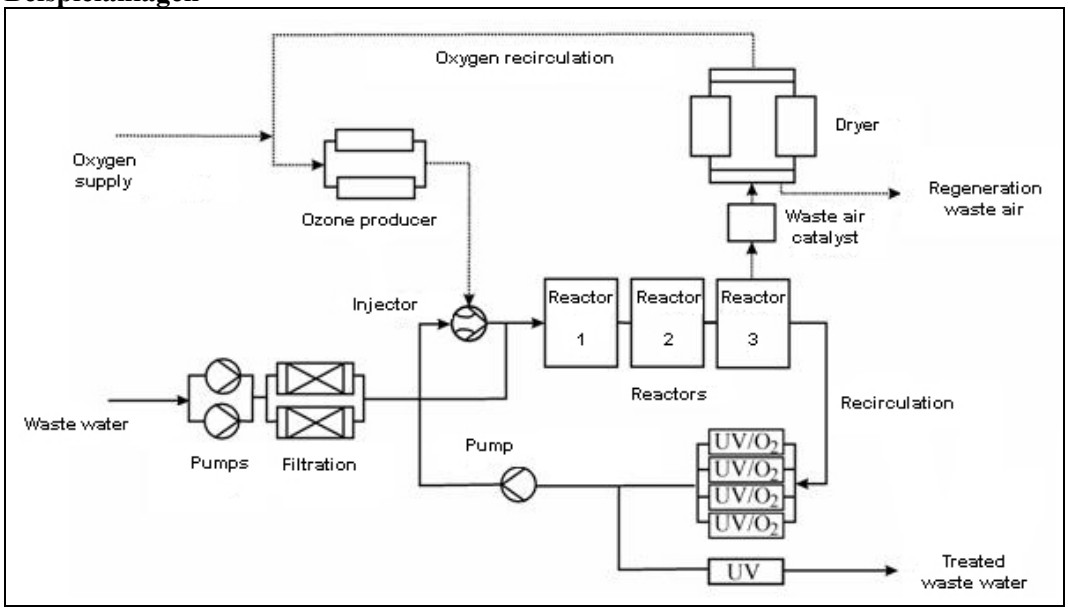


Abbildung 4.12: Beispiel eines Flussdiagramms für eine Ozon/UV-Behandlung von Abwasser [150, TWG, 2004]

[45] Anm.d.Übers.: Im Originaltext wird der Begriff "Kohlenhydrate" genutzt.

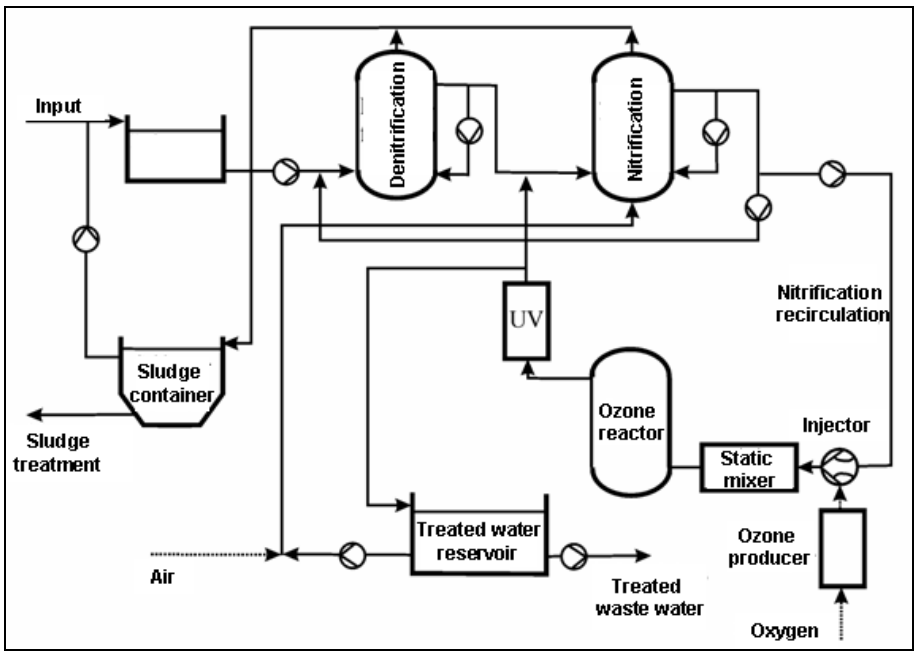


Abbildung 4.13: Beispiel eines Flussdiagramms für eine biologische und UV-Behandlung [150, TWG, 2004]

Literatur
[134, UBA, 2003], [150, TWG, 2004]

4.7.7 Berichterstattung über die Bestandteile des in Abfallbehandlungsanlagen erzeugten Abwassers

Beschreibung
Dieser Abschnitt soll Leitlinien aufzeigen, welche Abwasserparameter (Schadstoffe) des Abwassers einer Abfallbehandlungsanlage analysiert werden sollen. Die folgende Tabelle 4.78 enthält Informationen über untersuchte Wasserparameter, die erreichbaren Konzentrationen, der Häufigkeit der Messung und Hinweise, ob ein solcher Parameter kontinuierlich überwacht werden sollte, und welcher Typ von Abfallbehandlungsanlage welche Untersuchung von bestimmten Parametern erforderlich macht.

Wasser parameter	Erreichte Emissions-konzentrationen (mg/l)	Mittelung über die Zeit (kontinuierlich, täglich, monatlich, jährlich)	Beispiel von Abfallbehandlungsanlagen, aus denen die Daten zum Parameter berichtet wurden
pH		Kontinuierlich	Alle
Trockene Feststoffe	17000 – 27000		C-P-Anlagen
Suspendierte Feststoffe	0,1 – 79	Kontinuierlich	Alle
Leitfähigkeit (µS/cm)	900 – 21000	Kontinuierlich	CP-Behandlungen
Gesamt-Stickstoff	110 – 3500	Monatlich	Biologische und CP-Behandlungen
Ammoniak	10 – 2500		Biologische und CP-Behandlungen
Nitrit	0,01 – 10		Alle
Nitrat	0,9 – 10		Biologische und CP-Behandlungen
Gesamt- Phosphor	<0,1 – 2,6	Monatlich	Beim Umgang mit phosphorhaltigem Abfall, z.B. in C-P-Anlagen
Gesamt-Chlorid	1500 – 18240		Biologische und CP-Behandlungen
Freies Chlor	≤0,1 – 0,4		CP-Behandlungen
Freies Cyanid	<0,01 – 0,1		CP-Behandlungen
Fluorid	0,5 – 10		CP-Behandlungen
Gesamt-Cyanid	≤0,1		CP-Behandlungen
Sulfat	65 – 1070		CP-Behandlungen
Sulfit	≤1 - 50		CP-Behandlungen
Sulfide	≤0,1		CP-Behandlungen
Aquatische Toxizität			
Mikrobielle Indikatoren (z.B. Pathogene)			
Bakterienlumineszenz			
BSB	20 – 3000		
BTEX	<0,1 – 0,7		CP-Behandlungen
CSB	120 – 5000		Alle
Oberflächenaktive Stoffe	0,6 – 5,3		
Kohlenwasserstoffe	<0,1 – 3,8		Alle
PAH			
AOX	0,1 – 0,5		Alle
Phenole	0,1 – 1,9		CP-Behandlungen
VOC	<0,01 – 0,1		CP-Behandlungen
Lösemittel			
TOC			
Mineralöl-Kohlenwasserstoffe			
Metalle		Monatlich	CP-Behandlungen
Ag	≤0,1		
Al	<0,1 – 2		CP-Behandlungen
As	<0,01 – 0,1		Arsenhaltige Abfälle CP-Behandlungen
Ba	≤5		CP-Behandlungen
Cd	≤0,1		CP-Behandlungen
Co	<0,1 – 1,0		CP-Behandlungen
Cr(VI)	<0,01 – 0,1		CP-Behandlungen
Cr	<0,1 – 0,5		CP-Behandlungen
Cu	≤0,1 – 0,5		CP-Behandlungen
Fe	0,1 – 5,2		CP-Behandlungen
Hg	0,001 – 0,01		CP-Behandlungen
Mn	<0,1 – 0,9		
Ni	<0,1 – 1,0		CP-Behandlungen
Pb	<0,1 – 0,5		CP-Behandlungen
Se	≤0,1		CP-Behandlungen
Sn	<0,1 – 2,0		CP-Behandlungen
Zn	<0,1 – 2,0		CP-Behandlungen

Tabelle 4.78:Überwachte Wasserparameter in Abfallbehandlungsanlagen
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [134, UBA, 2003], [59, Hogg, et al., 2002], [150, TWG, 2004]

Erreichter Nutzen für die Umwelt
Ermittlung und Unterstützung bei der Überwachung von Schadstoffen, die üblicherweise freigesetzt werden.

Beispielanlagen
Im Allgemeinen spiegelt die Einleitungserlaubnis die am Standort durchgeführte Tätigkeit wieder, d.h. diejenigen Anlagen, die mit großen Volumina von Lösemitteln umgehen, müssen den Lösemittelgehalt untersuchen, andere müssen möglicherweise nur auf pH-Wert und CSB überprüfen.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [134, UBA, 2003], [59, Hogg, et al., 2002], [150, TWG, 2004]

4.7.8 Beispiele zu Abwasserbehandlungsanlagen in diesem Sektor

Ein Beispiel ist eine Abwasserreinigungsanlage, die in Altölbehandlungsanlagen genutzt wird und in der wässrige Abfälle eine chemisch-physikalische Anlage durchlaufen können, in der Eisenchlorid als Flockungsmittel zugegeben und Schlamm über die Filterpresse abgezogen wird. Der wässrigen Phase können danach Polyelektrolyte und Kalk zur Erhöhung des pH-Werts zudosiert werden, wodurch eine weitere Schlammschicht erzeugt wird, die anschließend zur Schlammpresse geht. Die Flüssigkeiten der Presse sowie der flüssige Überstand werden in eine biologische Behandlung geleitet, wo nun die Flüssigkeiten im Wesentlichen frei von Ölrückständen und Metallen sind, und der Gesamt-CSB auch gesenkt wurde.

4.8 Reststoffmanagement

Das Wort “Reststoff” wird in diesem Abschnitt benutzt, um den festen Abfall zu bezeichnen, der bei der Abfallbehandlung erzeugt wird und nicht in direkter Beziehung zu der in der Anlage behandelten Abfallart steht. Diese Konvention wird in Kapitel 3 und durch das gesamte Dokument verwendet (siehe auch Glossar). Zur Erinnerung, in Kapitel 3 wurde der Abfall, der aus der Anlage kommt, als Abfall-OUT bezeichnet. Der Abfall-OUT steht in direkter Beziehung zu dem Abfall-IN der Anlage. In Kapitel 3 wurde solcher Abfall prozessbedingter Abfall genannt, wie die Grafik in Abbildung 3.1 zeigte. Dieser Abschnitt enthält die folgende Techniken:

- Techniken zur Verringerung des Abfalls, der infolge der Behandlung generiert wird (untersucht in allen vorangehenden Abschnitten dieses Kapitels)
- Management des erzeugten Abfalls infolge der Behandlung und
- Techniken mit Fokus auf die Verringerung von Bodenkontamination.

4.8.1 Reststoffmanagementplan

Beschreibung
Die Abfallminimierung ist eine systematische Methode zur Verringerung des Abfalls an der Quelle. Dabei wird durch Verständnis und daraus folgenden notwendigen Veränderungen der Verfahren und Tätigkeiten Abfall vermieden und reduziert. Ein breites Spektrum von Techniken kann unter den allgemeinen Begriff der Abfallminimierung eingestuft werden. Ihr Umfang reicht:

- von grundlegenden Techniken der Betriebsführung
- über statistische Messtechniken
- über Anwendung sauberer Technologien
- über die Nutzung von Abfall als Brennstoff.

Im Einzelnen gehören zu den Techniken:

a. Untersuchung des Schlammes/Filterkuchens, um zu gewährleisten, dass die Verfahrensziele erreicht werden und dass das Verfahren effektiv arbeitet. Filterkuchen und Schlämme aus der Behandlung werden in der Regel weniger häufig untersucht, aber eine Untersuchung könnte es immer noch ermöglichen, eine Berechnung der Metallkonzentrationen durchzuführen. Filterkuchen und Behandlungsschlämme eignen sich normalerweise nicht für eine Deponierung, weil sie die Anforderungen der Deponierichtlinie nicht erfüllen.
b. Identifizierung, Charakterisierung und Quantifizierung aller erzeugten und von der Anlage abzutransportierenden Abfallströme. Der Einsatz eines Abfallrückverfolgungssystems kann Betreibern helfen, Aufkommen, Art, Herkunft und, wo es relevant ist, den Zielort, die Häufigkeit der Sammlung, die Art des Transports und die Behandlungsmethode für jeden Abfall aufzuzeichnen, der an dem Standort beseitigt oder verwertet wird.
c. Identifizierung der augenblicklichen oder beabsichtigten Behandlungseinrichtungen
d. vollständige Beschreibung der beabsichtigten Verwertung oder Beseitigung für jeden Abfallstrom. Wenn eine Beseitigung vorgesehen ist, muss erläutert werden, warum eine Verwertung technisch und ökonomisch nicht möglich ist, und danach beschrieben/erklärt werden, welche geplanten Maßnahmen zur Vermeidung oder Verringerung von Umweltauswirkungen vorgesehen sind
e. Sicherstellen, dass der Gehalt an trockenen Feststoffen nicht unter 15 Gew.-% liegt, um den Umgang mit der Mischung zu erleichtern
f. Sicherstellen, dass Staubansammlungen, die entfernt werden müssen, z.B. auf pH-Wert, CSB, Schwermetalle und andere bekannte Verunreinigungen aus Verschüttungen untersucht werden, um zu gewährleisten, dass der richtige Beseitigungsweg gewählt wird.

Einige Minderungstechniken sind:

g. Recycling des Filterkuchens aus der Behandlung saurer und alkalischer Lösungen und aus der Metallfällung, da er Metalle wie Zink und Kupfer im Prozentbereich enthalten kann, die sich für eine Rückgewinnung von Metallen eignen
h. Recycling kontaminierter Fässer. Unbeschädigte 205-Liter-Fässer und 800- und 1000-Liter IBCs können durch Säuberung und Instandsetzung verwertet werden. Zerstörte Behälter, für deren Instandsetzung kein Markt besteht und die nicht gefährliche Abfälle enthielten, können in den Altmetallhandel abgegeben werden. Wo es möglich ist, müssen leere Behälter, die in intaktem Zustand sind und entweder keine oder nur unbedeutende Mengen von Restabfall enthalten, zur Instandsetzung und Wiederverwertung oder zum Recycling geschickt werden
i. Nutzung von Mehrzweckbehältern anstelle von Fässern für alle Zwecke, soweit sie verfügbar sind
j. Einsatz von Abfällen mit ausreichendem Wärmegehalt und geringen Schadstoffwerten (siehe Abschnitte über Energiesysteme) als Primär-/Sekundärbrennstoff
k. Anwendung von Maßnahmen der Betriebsführung. Diese können so simpel sein, wie das Fegen der Böden vor dem Wischen. Diese Maßnahmen können Abfallvolumina erheblich reduzieren.

Erreichter Nutzen für die Umwelt
Die oben genannten Schritte tragen zur vernünftigen Nutzung natürlicher Rohstoffe bei und können die Menge des in der Abfallbehandlungsanlage erzeugten Abfalls senken. Sie senken die Emissionen aus dem Management der Reststoffbehandlung in der Anlage und minimieren das Aufkommen der anfallenden Reststoffe und tragen dazu bei, einen guten Beseitigungsweg zu finden.

Lösliche Schadstoffe können im Eluierungsmittel zusammen mit dem Wasser, das durch den Betrieb der Filterpresse entfernt wurde, auftauchen.

Medienübergreifende Auswirkungen
Das Verbrennen von Reststoffen kann zu höheren Luftemissionen führen als die Nutzung konventioneller Brennstoffe.

Betriebsdaten
Im Zusammenhang mit Technik h (im obigen Abschnitt “Beschreibung”) müssen Schilder und Beschriftungen vor der Wiederverwendung von Fässern entfernt werden.

Anwendbarkeit
Die Nutzung von Reststoffen als Brennstoff ist in Altölbehandlungsanlagen üblich.

Die Wiederverwendung von Verpackungen und Paletten hängt auch davon ab, ob die Verpackung für die Wiederverwendung geeignet ist. In manchen Fällen kann eine solche Wiederverwendung im Konflikt mit ADR-Vorschriften stehen, wenn die Verpackung nicht angemessen nachgerüstet wird.

Im Zusammenhang mit Technik h (im obigen Abschnitt “Beschreibung”) muss beim Recycling von Fässern die Verunreinigung der Fässer durch deren Inhalt berücksichtigt werden. Fässer, die sich nicht für ein direktes Recycling eignen, werden in der Regel zu einer geeigneten Behandlung, z.B. einer Verbrennung, verbracht. Z.B. werden Polyethylenfässer vollständig verbrannt, Stahlfässer werden gereinigt und in der Regel von Schlämmen befreit und anschließend recycelt. Die Deponierung verunreinigter Fässer ist in der Regel nicht zulässig.

Wirtschaftlichkeit
Im Hinblick auf Investitions- und Betriebskosten stellt die Schlammbehandlung einen bedeutenden Anteil dar, und das Management und die Beseitigung von festem Abfall wird für Betreiber eines der grundlegendsten Probleme bleiben.

Treibende Kraft für die Anwendung
Die Vermeidung und Minimierung der Abfallerzeugung als auch die Reduzierung seiner Gefährlichkeit sind allgemeine Prinzipien der IVU und der Abfallhierarchie.

Abfallarten, die an jedem Standort anfallen, sind in vielen Staaten Gegenstand von Genehmigungsverfahrens. Die Genehmigung kann auch vorschreiben, wie solche Abfälle gelagert und wie oft sie untersuchen werden müssen.

Die Wiederverwendung von Fässern ist auf die Fälle beschränkt, in denen die Fässer für ihren Zweck noch tauglich sind, sich in Übereinstimmung mit ADR-Regeln befinden und einfach gereinigt werden können. Alle anderen Fässer müssen vorbehandelt werden, bevor der Schrott wiederverwendet werden kann.

Beispielanlagen
In Deutschland wurde der Einsatz von Fässern so weit wie möglich eingeschränkt.

Literatur
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.8.2 Techniken zur Vermeidung von Bodenkontamination

Beschreibung
Diese Techniken beziehen sich auf Verschüttungen ins Wasser und andere diffuse Emissionen, wie sie schon in Abschnitt 4.1.3.6 behandelt wurden, sowie auf die Stilllegung, die bereits in Abschnitt 4.1.9. behandelt wurde. Zu den speziellen Techniken gehören:

a. Bereitstellung und anschließende Instandhaltung der Betriebsflächen, einschließlich der Durchführung von Maßnahmen zur Verhinderung oder schnellen Beseitigung von Leckagen und Verschüttungen, Sicherstellung der Instandhaltung von Entwässerungssystemen und anderen unterirdischen Konstruktionen
b. Verwendung eines undurchlässigen Fundaments und Einsatz einer betriebsinternen Entwässerung
c. Anwendung getrennter Entwässerungssysteme und Gruben, die eine Getrennthaltung bestimmter Gebiete des Standorts ermöglichen, wo Abfall gehandhabt und gemischt wird. Dadurch werden mögliche Verschüttungen zurückgehalten und Entwässerungen mit Oberflächenwasser vor Verunreinigung geschützt. Diese Maßnahmen können dazu beitragen, flüssige Emissionen zu reduzieren
d. Minimierung der Standortgröße und Minimierung des Einsatzes von unterirdischen Behältern und Leitungen
e. Durchführung einer regelmäßigen Überwachung von unterirdischen Behältern auf mögliche Leckagen (z.B. Füllstandsüberprüfungen der Behälter während Stillstandszeiten)
f. Auslegung der Bereiche, wo wassergefährdende Flüssigkeiten umgefüllt werden, als wasserdichte Auffangvorrichtungen. Die Auffangvorrichtung muss wasserdicht sein, so dass im Fall eines Unfalls die gefährliche Flüssigkeit zurückgehalten werden kann, bis weitere Sicherheitsmaßnahmen ergriffen werden
g. Sicherstellung, dass sowohl die Flächen, wo mit wassergefährdenden Stoffen umgegangen wird, als auch die Flächen mit Auffangvorrichtungen speziell gegen Versickerung abgedichtet sind, z.B. durch Anstriche, Beschichtungen, Beton einer entsprechenden Qualität, an der Innenseite angebrachte Abdichtungssysteme. Dabei muss das Abdichtungssystem jederzeit inspiziert werden können
h. Ausstattung der Behälter, die zur Lagerung/Sammlung von wassergefährdenden Stoffen eingesetzt werden, mit doppelten Wänden oder sie müssen in eingedämmte Tanks platziert sein. Dabei muss ihr Volumen so bemessen werden, dass das gesamte Volumen des größten Behälters oder 10 % des Volumens aller Behälter erfasst werden kann. Das größere Volumen ist in jedem Fall entscheidend
i. Ausstattung der Behälter, die zur Lagerung/Sammlung von wassergefährdenden Stoffen eingesetzt werden, mit Überlaufkontrollen, die durch ein Signalrelais mit dem Kontrollraum verbunden sind sowie durch optische und akustische Signale. Dabei sollten die Pumpen, mit denen die Behälter befüllt werden, und die zugehörigen Abschaltvorrichtungen (z.B. Absperrschieber) mit der Überlaufkontrolle verbunden werden.

Erzielter Nutzen für die Umwelt
Kann die kurz- und langfristige Kontamination des Standorts verhindern. Die Beschränkung der Verwendung von unterirdischen Behältern und Leitungen auf ein Minimum erleichtert die Aufgaben der Wartung und Inspektion.

Medienübergreifende Auswirkungen
Probleme wie Risse, blockierte Abflüsse zu Entwässerungen, Entwässerungskanäle aus Kies zwischen Betonplatten wurden in einigen Fällen identifiziert.

Anwendbarkeit
Die meisten Standorte besitzen einen undurchlässigen Boden (z.B. Betonboden) und betreiben betriebsinterne Entwässerungen

Treibende Kraft für die Anwendung
Die IVU-Richtlinie erfordert, dass bei der Ausübung industrieller Tätigkeiten vom Standort kein Risiko der Umweltverschmutzung ausgehen darf. Einige EG-Richtlinien und nationale Rechtsvorschriften gelten ferner für die Vermeidung der Bodenkontamination.

Beispielanlagen
Es wurde über einige Beispiele berichtet, deren Zustand suspekt war, obwohl diese Standorte eine undurchlässige Basis und eine betriebsinterne Entwässerung hatten. Fast alle Umladestationen für gefährliche Abfälle haben einen sicheren Untergrund mit Gefälle, wodurch Regenwasser sowie feste und flüssige Verschüttungen zu einem oder mehreren Flüssigkeitstanks oder zu Abscheidern entwässert werden.

C-P-Anlagen sind in der Regel mit Abdichtungsvorrichtungen zur Vermeidung von Verschüttungen ausgestattet, die zu einer Kontamination des Grundwassers oder zu einer Untergrundkontamination führen können. Von grundlegender Bedeutung für alle technischen Emissionsbegrenzungsmaßnahmen ist die Wahl der Baumaterialien, die eine hohe Beständigkeit, z.B. (je nach Anwendung) gegen Säuren, Alkalien und organische Lösemittel aufweisen müssen.

Literatur
[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003], [150, TWG, 2004]

4.8.3 Techniken zur Verringerung der Akkumulation von Reststoffen in der Anlage

Beschreibung
Zu den Techniken gehören:

a. klare Abgrenzung zwischen Verkaufs- und technischem Personal sowie ihrer Rollen und Verantwortlichkeiten. Wenn nicht-technisches Verkaufspersonal in Anfragen zur Abfallbeseitigung eingebunden ist, muss vor der Zustimmung eine abschließende technische Bewertung durchgeführt werden. Diese abschließende technische Überprüfung muss dazu eingesetzt werden, eine Ansammlung von Abfällen zu verhindern und zu gewährleisten, dass am Standort ausreichende Kapazität vorhanden ist. Zur Regulierung des Eingangs der Abfallströme sollten nicht kommerzielle Interessen im Vordergrund stehen, sondern vielmehr eine spezifischen Koordination der Ströme unter Einbeziehung des technischen Personals durchgeführt werden.
b. Vermeidung einer Akkumulation von Abfall, die wiederum zu einer Zustandsverschlechterung oder Deformierung des Behälters führen kann
c. Führen eines Überwachungsinventars für den Abfall auf dem Betriebsgelände unter Verwendung der Aufzeichnungen über die Mengen der angenommenen Abfälle und über die verarbeiteten Abfälle
d. Durchführung einer monatlichen Inventur aller Abfälle auf dem Betriebsgelände, um die Lagerbestände zu überwachen und alle alternden Abfälle zu ermitteln
e. Sicherstellung, dass bei allen Ansammlungen von Flüssigkeiten in Auffangvorrichtungen, Gruben usw. sofort reagiert wird.

Erzielter Nutzen für die Umwelt
Über einige Anlagen wurde berichtet, dass Misserfolge, einen angemessenen Durchsatz von Abfall zu gewährleisten, zu einer Lagerung von großen Mengen von Abfällen, Fässern und Behältern geführt haben. Die betroffenen Abfälle werden in der Regel nicht überprüft und Fässer werden oft einfach dem Verfall überlassen. Solche Situationen sind oft mit Standorträumungen in großem Maßstab verbunden und können mit Konkurrenzdruck und einem Insistieren des Kunden auf die Annahme zusätzlicher Abfallströme verbunden sein. In der Regel sind solche Abfälle schwierig zu behandeln und möglicherweise wurden sie zwischen verschiedenen Betreibern transferiert, was folglich mit einem Verlust von Informationen über ihre Zusammensetzung und den ursprünglichen Erzeuger verbunden ist.

Langjährige Akkumulationen können auch Standards im Zusammenhang mit Aufzeichnungen beeinträchtigen, was wiederum zum Verlust der Identität des Abfalls führen kann, was die Lagersituation weiter verschlimmert.

Treibende Kraft für die Anwendung
In der Regel wird in der Betriebsgenehmigung die Menge verschiedener Arten von Abfall, die zur Lagerung zugelassen ist, genau bestimmt. In der Genehmigung werden im Allgemeinen die Kapazitäten begrenzt, und es kann eine Zeitspanne zwischen Annahme und Behandlung des Abfalls vorgegeben sein.

Literatur
[55, UK EA, 2001], [86, TWG, 2003]

4.8.4 Förderung von Reststoffbörsen

Beschreibung
Zwar ist die Wiederverwendung innerhalb einer produzierenden Anlage die am meisten erwünschte Art des Recyclings, doch ist es nicht immer möglich, eine andere Abteilung oder ein anderes Verfahren zu finden, das den Rohstoff effizient nutzen kann. Als Alternative kann eine andere Firma ermittelt werden, die aus dem Reststoff einen Nutzen ziehen kann. Eine Abfallbörse ist eine regionale Clearingstelle für solche Transaktionen. Abfallbörsen pflegen Computerdatenbanken und/oder veröffentlichen periodische Listen von verfügbaren Abfällen oder von in verschiedenen Branchen gesuchten Materialien. Zu den Basisinformationen der Abfallbörse gehören in der Regel:

a. Firmencode
b. Kategorie (z. B. Säure, Lösemittel usw.)
c. Beschreibung der primär nutzbaren Anteile
d. Kontaminationen
e. physikalischer Zustand
f. Menge
g. Ort
h. Verpackung.

Erzielter Nutzen für die Umwelt
Ermöglicht eine geeignete Nutzung oder Beseitigung eines Abfalls.

Literatur
[53, LaGrega, et al., 1994]

5 BESTE VERFÜGBARE TECHNIKEN

Um dieses Kapitel und seine Inhalte zu verstehen, muss die Aufmerksamkeit des Lesers zurück auf das Vorwort des Dokuments gelenkt werden, insbesondere auf den fünften Abschnitt: „Anleitung zum Verständnis und zur Benutzung des Dokuments“. Die in diesem Kapitel vorgestellten Techniken, und die damit verbundenen Emissions- und/oder Verbrauchswerte oder Wertebereiche, wurden durch einen iterativen Prozess bewertet, der folgende Schritte umfasste:

- Identifizierung der wichtigsten Umweltthemen für den Abfallbehandlungssektor. Zu diesen gehören Luftemissionen, Wasseremissionen, Abfall, Bodenkontaminationen sowie Energie. Allerdings sind, infolge des breiten Spektrums an Abfallbehandlungen und Abfallarten die in diesem Dokument behandelt werden, nicht alle Emissionstypen für alle Abfallbehandlungen relevant
- Überprüfung der relevantesten Techniken, um solche Schlüsselthemen zu behandeln
- Identifizierung der besten Umweltleistungswerte, auf der Basis von verfügbaren Daten aus Staaten der Europäischen Union und auch weltweit
- Überprüfung der Gegebenheiten, mit denen diese Leistungswerte erreicht wurden, wie etwa Kosten, medienübergreifende Auswirkungen, die wichtigsten treibenden Kräfte für die Implementierung dieser Techniken
- Auswahl der besten verfügbaren Techniken (BVT) und der damit verbundenen Emissions- und/oder Verbrauchswerte für diesen Sektor im Allgemeinen[46], gemäß Artikel 2(11) und Anhang IV der Richtlinie.

Die Expertenbewertung durch das IPPC-Büro der EU und der zuständigen Technical Working Group (TWG), hat bei jedem dieser Schritte sowie bei der Art wie die Informationen hier dargestellt werden, eine Schlüsselrolle gespielt.

Auf Basis dieser Bewertung werden Techniken und, nach Möglichkeit, Verbrauchs- und Emissionswerte, die mit der Nutzung der BVT verbunden sind, in diesem Kapitel vorgestellt, von denen erwartet wird, dass sie für den ganzen Sektor geeignet sind und in vielen Fällen die aktuelle Leistung einiger Anlagen innerhalb des Sektors widerspiegeln. Wenn Emissions- oder Verbrauchswerte „verbunden mit besten verfügbaren Techniken“ präsentiert werden, muss dies so verstanden werden, dass jene Werte die die Umweltleistung darstellen, als Resultat der Anwendung der in diesem Sektor beschriebenen Technik angesehen werden kann. Dies geschieht unter Berücksichtigung der Kostenbilanz und der inhärenten Vorteile durch die Definition von BVT. Allerdings sind diese weder Emissions- noch Verbrauchsgrenzwerte und sollten nicht als solche verstanden werden. In einigen Fällen kann es technisch möglich sein, bessere Emissions- oder Verbrauchswerte zu erreichen, doch infolge der mit ihnen verbundenen Kosten, oder den medienübergreifenden Betrachtungen, werden sie nicht für den gesamten Sektor als BVT für geeignet gehalten. Allerdings können solche Werte in sehr spezifischen Fällen als spezifische treibende Kraft als gerechtfertigt betrachtet werden.

Die Verbrauchs- und Emissionswerte, die mit der Nutzung der BVT verbunden werden, müssen zusammen mit allen spezifizierten Referenzbedingungen betrachtet werden (z.B. Zeitbereich für Mittelwertbestimmungen). Das oben beschriebene Konzept der “Werte verbunden mit BVT” muss vom Begriff “erreichbarer Wert”, welcher anderswo im Dokument benutzt wird, unterschieden werden. Wenn ein Wert als „erreichbar“ beschrieben wird, indem eine bestimmte Technik oder Kombination von Techniken genutzt wird, sollte dies so verstanden werden, dass der erwartete Wert über eine bestimmte Zeit, in einer gut gewarteten und betriebenen Anlage oder einem ebensolchen Verfahren, das jene Technik nutzt, erreicht werden kann.

Soweit verfügbar, wurden Daten über Kosten zusammen mit der Beschreibung der Techniken, die in den vorhergehenden Kapiteln vorgestellt wurden, angegeben. Diese geben grobe Hinweise auf die Größenordnung der mit den Techniken verbundenen Kosten. Allerdings sind die tatsächlichen Kosten der Anwendung einer Technik stark von der spezifischen Situation abhängig, z.B. in Hinblick auf Steuern, Gebühren und technische Eigenschaften der betroffenen Anlage. Es ist nicht möglich, solche standortspezifischen Faktoren in diesem Dokument vollständig auszuwerten. Falls keine Daten über Kosten vorliegen, werden Schlüsse zur ökonomischen Realisierbarkeit von Techniken aus den Beobachtungen bestehender Anlagen gezogen.

[46] Anm.d.Übers.: Im Originaltext werden hier die Begriffe „general sense“ genannt. Im „allgemeinen/generellen Sinn“ ist aber missverständlich.

Es ist die Absicht, dass die allgemeinen BVT in diesem Kapitel als Richtwerte konzipiert sind, nach denen die augenblickliche Leistung einer bestehenden Anlage oder die Projektierung einer neuen Anlage beurteilt werden. Auf diese Weise unterstützen sie die Festlegung geeigneter "BVT-basierter" Konditionen für die Anlage oder bei der Feststellung von allgemein bindenden Vorschriften gemäß Artikel 9(8). Es wird davon ausgegangen, dass neue Anlagen so geplant werden können, dass ihre Leistung den hier vorgestellten allgemeinen BVT-Werten entspricht oder sie sogar übertrifft. Es wird auch berücksichtigt, dass bestehende Anlagen in Richtung allgemeiner BVT-Werte angepasst werden oder diese, je nach technischer und ökonomischer Anwendbarkeit der Techniken im Einzelfall, übersteigen könnten.

Obwohl die BVT-Merkblätter keine rechtlich bindende Standards aufführen, sollen sie jedoch Informationen zur Anleitung der Industrie, der Mitgliedstaaten und der Öffentlichkeit, zu erreichbaren Verbrauchs- und Emissionswerten liefern, wenn spezifische Techniken genutzt werden. Die sachgemäßen Grenzwerte müssen für jeden spezifischen Fall, unter Berücksichtigung der Ziele der IVU-Richtlinie und der lokalen Gegebenheiten, bestimmt werden.

Einige Schlüsselfeststellungen, um Nutzern/Lesern dieses Dokuments zu helfen
Während der Erarbeitung dieses Dokuments wurden durch die TWG einige wichtige Themen hervorgehoben und beraten; Kenntnisse hinsichtlich der Themen können den Nutzern/Lesern des Dokuments helfen.

- Infolge der komplexen Natur der Branche ist es sehr empfehlenswert, Kapitel 5 zusammen mit Kapitel 4 zu lesen. Um dem Nutzer/Leser zu helfen, werden in Kapitel 5 Querverweise zu Kapitel 4 aufgeführt
- Viele Faktoren beeinflussen die Entscheidung darüber, ob eine Abfallbehandlungsanlage eine bestimmte Verfahrenstechnik oder Schadstoffminderungstechnik einsetzen sollte oder nicht. Faktoren wie die Art der Behandlung und die Abfallart, die verarbeitetet werden soll, müssen berücksichtigt werden, wenn dieses Dokument auf lokaler Ebene genutzt wird
- Zusätzlich zu den BVT auf die in diesem Kapitel verwiesen wird, enthalten die BVT für Abfallbehandlungsanlagen auch Elemente aus anderen IVU-Dokumenten und internationalen Rechtsvorschriften. In diesem Kontext soll die spezifische Aufmerksamkeit auf folgende BVT-Merkblätter gelegt werden: „Lagerung", „Industrielle Kühlsysteme", „Abwasser- und Abgasbehandlung/-management in der chemischen Industrie", „Abfallverbrennungsanlagen" und dem BVT-Merkblatt über „Allgemeine Überwachungsgrundsätze".
- Abfallbehandlungsanlagen, die mit diesem Dokument abgedeckt werden, entsprechen nur einem Teil der gesamten Abfallwirtschaftskette. Maßnahmen, die vor und nach der Behandlung des Abfalls in der Anlage erfolgen, haben große Auswirkungen auf die Anlage und folglich einen Einfluss auf ihre Umweltleistung
- Im Allgemeinen besitzt die Abfallwirtschaft viele unterschiedliche Arten von Behandlungstätigkeiten (Behandlungskette), die letztendlich zu einer Verwertung oder Beseitigung führen, wobei aber einige Tätigkeiten außerhalb des Anwendungsbereichs dieses BVT-Merkblatts liegen können. Gemäß der Abfallhierarchie haben Verwertungstätigkeiten Vorrang vor der Beseitigung. Allerdings wurde berichtet, dass diese Hierarchie aus Sicht der Umwelt in bestimmten Situationen nicht die beste Lösung ist, insbesondere, wenn die gesamte Abfallbehandlungskette berücksichtigt wird (die aber außerhalb des Anwendungsbereichs des Dokuments liegt). Diese Gesichtspunkte können, zusammen mit nicht umweltbezogenen Aspekten, die Wahl der eingesetzten Abfallbehandlung beeinflussen.

Einige Hilfen zum Verständnis des Rests dieses Kapitels

In diesem Kapitel werden die BVT-Schlussfolgerungen für die Abfallbehandlungsbranche auf zwei Ebenen aufgeführt: Abschnitt 5.1 behandelt allgemeine BVT-Schlussfolgerungen, d.h. diese sind allgemein auf den gesamten Sektor anwendbar. Falls Ausnahmen für bestimmte Umstände oder Fälle bestehen, in denen die BVT nicht anwendbar sind, werden sie in den BVT- Schlussfolgerungen erwähnt. Abschnitt 5.2 enthält spezifischere BVT-Schlussfolgerungen, z.B. für jene verschiedenen Arten an spezifischen Verfahren und Tätigkeiten wie sie im Anwendungsbereich definiert sind. Daher bestehen die BVT für jede einzelne spezifische Art von Abfallbehandlungsanlage aus einer Kombination von nicht tätigkeitsspezifischen Elementen (allgemeine oder übliche Punkte) und tätigkeitsspezifischen Elementen die in bestimmten Fällen anwendbar sind, sowie den oben erwähnten anderen BVT-Merkblättern. Emissionswerte, die mit der Nutzung von BVT dieses Kapitels zusammenhängen beziehen sich auf Tagesdurchschnittswerte.

Infolge der großen Bandbreite an verschiedenen Abfallarten die mit diesem Dokument abgedeckt werden, ist es praktisch unmöglich, alle in der EU existierenden Unterschiede zu berücksichtigen. Aus diesem Grund werden die Abfälle in diesem Kapitel in zwei Arten eingeteilt. Eine bezieht sich auf nicht gefährliche Abfälle, welche die allgemeine Grundlage für BVT in der Abfallbranche darstellen. Die andere Art bezieht sich auf weitaus schädlichere Abfälle (z.B. gefährliche Abfälle), für welche weitere Maßnahmen als BVT benannt sein können. *Als Hilfestellung für den Benutzer/Leser wurden die BVTs, die sich auf gefährliche Abfälle beziehen, in kursiver Schrift dargestellt.*

Insbesondere in diesem BVT-Dokument werden die BVT qualitativ beschrieben und beruhen meist auf der gängigen Praxis. Dies ist auf fehlende Informationen zur Quantifizierung von Umweltleistungsparametern (z.B. Emissionen, Verbräuchen) zurückzuführen, da sich die meisten bereitgestellten Informationen auf Emissionsgrenzwerte beziehen, die in bestimmten Staaten oder Regionen gelten.

5.1 Allgemeine BVT

Umweltmanagement
Dies sind Techniken, die in Zusammenhang mit einer kontinuierlichen Verbesserung der Umweltleistung stehen. Sie bilden den Rahmen zur Sicherstellung der Identifizierung sowie der Einführung und Befolgung von BVT-Möglichkeiten. Diese sind gleichwohl bedeutend und spielen eine wichtige Rolle für die Verbesserung der Umweltleistung einer Anlage. In der Tat vermeiden diese Betriebsführungs/Management-Techniken oft Emissionen.

Eine Anzahl von Umweltmanagementtechniken entsprechen den BVT. Der Umfang (z.B. Detaillierungsgrad) und die Art des Umweltmanagementsystems (UMS) (z.B. standardisiert oder nicht standardisiert) stehen im Allgemeinen in engem Zusammenhang mit Art, Größe und Komplexität der Anlage sowie dem Bereich an Umweltauswirkungen, die sie haben kann. Die BVT bestehen darin:

1. ein UMS ist zu implementieren und zu befolgen, es muss für individuelle Gegebenheiten geeignet sein und folgende Kenndaten enthalten (siehe Abschnitt 4.1.2.8):
    a. Festlegung einer Umweltpolitik für die Anlage durch die Betriebsführung (die Verpflichtung der Betriebsführung wird als Voraussetzung einer erfolgreichen Anwendung anderer Kenndaten des UMS betrachtet)
    b. Planung und Durchführung der notwendigen Prozeduren
    c. Umsetzung der Prozeduren unter besonderer Berücksichtigung von
        - Struktur und Verantwortlichkeit
        - Schulung, Bewusstsein und Kompetenz
        - Kommunikation
        - Einbeziehung der Mitarbeiter
        - Dokumentation
        - Effizienter Verfahrenskontrolle
        - Wartungsprogrammen
        - Notfallvorsorge und –maßnahmen
        - Sicherstellung der Einhaltung von Umweltrechtsvorschriften.
    d. Überprüfung der Leistung und Ergreifen von Korrekturmaßnahmen, dies unter besonderer Berücksichtigung von
        - Überwachung und Messungen (siehe auch das BVT-Merkblatt über Allgemeine Überwachungsgrundsätze)
        - Korrektur- und Vorsorgemaßnahmen
        - Aufrechterhaltung von Aufzeichnungen
        - Unabhängige interne Audits (wenn praktikabel), um zu ermitteln, ob das Umweltmanagementsystem mit den geplanten Vereinbarungen konform ist und ordnungsgemäß implementiert und aufrechterhalten wird
    e. Überprüfung durch Betriebsführung.

Drei weitere Kenndaten, welche die obigen schrittweise vervollständigen können, werden als unterstützende Maßnahmen betrachtet. Allerdings gilt deren Fehlen im Allgemeinen nicht als inkonsistent mit den BVT. Diese drei zusätzlichen Schritte sind:

f. Überprüfung und Bestätigung des Managementsystems und der Auditprozedur durch eine zugelassene Akkreditierungsstelle oder einen externen UMS-Gutachter
g. Vorbereitung und Veröffentlichung (möglicherweise mit externer Validierung) einer regelmäßigen Umwelterklärung, die alle bedeutenden Umweltaspekte der Anlage beschreibt und einen jährlichen Vergleich, sowohl mit den Umweltzielsetzungen und Vorgaben, als auch mit den Benchmarks der Branche, falls angemessen, ermöglicht
h. Implementierung und Einhaltung eines international anerkannten freiwilligen Systems wie EMAS oder EN ISO 14001:1996. Dieser freiwillige Schritt könnte das UMS glaubwürdiger machen. Insbesondere EMAS, welches alle oben aufgeführten Kennpunkte enthält, führt zu einer höheren Glaubwürdigkeit. Allerdings können auch nicht standardisierte Systeme prinzipiell genauso effektiv sein, vorausgesetzt, dass sie richtig geplant und implementiert werden.

Speziell für diese Industriebranche ist es wichtig folgende potenzielle Kernpunkte der UMS zu berücksichtigen:

i. Berücksichtigung der Umweltauswirkungen einer eventuellen endgültigen Stilllegung der Anlage schon im Stadium der Planung der neuen Anlage
j. Berücksichtigung der Entwicklung sauberer Technologien
k. wo praktikabel, Durchführung von regelmäßigen sektoralen Benchmarkings, einschließlich Energieeffizienz- und Energieeinsparungsaktivitäten, Wahl der Inputmaterialien, der Luftemissionen, der Einleitungen ins Wasser, des Wasserverbrauchs und der Abfallerzeugung.

2. sicherzustellen, dass Informationen über die auf dem Betriebsgelände ausgeübten Tätigkeiten bereitgestellt werden. Einzelheiten hierüber sind in der folgenden Dokumentation enthalten (siehe Abschnitt 4.1.2.7 und in Zusammenhang mit BVT Nummer 1.g)
   a. Beschreibungen der gegenwärtigen Abfallbehandlungsmethoden und -Prozeduren in der Anlage
   b. Diagramme zu Hauptanlagenteile, die eine Umweltrelevanz besitzen, zusammen mit Flussdiagrammen des Verfahrens (Grafiken)
   c. Details zu den chemischen Reaktionen, ihrer Reaktionskinetik/Energiebilanz
   d. Details zu der Kontrollsystemsphilosophie und zur Art und Weise wie das Kontrollsystem Informationen aus der Umweltüberwachung verarbeitet
   e. Details darüber, wie der Schutz während ungewöhnlicher Betriebsbedingungen wie kurzfristigen Betriebsstopps, Anfahren und Abfahren sichergestellt wird
   f. Bedienungshandbuch
   g. Betriebstagebuch (Zusammenhang mit BVT Nummer 3)
   h. jährliche Begutachtung der durchgeführten Tätigkeiten und der behandelten Abfälle. Die jährliche Begutachtung sollte auch Vierteljahresbilanzen für Abfall- und Reststoffströme enthalten, einschließlich der Hilfsmittel, die an dem Standort eingesetzt werden (Zusammenhang mit BVT Nummer 1.g).

3. Vorhandensein einer Prozedur zur guten Betriebsführung, die auch Wartungsprozeduren enthält sowie ein geeignetes Schulungsprogramm, welches Vorsorgemaßnahmen, die von Beschäftigten in Bezug auf Gesundheit, Sicherheit und Umweltrisiken eingehalten werden müssen, enthält. (siehe Abschnitte 4.1.1.4, 4.1.1.5, 4.1.2.5, 4.1.2.10, 4.1.4.8 und 4.1.4.3)

4. zu versuchen, eine enge Beziehung zum Abfallerzeuger/besitzer zu erlangen, damit der Betrieb Maßnahmen zur Erzeugung der erforderlichen Abfallqualität implementiert, die zur Durchführung des Abfallbehandlungsverfahrens notwendig sind (siehe Abschnitt 4.1.2.9)

5. Vorhandensein von ausreichend Mitarbeitern mit erforderlicher Qualifikation, die jederzeit zur Verfügung stehen. Alle Mitarbeiter sollten eine spezielle berufliche Schulung und Weiterbildung absolvieren (siehe Abschnitt 4.1.2.10. Dies steht auch im Zusamenhang mit BVT Nummer 3)

Abfall-IN

Um die Kenntnisse über den Abfall-IN zu verbessern, bestehen die BVT darin:

6. genaue Kenntnisse über den Abfall-IN zu besitzen. Solche Kenntnisse müssen den Abfall-OUT, die durchzuführende Behandlung, die Abfallart, die Herkunft des Abfalls, die in Betracht gezogenen Prozedur (siehe BVT Nummer 7 und 8) und das Risiko (im Zusammenhang mit dem Abfall-OUT und der Behandlung) berücksichtigen (siehe Abschnitt 4.1.1.1). Anleitungen zu manchen dieser Punkte liefern die Abschnitte 4.2.3, 4.3.2.2 und 4.4.1.2
7. eine Prozedur für Voruntersuchungen einzuführen, die mindestens folgende Punkte enthalten (siehe Abschnitt 4.1.1.2):
    a. Untersuchung der ankommenden Abfälle im Hinblick auf die geplante Behandlung
    b. Sicherstellung, dass alle notwendigen Informationen zu den Eigenschaften des/der Verfahren(s), in dem der Abfall erzeugt wird, empfangen wurden, einschließlich der Berücksichtigung von Verfahrensschwankungen. Die Mitarbeiter, die mit den Voruntersuchungen befasst sind, müssen infolge ihrer Ausbildung und/oder Sachkenntnis in der Lage sein, mit allen notwendigen Fragestellungen umzugehen, die für die Behandlung der Abfälle in der Abfallbehandlungsanlage von Relevanz sind
    c. ein System für das Bereitstellen und Analysieren repräsentativer Probe(n) von Abfällen aus den Produktionsverfahren des aktuellen Besitzer in dem dieser Abfall erzeugt wird
    d. ein System zur sorgfältigen Verifizierung der Informationen, die in der Phase der Voruntersuchungen eingehen, falls nicht direkt mit dem Abfallerzeuger verhandelt wird. Dazu gehören die Kontaktdaten des Abfallerzeugers und eine geeignete Beschreibung des Abfalls in Bezug auf seine Zusammensetzung und Gefährlichkeit
    e. Sicherstellung, dass ein Abfallschlüssel gemäß dem Europäischen Abfallverzeichnis (EAV) angegeben wird
    f. Identifizierung einer geeigneten Behandlung für alle Abfälle, die an der Anlage entgegengenommen werden (siehe Abschnitt 4.1.2.1) und zwar durch Identifizierung einer entsprechenden Behandlungsmethode für jede neue Abfallanfrage. Vorhandensein einer klaren Methodik zur Bewertung der Abfallbehandlung, die physikalisch-chemische Eigenschaften des jeweiligen Abfalls und deren Spezifikationen für den behandelten Abfall berücksichtigt.
8. eine Annahmeprozedur zu implementieren, die mindestens folgende Punkte enthält (siehe Abschnitt 4.1.1.3):
    a. ein klares und spezifiziertes System, das es dem Betreiber ermöglicht, Abfälle nur dann anzunehmen, wenn eine definierte Behandlungsmethode sowie Beseitigungs/Verwertungswege für die Outputs der Behandlung festgelegt sind (siehe Voruntersuchungen in BVT Nummer 7). Bereits bei der Planung der Abfallannahme muss sichergestellt werden, dass die erforderlichen Lagerbedingungen (siehe Abschnitt 4.1.4.1), die Behandlungskapazitäten und Abfertigungsbedingungen (z.B. Annahmekriterien des Output für eine andere Anlage) berücksichtigt sind
    b. Vorhandensein von Maßnahmen zur vollständigen Dokumentation und zum Umgang mit zulässigen Abfällen, die am Standort ankommen, wie etwa Vorbuchungssysteme, um z.B sicherzustellen, dass genügend Kapazität zur Verfügung steht
    c. klare und eindeutige Kriterien für die Zurückweisung von Abfällen und Berichterstattung aller Nichtübereinstimmungen
    d. ein System zur Bestimmung der maximalen Kapazitätsgrenze für Abfall, der in der Anlage gelagert werden kann (im Zusammenhang mit BVT Nummer 10.b, 10.c, 27 und 24.f)
    e. visuelle Überprüfung des Abfall-IN, um eine Übereinstimmung mit der im Voruntersuchungsverfahren erhaltenen Beschreibung sicherzustellen. *Für manche flüssige und gefährliche Abfälle ist diese BVT nicht anwendbar (siehe Abschnitt 4.1.1.3).*

9. verschiedene Probenahmeverfahren, für alle unterschiedlichen ankommenden Abfallbehälter, die in großen Gebinden und/oder in Containern angeliefert werden, einzuführen. Diese Probenahmeverfahren können die folgenden Punkte enthalten (siehe Abschnitt 4.1.1.4):
    a. Probenahmeverfahren die auf einen Risikoansatz basieren. Einige zu berücksichtigende Elemente sind die Abfallart (z.B. *gefährlich* oder nicht gefährlich) und Kenntnisse über den Kunden (z.B. Abfallerzeuger)
    b. Überprüfung der relevanten physikalisch-chemischen Parameter. Die relevanten Parameter gehören zu den Kenntnissen über den Abfall, die in jedem Fall benötigt werden (siehe BVT Nummer 6)

c. Registrierung aller Abfallstoffe
d. Vorhandensein verschiedener Probenahmeprozeduren für große Gebinde (flüssige und feste), große und kleine Behälter und Laborkleinabfälle. Die Anzahl der gezogenen Proben sollte mit der Anzahl der Behälter zunehmen. Bei aussergewöhlichen Stuationen müssen alle kleinen Container mit ihren Begleitpapieren verglichen werden. Die Prozedur sollte ein System enthalten, mit dem die Probennummern und der Grad der Konsolidierung festgehalten werden
e. Details der Beprobung von Abfällen in Fässern innerhalb ausgewiesener Lagerbereiche, z.B. Zeitraum nach Annahme
f. Beprobung vor der Annahme
g. Pflege von Aufzeichnungen über das Probenahmesystem in der Anlage für jede Ladung, zusammen mit Aufzeichnungen zur Begründung der Auswahl der jeweiligen Option
h. System zur Bestimmung und Aufzeichnung von:
   - den geeigneten Orten für die Probeennahme
   - der Kapazität des beprobten Behälters (für Proben aus Fässern wäre die Gesamtanzahl der Fässer ein zusätzlicher Parameter)
   - der Anzahl der Proben und Grad der Konsolidierung
   - der Betriebsbedingungen zur Zeit der Probenahme.
i. ein System zur Gewährleistung, dass die Abfallproben analysiert werden (siehe Abschnitt 4.1.1.5)
j. Im Fall kalter Umgebungstemperaturen kann eine Zwischenlagerung erforderlich sein, um eine Probenahme nach dem Auftauen zu ermöglichen. Dies kann die Anwendbarkeit einiger der oben genannten Punkte bei dieser BVT einschränken (siehe Abschnitt 4.1.1.5).

10. Vorhandensein einer Annahmeeinrichtung, in der mindestens folgende Aspekte beachtet werden (siehe Abschnitt 4.1.1.5):
    a. Vorhandensein eines Labors zur Untersuchung aller Proben in einem Zeitraum, der den Anforderungen der BVT entspricht. In der Regel erfordert dies ein stabiles Qualitätssicherungsverfahren, Methoden zur Qualitätskontrolle und die Pflege geeigneter Aufzeichnungen, um die Analyseergebnisse aufzubewahren. *Insbesondere für gefährliche Abfälle bedeutet dies oft, dass sich das Labor auf dem Betriebsgelände befinden muss*
    b. Vorhandensein ausgewiesener Quarantäne-Abfalllagerbereiche sowie schriftlich festgehaltener Prozeduren zum Umgang mit nicht angenommenen Abfällen. Wenn eine Inspektion oder Analyse zeigt, dass Abfälle die Annahmebedingungen nicht erfüllen (einschließlich z.B. beschädigter, korrodierter oder nicht gekennzeichneter Fässer), können sie dort vorübergehend sicher gelagert werden. Solche Lagerungen und Prozeduren sollten so geplant und betrieben werden, dass sie eine schnelle (in der Regel innerhalb von Tagen oder schneller) Lösung für das Management des Abfalls unterstützen
    c. Vorhandensein klarer Prozeduren für den Umgang mit Abfällen, bei denen während der Inspektion und/oder Analyse festgestellt wurde, dass sie die Annahmebedingungen der Anlage nicht erfüllen oder die Abfallbeschreibungen aus den Voruntersuchungen nicht passen. Die Prozedur sollte alle Maßnahmen enthalten, die in der Genehmigung oder durch nationale/internationale Gesetzgebung gefordert werden, wie die Information der zuständigen Behörden, die sichere Lagerung der Anlieferung für eine Übergangszeit oder die Zurückweisung und Zurücksendung des Abfalls zum Abfallerzeuger oder einen anderen zugelassenen Bestimmungsort
    d. Transport von Abfall in den Lagerbereich nur nach Annahme des Abfalls (Zusammenhang mit BVT Nummer 8)
    e. Markierung der Überprüfungs-, Entladungs- und Probenahmebereiche auf dem Lageplan des Betriebsgeländes
    f. Vorhandensein eines abgedichtetes Entwässerungssystems (Zusammenhang mit BVT Nummer 63)
    g. Verfahren zur Sicherstellung, dass das Betriebspersonal, das an der Probenahme, Überprüfung und Analyse beteiligt ist, geeignet qualifiziert und angemessen geschult ist, und dass die Schulung regelmäßig wiederholt wird (Zusammenhang mit BVT Nummer 5)
    h. Anwendung eines Systems zur Rückverfolgung der Abfälle durch eindeutige Kennzeichnung (Label/Code) für jeden Behälter der sich in diesem Stadium befindet. Die Kennzeichnung enthält mindestens das Datum der Ankunft auf dem Betriebsgelände und die Abfallschlüsselnummer (Zusammenhang mit BVT Nummer 9 und 12).

Abfall-OUT

Die BVT zur Verbesserung der Kenntnisse über den Abfall-OUT bestehen darin:

11. den Abfall-OUT auf die relevanten Parameter zu analysieren, die für die annehmende Anlage von Bedeutung sind (z.B. Deponie, Verbrennungsanlage) (siehe Abschnitt 4.1.1.1)

Managementsysteme

Die BVT bestehen darin:

12. ein System zu besitzen, dass die Rückverfolgbarkeit bei der Abfallbehandlung gewährleistet. Verschiedene Prozeduren können erforderlich sein, um die physikalisch-chemischen Eigenschaften des Abfalls (z.B. flüssig, fest), die Art des Abfallbehandlungsverfahrens (z.B. kontinuierlich, Batch) als auch die Veränderungen der physikalisch-chemischen Eigenschaften der Abfälle während der Behandlung zu berücksichtigen. Ein gutes Rückverfolgungssystem enthält folgende Punkte (siehe Abschnitt 4.1.2.3):
    a. Dokumentation der Behandlungen durch Flussdiagramme und Massenbilanzen (siehe Abschnitt 4.1.2.4, dies steht auch im Zusammenhang mit BVT Nummer 2.a)
    b. Durchführen der Rückverfolgbarkeit der Daten über mehrere Behandlungsschritte hinweg (z.B. Voruntersuchungen/Annahme/Lagerung/Behandlung/Auslieferung). Dabei können Aufzeichnungen geführt und fortlaufend aktualisiert werden, um Anlieferungen, Behandlungen auf dem Betriebsgelände und Auslieferungen widerzuspiegeln. Nachdem der Abfall das Betriebsgelände verlassen hat, werden die Aufzeichnungen in der Regel für mindestens sechs Monate aufbewahrt
    c. Aufzeichnung und Verweise zu Informationen über Abfalleigenschaften und der Herkunft des Abfallstroms, so dass sie jederzeit zur Verfügung stehen. Dem Abfall muss eine Referenznummer gegeben werden, die zu jedem Zeitpunkt des Verfahrens zur Verfügung stehen muss. Mit dieser muss ein Betreiber feststellen können, wo und wie lange sich ein bestimmter Abfall in der Anlage befindet und wie der beabsichtigte oder aktuelle Behandlungsweg ist
    d. Führung von elektronischen Datenbanken, die regelmäßig gesichert werden. Das Rückverfolgungssystem arbeitet als ein Abfallinventar-/Lagerkontrollsystem und umfasst: Datum der Ankunft auf der Anlage, Details zum Abfallerzeuger, Details über alle vorherigen Besitzer, eine eindeutige Kennzeichnung, Analyseergebnisse der Vor- und Annahmeuntersuchungen, Verpackungsart und –größe, beabsichtigter Behandlungs-/Beseitigungsweg, eine präzise Aufzeichnung von Art und Menge aller Abfälle auf dem Betriebsgelände, einschließlich aller Gefahren, den Ort an dem sich der Abfall befindet in Bezug auf den Lageplan, an welchem Punkt des vorgesehenen Beseitigungswegs sich der Abfall derzeit befindet
    e. ein Transport von Fässern und anderen mobilen Behältern zwischen verschiedenen Orten der Anlage (oder Beladung für den Abtransport vom Betriebsgelände) nur unter Anweisung des zuständigen Mitarbeiters. Sicherstellung, dass diese Veränderungen im Abfallrückverfolgungssystem ergänzt werden (siehe Abschnitt 4.1.4.8).
13. Regeln für das Mischen/Vermischen fester und flüssiger Abfälle zu besitzen und zu befolgen. Diese sollen sich auf Abfallarten beschränken, die miteinander gemixt/gemischt werden können, um eine ansteigende Umweltverschmutzung bei folgenden Abfallbehandlungsverfahren zu vermeiden. Diese Regeln müssen die Abfallart (z.B. *gefährlich*, nicht gefährlich), die anzuwendende Abfallbehandlung sowie auch folgende Schritte, denen der Abfall-OUT unterzogen wird, berücksichtigen (siehe Abschnitt 4.1.5)

14. Prozeduren zur Getrennthaltung und zur Kompatibilität zu besitzen (siehe Abschnitt 4.1.5, und steht im Zusammenhang mit BVT Nummer 13 und 24.c), einschließlich:
    a. Dokumentation der Untersuchungen, einschließlich aller Reaktionen die ein ansteigen von Sicherheitsparametern auslösen (Anstieg der Temperatur, Erzeugung von Gasen oder Anstieg des Drucks), einer Aufzeichnung der Betriebsparameter (Änderung der Viskosität, Abtrennung oder Ausfällung von Feststoffen) und aller weiteren relevanten Parameter, wie etwa die Entstehung von Gerüchen (siehe Abschnitte 4.1.4.13 und 4.1.4.14)
    b. Verpackung von Chemikalienbehältern in getrennte Fässer auf Grundlage ihrer Gefahrenklassifizierung. Unverträgliche Chemikalien (z.B. Oxidationsmittel und entzündliche Flüssigkeiten) sollten nicht im selben Fass gelagert werden (siehe Abschnitt 4.1.4.6).
15. eine Methode zur Effizienzsteigerung der Abfallbehandlung zu besitzen. Dazu gehören in der Regel die Bestimmung geeigneter Indikatoren zur Berichterstattung über die Effizienz der Abfallbehandlung sowie ein Überwachungsprogramm (siehe Abschnitt 4.1.2.4 und dies steht auch im Zusammenhang mit BVT Nummer 1)

16. einen strukturierten Unfallmanagementplan aufzustellen (siehe Abschnitt 4.1.7)

17. ein Tagebuch für Zwischenfälle zu besitzen und richtig zu nutzen (siehe Abschnitt 4.1.7 und dies steht auch im Zusammenhang mit BVT Nummer 1 und mit einem Qualitätsmanagementsystem)

18. einen Lärm- und Erschütterungsminderungsplan als Teil des UMS aufzustellen (siehe Abschnitt 4.1.8 und dies steht auch in Zusammenhang mit BVT Nummer 1). Für manche Abfallbehandlungsanlagen sind Lärm und Erschütterungen möglicherweise kein Umweltproblem
19. jegliche zukünftige Stilllegung bereits im Planungsstadium zu betrachten. Für bestehende Anlagen und wo Probleme im Zusammenhang mit der Stilllegung ermittelt wurden, ist ein Programm zur Minimierung dieser Probleme aufzustellen (siehe Abschnitt 4.1.9 und dies steht auch im Zusammenhang mit BVT Nummer 1.i).

Energie-, Wasser- und Rohstoffmanagement

Die BVT bestehen darin:

20. eine Aufschlüsselung von Energieverbrauch und -erzeugung (einschließlich Energieexport) nach Art der Quellen durchzuführen (d.h. Elektrizität, Gas, flüssige konventionelle Brennstoffe, feste konventionelle Brennstoffe und Abfall) (siehe Abschnitt 4.1.3.1 und im Zusammenhang mit BVT Nummer 1.k). Dazu gehören:
    a. Berichterstattung über den Energieverbrauch auf Basis der angelieferten Energie
    b. Berichterstattung über den Energieexport aus der Anlage
    c. Erbringen von Informationen zu Energieflüssen der Anlage (zum Beispiel Diagramme oder Energiebilanzen), aus denen hervorgeht, wie die Energie innerhalb des Verfahrens eingesetzt wird.
21. die Energieeffizienz der Anlage kontinuierlich zu steigern durch (siehe Abschnitt 4.1.3.4):
    a. die Entwicklung eines Energieeffizienzplans
    b. die Nutzung von Techniken zur Senkung des Energieverbrauchs, wodurch sowohl direkte (auf dem Betriebsgelände erzeugte Emissionen und Abwärme) und indirekte Emissionen (Emissionen aus einem entfernten Kraftwerk) vermieden werden
    c. Festlegung und Berechnung des spezifischen Energieverbrauchs der Tätigkeit (oder Tätigkeiten), wobei Schlüsselleistungsindikatoren auf jährlicher Basis aufgestellt werden (z.B. MWh/Tonne verarbeiteten Abfalls, Zusammenhang mit BVT Nummer 1.k und 20).
22. eine betriebsinterne Benchmark-Bewertung des Rohstoffverbrauchs durchzuführen (z.B. auf Jahresbasis) (Zusammenhang mit BVT Nummer 1.k). Einige Anwendungsbeschränkungen werden in Abschnitt 4.1.3.5 aufgeführt.
23. die Möglichkeiten zum Einsatz von Abfall als Rohmaterial zur Behandlung anderer Abfälle zu untersuchen (siehe Abschnitt 4.1.3.5). Falls Abfall zur Behandlung anderer Abfälle eingesetzt wird, muss ein System vorliegen, dass eine sichere Versorgung mit dem Abfall gewährleistet. Wenn dies nicht garantiert werden kann, sollten eine zweite Behandlung oder andere Rohstoffe vorhanden sein, um unnötige Wartezeit vor der Behandlung zu vermeiden (siehe Abschnitt 4.1.2.2)

Lagerung und Umschlag

Die BVT bestehen darin:

24. im Zusammenhang mit der Lagerung folgende Techniken anzuwenden (siehe Abschnitt 4.1.4.1):
    a. Standort der Lagerbereiche:
        - nicht in der Nähe von Wasserläufen und empfindlichen Bereichen und
        - in einer Art und Weise, dass eine mehrfache Handhabung von Abfällen in der Anlage auf ein Minimum reduziert oder vermieden wird
    b. Sicherstellung, dass die Entwässerungsinfrastruktur der Lager alle möglichen verunreinigten Abläufe fassen kann, und dass Abläufe unverträglicher Abfälle nicht in Kontakt kommen können
    c. Nutzung eines ausgewiesenen Gebiets/Lagers für die Sortierung und Wiederverpackung von Laborkleinabfällen oder ähnlichen Abfällen, dass mit allen notwendigen Maßnahmen im Hinblick auf die spezifischen Risiken der Abfälle ausgestattet ist. Diese Abfälle werden entsprechend ihrer Gefahrenklassifizierung sortiert und anschließend wiederverpackt, wobei alle potenziellen Unverträglichkeitsprobleme berücksichtigt werden müssen. Danach werden sie zu einem geeigneten Lagerbereich abtransportiert
    d. Umschlag geruchsintensiver Materialien in vollständig geschlossenen oder mit geeigneten Minderungstechniken ausgestatteten Behältern und Lagerung dieser Materialien in geschlossenen Gebäuden, die mit einer Minderungstechnik verbunden sind
    e. Sicherstellung, dass alle Verbindungen zwischen den Behältern durch Ventile geschlossen werden können. Überlaufröhren müssen zu einem Entwässerungssystem mit Rückhaltevorrichtung führen (d.h. zu einem passenden Auffangbereich oder zu einem anderen Behälter)

f. Vorhandensein von Maßnahmen zur Verhinderung des Aufbaus von Schlämmen oberhalb einer bestimmten Höhe und zur Verhinderung des Entstehens von Schäumen, die solche Maßnahmen in Flüssigkeitstanks beeinträchtigen können, z.B. durch einer regelmäßigen Überwachung der Tanks, eines Absaugens der Schlämme zur geeigneten Weiterbehandlung und dem Einsatz von Entschäumern
g. Ausstattung von Tanks und Behälter mit geeigneten Minderungssystemen, wenn flüchtige Emissionen erzeugt werden können, zusammen mit Füllstandmessern und Alarmvorrichtungen Diese Anlagen müssen ausreichend robust sein (bei Anwesenheit von Schlamm und Schaum arbeitsfähig sein) und regelmäßig gewartet werden
h. Lagerung organischer flüssiger Abfälle mit niedrigem Flammpunkt unter einer Stickstoffatmosphäre, um sie zu inertisieren. Jeder Lagertank steht in einem wasserundurchlässigen Rückhaltebereich. Gasemissionen werden erfasst und behandelt.

25. die Bereiche zum Umfüllen von Flüssigkeiten sowie die Lagerbereiche mit getrennten Auffangvorrichtungen auszustatten, die genutzten Auffangvorrichtungen müssen undurchlässig und resistent gegenüber den gelagerten Materialien sein (siehe Abschnitt 4.1.4.4)

26. für die Beschriftung von Behältern und Prozessrohrleitungen die folgenden Techniken anzuwenden (siehe Abschnitt 4.1.4.12):
    a. klare Kennzeichnung aller Behälter im Bezug auf ihre Inhalte und Kapazität, dies unter Verwendung einer eindeutigen Kennzeichnung. Für Behälter muss ein geeignetes Beschriftungssystem vorhanden sein, dass Nutzung sowie Inhalt berücksichtigt
    b. Sicherstellung, dass die Beschriftung zwischen Abwasser und Prozesswasser, brennbaren Flüssigkeiten und brennbarem Gas unterscheidbar ist und die Fließrichtung angibt (z.B. Zu- oder Abfluss)
    c. Dokumentation über alle Behälter, Details zur eindeutigen Kennzeichnung; Kapazität; ihre Bauweise einschließlich der Materialien; die Wartungspläne und Inspektionsergebnisse; ihre Armaturen und die Abfallarten die im Behälter gelagert/behandelt werden dürfen, einschließlich der Grenzwerte für den Flammpunkt.
27. Maßnahmen zu ergreifen, mit denen Probleme vermieden werden können, die aus der Lagerung/-Ansammlung von Abfall entstehen. Dies kann in Konflikt mit BVT Nummer 23 stehen, wenn Abfall als Reaktionsmittel genutzt wird (siehe Abschnitt 4.1.4.10)

28. die folgenden Techniken bei der Handhabung mit Abfall anzuwenden (siehe Abschnitt 4.1.4.6):
    a. Vorhandensein von Verfahren und Prozeduren, um sicherzustellen, dass Abfälle sicher zur geeigneten Lagerung transportiert werden
    b. Vorhandensein eines Managementsystems zum Be- und Entladen von Abfall in der Anlage, mit dem alle Risiken berücksichtigt werden die bei diesen Tätigkeiten entstehen können. Einige Optionen hierfür umfassen ein Ticketingsystem, Aufsicht durch Anlagenpersonal, Benutzung von Symbolen oder Farbcodes für Stellen/Schläuche oder Armaturen in bestimmten Größen
    c. Sicherstellung, dass auf dem Betriebsgelände des Abfallbesitzers eine qualifizierte Person anwesend ist, die Laborkleinabfälle, alte Abfälle, Abfälle unklarer Herkunft und undefinierte Abfälle (insbesondere in Fässern) überprüft, und die Stoffe entsprechend klassifiziert und in spezielle Behälter verpackt. In manchen Fällen müssen die einzelnen Verpackungen mittels Füllmaterialien, welche an Eigenschaften des verpackten Abfalls angepasst sind, vor einer mechanischer Beschädigung im Fass geschützt werden
    d. Sicherstellung, dass beschädigte Schläuche, Ventile und Verbindungen nicht benutzt werden
    e. Erfassung der Abgase aus Behältern und Tanks, wenn flüssige Abfälle gehandhabt werden
    f. Entladung von Feststoffen und Schlamm in abgeschlossenen Bereichen mit Absauganlagen, die mit Minderungstechniken verbunden sind, wenn der zu handhabende Abfall potenziell Emissionen (z.B. Gerüche, Staub, VOCs) in die Luft verursachen kann (siehe Abschnitt 4.1.4.7)
    g. Nutzung eines Verfahrens, das sicherstellt, dass verschiedene Chargen nur nach einer vorhergehenden Kompatibilitätsprüfung zusammengeschüttet werden (siehe Abschnitte 4.1.4.7 und 4.1.5 und dies steht auch im Zusammenhang mit BVT Nummern 13, 14 und 30).
29. sicherzustellen, dass das Zusammenschütten/Mischen von Abfall in oder aus Verpackungen nur unter Anleitung und unter Aufsicht stattfindet und durch geschultes Personal durchgeführt wird. Für bestimmte Abfallarten muss ein solches Zusammenschütten/Mischen unter einer Absaugentlüftung durchgeführt werden (siehe Abschnitt 4.1.4.8)

30. sicherzustellen, dass chemisch unverträgliche[47] Abfälle entsprechend den Erforderlichkeiten während der Lagerung getrennt gehalten werden (siehe Abschnitte 4.1.4.13 und 4.1.4.14 und dies steht auch im Zusammenhang mit BVT Nummer 14)
31. folgende Techniken sind beim Umgang mit Abfällen in Behältern anzuwenden (siehe Abschnitt 4.1.4.2):
    a. Lagerung von Abfällen in Behältern unter einer Überdachung. Dies kann auch auf alle Behälter angewendet werden, die in Erwartung der Probenahme sowie Entleerung gelagert werden. Einige Ausnahmen der Anwendung dieser Technik mit Behältern oder Abfällen, die nicht durch Umwelteinflüsse (z.B. Sonnenlicht, Temperatur, Wasser) beeinflusst werden, wurden identifiziert (siehe Abschnitt 4.1.4.2). Überdachte Bereiche müssen geeignete Belüftungsvorrichtungen haben
    b. Aufrechterhaltung der Verfügbarkeit und des Zugangs zu Lagerbereichen für Behälter, die Stoffe enthalten, die bekanntermaßen gegenüber Hitze, Licht und Wasser empfindlich sind und die unter einer Abdeckung geschützt vor Hitze und direkter Sonneneinstrahlung gehalten werden müssen.

Andere übliche Techniken, die oben nicht erwähnt wurden

Die BVT bestehen darin:

32. Brech-, Schredder- und Siebvorgänge in Bereichen durchzuführen, die mit Absaugentlüftungssystemen ausgestattet und mit Minderungstechniken verbunden sind (siehe Abschnitt 4.1.6.1), falls Materialien, die Luftemissionen (z.B. Gerüche, Staub, VOCs) erzeugen können, behandelt werden
33. Brech- und Schreddervorgänge (siehe Abschnitte 4.1.6.1 und 4.6) für Fässer/Behälter, die entzündliche oder leichtflüchtige Stoffe enthalten, unter einer vollständigen Einkapselung und unter inerter Atmosphäre durchzuführen. Dies verhindert ein Entzünden. Die inerte Atmosphäre muss gemindert werden
34. Waschvorgänge unter Berücksichtigung folgender Punkte durchzuführen (siehe Abschnitt 4.1.6.2):
    a. Bestimmung der Inhaltsstoffe, die in dem zu waschenden Gegenstand vorhanden sein können (z.B. Lösemittel)
    b. Transport von Waschwässern zu einer geeigneten Lagerung und anschließende Behandlung dieser auf dieselbe Art und Weise wie der Abfall aus dem sie stammen behandelt wurde
    c. Zum Waschen die Nutzung von behandeltem Abwasser aus der Abfallbehandlungsanlage anstelle von Frischwasser. Das entstehende Abwasser kann dann in der Abwasserbehandlungsanlage behandelt oder in der Anlage wiederverwendet werden.

Behandlung von Luftemissionen

Die BVT zur Vermeidung oder Kontrolle der Emissionen wie vor allem von Staub, Gerüchen und VOC und einiger anorganischer Verbindungen bestehen darin:

35. die Nutzung von oben offenen Tanks, Behältern und Gruben dadurch einzuschränken:
    a. dass bei der Lagerung von Materialien, die Emissionen in die Luft (z.B. Gerüche, Staub, VOCs) erzeugen können, keine direkte Entlüftungen oder Ableitungen in die Luft zugelassen werden und alle Entlüftungen mit geeigneten Minderungstechniken verbunden sind (siehe Abschnitt 4.1.4.5)
    b. dass der Abfall oder die Rohstoffe unter Abdeckung oder in wasserdichten Verpackungen gehalten werden (siehe Abschnitt 4.1.4.5 und dies steht im Zusammenhang mit BVT Nummer 31.a)
    c. dass der Luftraum oberhalb der Absetztanks (z.B. wenn die Behandlung von Öl ein Vorbehandlungsverfahren innerhalb einer chemischen Behandlungsanlage ist) mit den Entlüftungsanlagen und Gaswäschern des Gesamtstandorts verbunden sind (siehe Abschnitt 4.1.4.1).
36. eine eingehauste Anlage mit Entlüftung oder Unterdruck zu nutzen, die mit einer geeigneten Minderungsanlage verbunden ist. Diese Technik ist besonders bedeutend bei Verfahren, die mit dem Umschlag flüchtiger Flüssigkeiten verbunden sind, einschließlich der Be- und Entladung von Tankfahrzeugen (siehe Abschnitt 4.6.1)

37. ein Entlüftungssystem angemessener Größe einzusetzen, das die befüllten Behälter, Vorbehandlungsbereiche, Misch- und Reaktionstanks und den Filterpressenbereich umfasst oder ein getrenntes System vorzuhalten, mit dem Entlüftungsabgase aus spezifischen Behältern behandelt werden können (z.B. Aktivkohlefilter für Behälter die lösemittelkontaminierte Abfälle beinhalten) (siehe Abschnitt 4.6.1)

38. die Minderungstechniken richtig zu betreiben und zu warten, einschließlich des Umgangs mit und der Behandlung/Beseitigung von verbrauchten Gaswäscherflüssigkeiten (siehe Abschnitt 4.6.11)

[47] Anm.d.Übers.: Im Originaltext steht hier nur “Unverträglichkeiten“ – ohne Abfall.

39. eine Gaswäscheranlage für die wichtigsten anorganischen gasförmigen Emissionen an solchen Einheiten der Anlage vorzuhalten, die einen Punktauslass für prozessbedingte Emissionen besitzen. Eine zweite Gaswäschereinheit für bestimmte Vorbehandlunganlagen zu installieren, wenn Emissionen für die Haupt-Gaswäscher unverträglich oder zu hoch konzentriert sind (siehe Abschnitt 4.6.11)

40. ein Lecksuch- und Reparaturprogramm in Anlagen zu haben, das a) eine hohe Anzahl von Leitungskomponenten sowie das Lager und b) Verbindungen die leicht durch Leckagen entweichen können und dabei ein Umweltproblem verursachen können (z.B. flüchtige Emissionen, Bodenkontamination), abdeckt[48] (siehe Abschnitt 4.6.2). Dies kann als Element des UMS betrachtet werden (siehe BVT Nummer 1)

41. die Luftemissionen auf folgende Werte zu reduzieren,

Luftparameter	Emissionswerte verbunden mit der Nutzung von BVT (mg/Nm^3)
VOC	7 – 20[1]
PM	5 – 20
[1] Für niedrige VOC-Frachten kann der Bereich bis 50 ausgedehnt werden	

indem eine geeignete Kombination von Vorsorge- und/oder Minderungstechniken eingesetzt wird (siehe Abschnitt 4.6). Die oben im BVT-Abschnitt „Behandlung von Luftemissionen“ (BVT Nummer 35-41) erwähnten Techniken tragen auch dazu bei, diese Werte zu erreichen

Abwasserbehandlung

Die BVT bestehen darin:

42. den Wasserverbrauch und die Kontaminationen des Wassers zu reduzieren durch (siehe Abschnitte 4.1.3.6 und 4.7.1):
    a. Anwendung abgedichteter Standorte und Rückhaltemetoden für Lagerbereiche
    b. Durchführung regelmäßiger Überprüfungen der Behälter und Gruben, insbesondere, wenn sie unterirdisch angelegt sind
    c. Anwendung getrennter Entwässerungen nach Grad der Verschmutzung (Regenwasser von Dächern, Wasser von Straßen, Prozesswasser)
    d. Nutzung eines Sicherheits-Sammelbeckens
    e. Durchführung regelmäßiger Wasseraudits mit dem Ziel, den Wasserverbrauch zu senken und Wasserkontaminationen zu vermeiden
    f. Getrennthaltung von Prozesswasser und Regenwasser (siehe Abschnitt 4.7.2 und dies steht auch im Zusammenhang mit BVT Nummer 46).

43. Prozeduren zu besitzen, die sicherstellen, dass die Abwasserspezifikationen für die betriebsinterne Abwasserbehandlungsanlage oder für die Einleitung geeignet sind (siehe Abschnitt 4.7.1)

44. zu vermeiden, dass Abwasser die Behandlungsanlage umgeht (siehe Abschnitt 4.7.1)

45. ein geschlossenes System zu besitzen und zu betreiben, indem Regenwasser von den Betriebsflächen zusammen mit Tank-Waschwasser, gelegentlichen Verschüttungen, Behälterwaschwasser usw. gesammelt und zur Aufbereitungsanlage zurückgeführt oder in einem kombinierten Abscheider gesammelt wird (siehe Abschnitt 4.7.1)

46. die Wassersammelsysteme für potenziell stark verunreinigte Abwässer und für weniger verunreinigte Abwässer getrennt zu halten (siehe Abschnitt 4.7.2)

47. im gesamten Behandlungsbereich einen Betonboden zu besitzen, der zu den betriebsinternen Entwässerungssystemen hin abfällt, welche wiederum zu Sammeltanks oder Abscheider führen, in denen Regenwasser und Verschüttungen gesammelt werden können. Abscheider mit einem Überlauf zur Abwasserleitung benötigen üblicherweise automatische Überwachungsverfahren, etwa für den pH-Wert, mit denen der Überlauf geschlossen werden kann (siehe Abschnitt 4.1.3.6 und dies steht auch im Zusammenhang mit BVT Nummer 63),

48. das Regenwasser in einem speziellen Becken für die Überprüfung zu sammeln und im Fall von Kontaminationen zu behandeln und weiter zu nutzen (siehe Abschnitt 4.7.1)

[48] Anm.d.Übers.: Im Originaltext ist das Wort “abdeckt” nicht enthalten.

49. die Wiederverwendung von behandelten Abwässern zu maximieren und Regenwasser soweit wie möglich in der Anlage zu nutzen (siehe Abschnitt 4.7.1)

50. tägliche Überprüfungen des Abwassermanagementsystems durchzuführen und ein Tagebuch über aller durchgeführten Überprüfungen zu führen indem ein System zur Überwachung der Einleitungen ins Abwasser und der Schlammqualität vorhanden ist (siehe Abschnitt 4.7.1)

51. erstens zu ermitteln, welche Abwässer gefährliche Verbindungen enthalten können (z.B. adsorbierbare organisch gebundene Halogene (AOX), Cyanide, Sulfide, aromatische Verbindungen, Benzol oder Kohlenwasserstoffe (gelöste, emulgierte oder ungelöste); und Metalle wie Quecksilber, Cadmium, Blei, Kupfer, Nickel, Chrom, Arsen und Zink) (siehe Abschnitt 4.7.2). Zweitens, die vorher ermittelten Abwasserströme auf dem Betriebsgelände getrennt zu halten und drittens, Abwässer betriebsintern oder betriebsextern spezifisch zu behandeln.

52. nach der Anwendung von BVT Nummer 42 letztendlich die geeignete Behandlungstechnik für jede Art von Abwasser auszuwählen und diese durchzuführen (siehe Abschnitt 4.7.1)

53. Maßnahmen zur Erhöhung der Verlässlichkeit einzuführen, mit der die erforderliche Kontroll- und Minderungsleistung realisiert werden kann (z.B. Optimierung der Fällung von Metallen) (siehe Abschnitt 4.7.1)

54. die wichtigsten chemischen Bestandteile des behandelten Abwassers zu ermitteln (einschließlich der Zusammensetzung des CSB) und anschließend eine sachkundige Bewertung des Verbleibs dieser Chemikalien in der Umwelt durchzuführen (siehe Abschnitt 4.7.1 und die dort genannten Anwendungsbeschränkungen)

55. das Abwasser nur nach Abschluss aller Behandlungsmaßnahmen und einer anschließenden Enduntersuchung vom Ort seiner Lagerung einzuleiten (siehe Abschnitt 4.7.1)

56. die folgenden Emissionswerte im Abwasser vor seiner Einleitung zu erreichen

Wasserparameter	Emissionswerte verbunden mit Nutzung der BVT (ppm)
CSB	20 – 120
BSB	2 – 20
Schwermetalle (Cr, Cu, Ni, Pb, Zn)	0,1 – 1
Hochgiftige Schwermetalle:	
As	<0,1
Hg	0,01 – 0,05
Cd	<0,1 – 0,2
Cr(VI)	<0,1 – 0,4

durch Anwendung geeigneter Kombinationen der in den Abschnitten 4.4.2.3 und 4.7. erwähnten Techniken. Die oben in diesem Abschnitt erwähnten Techniken zur „Abwasserbehandlung“ (BVT Nummer 42 – 55) tragen auch dazu bei, diese Werte zu erreichen.

Management für die im Verfahren erzeugten Reststoffe

Die BVT bestehen darin:

57. einen Reststoffmanagementplan als Teil des UMS zu besitzen (siehe Abschnitt 4.8.1), der folgendes enthält:
    a. grundlegende Betriebsführungstechniken (im Zusammenhang mit BVT Nummer 3)
    b. interne Benchmark-Techniken (siehe Abschnitt 4.1.2.8, dies steht auch im Zusammenhang mit BVT Nummer 1.k und 22).

58. die Nutzung von wiederverwendbaren Verpackungen zu maximieren (Fässer, Container, IBCs, Paletten usw.) (siehe Abschnitt 4.8.1)

59. Fässer wiederzuverwenden, wenn sie sich in einem guten Zustand befinden. In anderen Fällen sollten sie einer geeigneten Behandlung unterzogen werden (siehe Abschnitt 4.8.1)

60. eine Bestandsüberwachung über den Abfall auf dem Betriebsgelände zu führen, bei dem Aufzeichnungen über die erhaltenen und verarbeiteten Abfallmengen genutzt werden (siehe Abschnitt 4.8.3 und dies steht auch im Zusammenhang mit BVT Nummer 27)

61. den Abfall aus einer Tätigkeit/Behandlung möglicherweise als Einsatzstoff für eine andere Behandlung wiederzuverwenden (siehe Abschnitt 4.1.2.6 und dies steht auch im Zusammenhang mit BVT Nummer 23)

Bodenkontamination
Die BVT zur Verhinderung von Bodenkontamination bestehen darin:

62. Oberflächen für die Betriebsbereiche bereitzustellen und instandzuhalten, einschließlich der Durchführung von Maßnahmen zur Verhinderung oder schnellen Beseitigung von Leckagen und Verschüttungen, Sicherstellung der Instandhaltung von Entwässerungssystemen und anderen unterirdischen Konstruktionen (siehe Abschnitt 4.8.2)

63. ein undurchlässiges Fundament und eine betriebsinterne Entwässerung zu besitzen (siehe Abschnitte 4.1.4.6, 4.7.1, und 4.8.2)

64. die Größe des Betriebsgeländes und die Nutzung unterirdischer Behälter und Leitungen auf ein Minmum zu beschränken (siehe Abschnitt 4.8.2 und dies steht auch im Zusammenhang mit BVT Nummer 10.f, 25 und 40)

5.2 BVT für spezifische Arten der Abfallbehandlung

Dieser Abschnitt stellt die BVT-Elemente für alle Verfahren/Tätigkeiten vor, die mit diesem Dokument abgedeckt werden. Es wurde ähnlich gegliedert wie die vorherigen Kapitel.

Biologische Behandlung
Die BVT bestehen darin:

65. die folgenden Techniken bei Lagerung und Handhabung in biologischen Behandlungsanlagen anzuwenden (siehe Abschnitt 4.2.2):
    a. für weniger geruchsintensive Abfälle die Nutzung von automatisch und schnell schließenden Türen (wobei Türöffnungszeiten auf ein Minimum beschränkt bleiben), in Verbindung mit einer geeigneten Ablufterfassung, die einen Unterdruck in der Halle erzeugt
    b. für stark geruchsintensive Abfälle die Nutzung von geschlossenen Aufgabebunkern mit Fahrzeugschleuse
    c. Einhausung und Ausstattung des Bunkerbereichs mit einer Ablufterfassung.

66. die zugelassenen Abfallarten und Trennungsverfahren mit den durchgeführten Verfahren und den verwendbaren Minderungstechniken abzustimmen (z.B. abhängig vom Gehalt nicht biologisch abbaubarer Bestandteile) (siehe Abschnitt 4.2.3)

67. die folgenden Techniken bei der Anwendung der Vergärung zu nutzen (siehe Abschnitte 4.2.4 und 4.2.5):
    a. Anwendung einer engen Vernetzung von Verfahrens- und Wassermanagement
    b. Recycling der größtmöglichen Abwassermenge im Reaktor. Siehe betriebliche Aspekte, die bei der Anwendung der Technik auftauchen können, in Abschnitt 4.2.4
    c. Betrieb des Verfahrens unter thermophilen Vergärungsbedingungen. Bei bestimmten Abfallarten können keine thermophilen Bedingungen erreicht werden (siehe Abschnitt 4.2.4)
    d. Messung von TOC-, CSB-, N-, P- und Cl-Werten im Zu- und Abfluss. Wenn eine bessere Verfahrenskontrolle oder bessere Qualität des Abfall-OUT gefordert ist, müssen weitere Parameter gemessen und überwacht werden
    e. Maximierung der Biogaserzeugung. Bei Einsatz dieser Technik müssen die Auswirkung auf den Gärrückstand und die Biogasqualität berücksichtigt werden.

68. die Luftemissionen bei Nutzung von Biogas als Brennstoff zu reduzieren, indem Emissionen von Staub, NO_x, SO_x, CO, H_2S und VOC durch Einsatz einer geeigneten Kombination folgender Techniken minimiert werden (siehe Abschnitt 4.2.6):
    a. Waschen des Biogases mit Eisensalzen
    b. Nutzung von Entstickungstechniken wie SCR
    c. Nutzung einer thermischen Oxidationsanlage
    d. Nutzung von Aktivkohlefiltern.

69. die mechanisch-biologische Behandlung (MBA) zu verbessern durch (siehe Abschnitte 4.2.2, 4.2.3, 4.2.8, 4.2.10, 4.6.23):
    a. Einsatz vollständig eingehauster Bioreaktoren
    b. Vermeidung anaerober Bedingungen während der aeroben Behandlung durch Kontrolle des Abbaus[49] und der Luftzufuhr (durch Einsatz eines stabilisierten Luftkreislaufs) und durch Anpassung der Belüftung an die tatsächliche biologische Abbauaktivität
    c. die effiziente Nutzung von Wasser
    d. Thermoisolierung der Hallendecke, unter der bei aeroben Verfahren der biologische Abbau stattfindet
    e. Minimierung der Abgaserzeugung auf Werte zwischen 2500 bis 8000 Nm^3 pro Tonne. Werte unter 2500 Nm^3 pro Tonne wurden nicht berichtet
    f. garantiert gleichartige Beschickung von Materialien
    g. Recycling von Prozesswasser oder schlammigen Rückständen innerhalb des aeroben Behandlungsverfahrens, um Wasseremissionen vollständig zu vermeiden. Falls Abwasser erzeugt wird, sollte es so behandelt werden, dass es die in BVT Nummer 56 genannten Werte erreicht

[49] Anm.d.Übers.: Im Originaltext steht „digestion“ was auch mit Vergärung/Faulung übersetzt werden kann.

h. kontinuierliches Lernen über den Zusammenhang zwischen den überwachten Kennwerten des biologischen Abbaus und den gemessenen (gasförmigen) Emissionen
i. Reduzierung der Emissionen von Stickstoffverbindungen durch Optimierung des C:N-Verhältnisses.

70. die Emissionen aus mechanisch-biologischen Behandlungsanlagen auf folgende Werte zu reduzieren (siehe Abschnitt 4.2.12),

durch den Einsatz einer geeigneten Kombination folgender Techniken (siehe Abschnitt 4.6):
a. Sicherstellung einer guten Betriebsführung (im Zusammenhang mit BVT Nummer 3)
b. regenerative thermische Oxidationsanlage
c. Staubabscheidung.

Parameter	Behandeltes Abgas
Gerüche (GE/m^3)	<500 – 6000
NH_3 (mg/Nm^3)	<1 – 20
Für VOC und PM siehe allgemeine BVT 41 Die TWG hat erkannt, dass N_2O (siehe Abschnitt 4.6.10) und Hg dieser Tabelle ebenfalls hinzugefügt werden müssen, es lagen jedoch nicht genügend Daten vor, um Werte zu diesen Punkten zu validieren.	

71. die Emissionen in das Wasser auf die in BVT Nummer 56 genannten Werte zu reduzieren. Zusätzlich auch eine Beschränkung der Emissionen von Gesamt-Stickstoff, Ammoniak, Nitrat und Nitrit (siehe Abschnitt 4.7.7 und die abschließenden Bemerkungen in Kapitel 7)

Chemisch-physikalische Behandlung

Für die chemisch-physikalische Behandlung von Abwässern bestehen die BVT darin:

72. die folgenden Techniken in chemisch-physikalischen Reaktoren anzuwenden (siehe Abschnitt 4.3.1.2):
a. klare Definition der Zielsetzung und der erwarteten Reaktionschemie für jedes Behandlungsverfahren
b. Bewertung jeder neuen Reihe an Reaktionen und beabsichtigten Mischung von Abfällen und Reagenzien durch Tests im Labormaßstab vor der Abfallbehandlung
c. spezifische Auslegung und Betrieb des Reaktionsbehälters, so dass er für seinen beabsichtigten Zweck geeignet ist
d. Einhausung aller Behandlungs/Reaktionsbehälter und Sicherstellung, dass sie über ein geeignetes Gaswäsche- und Minderungssystem entlüftet werden
e. Überwachung der Reaktion, um sicherzustellen, dass sie unter Kontrolle ist und zum erwarteten Ergebnis führt
f. Verhindern der Mischung von Abfällen oder anderen Strömen, die zeitgleich Metalle und Komplexbildner enthalten (siehe Abschnitt 4.3.1.3).

73. zusätzlich zu den allgemeinen Parametern, die in BVT Nummer 56 festgelegt wurden, müssen zusätzliche Parameter für die chemisch-physikalische Behandlung von Abwässern identifiziert werden. Einige Hinweise zu diesem Punkt geben die abschließenden Bemerkungen in Kapitel 7.

74. die folgenden Techniken für das Neutralisationsverfahren anzuwenden (siehe Abschnitt 4.3.1.3)
a. Sicherstellung, dass die betriebsüblichen Messmethoden genutzt werden
b. getrennte Lagerung des neutralisierten Abwassers
c. Durchführung einer Endüberprüfung des neutralisierten Abwassers, nachdem eine ausreichende Lagerzeit verstrichen ist.

75. die folgenden Techniken anzuwenden, um die Fällung der Metalle in Behandlungsverfahren zu unterstützen (siehe Abschnitt 4.3.1.4):
    a. Einstellung des pH-Werts auf den Punkt minimaler Löslichkeit, an dem die Metalle ausfällen
    b. Verhinderung des Eintrags von Komplexbildnern, Chromaten und Cyaniden
    c. Verhinderung des Eintrags von organischen Materialien, die eine Fällung behindern, in das Verfahren
    d. Berücksichtigung einer möglichen Klärung des behandelten Abfalls durch Dekantieren, falls möglich, und/oder durch Zusatz anderer Entwässerungsvorrichtungen
    e. Nutzung der Sulfidfällung, wenn Komplexbildner vorhanden sind. Diese Technik kann zur Erhöhung der Sulfidkonzentration im behandelten Abwasser führen.

76. die folgenden Techniken bei der Emulsionstrennung anzuwenden (siehe Abschnitt 4.3.1.5):
    a. Überprüfung der Anwesenheit von Cyaniden in den zu behandelnden Emulsionen. Falls Cyanide vorhanden sind, benötigen die Emulsionen eine spezielle Vorbehandlung
    b. Durchführung von Simulationstests im Labor.

77. die folgenden Techniken bei der Oxidation/Reduktion anzuwenden (siehe Abschnitt 4.3.1.6):
    a. Minderung der Luftemissionen, die während der Oxidation/Reduktion entstehen
    b. Vorhandensein von Sicherheitsmaßnahmen und Gasdetektoren (z.B. geeignet zur Detektion von HCN, H_2S, NO_x).

78. die folgenden Techniken für cyanidhaltige Abwässer anzuwenden (siehe Abschnitt 4.3.1.7):
    a. Zerstörung der Cyanide durch Oxidation
    b. Zugabe von Natronlauge im Überschuss, um ein Sinken des pH-Werts zu verhindern
    c. Vermeidung der Mischung von Cyanidabfällen mit sauren Verbindungen
    d. Überwachung des Ablaufs der Reaktion anhand des elektrischen Potenzials.

79. die folgenden Techniken auf Abwässer, die Chrom(VI)-haltige Verbindungen enthalten, anzuwenden (siehe Abschnitt 4.3.1.8):
    a. Vermeidung der Mischung von Cr(VI)-Abfällen mit anderen Abfällen
    b. Reduktion von Cr(VI) zu Cr(III)
    c. Fällung des dreiwertigen Metalls.

80. die folgenden Techniken auf nitrithaltige Abwässer anzuwenden (siehe Abschnitt 4.3.1.9):
    a. Vermeidung der Mischung von Nitritabfällen mit anderen Abfällen
    b. Überprüfung und Verhinderung der Entstehung nitroser Gase während der Oxidations/Ansäuerungbehandlung von Nitriten.

81. die folgenden Techniken auf ammoniakhaltige Abwässer anzuwenden (siehe Abschnitt 4.3.1.11):
    a. Nutzung eines Luftstrippsystems über zwei Kolonnen mit einer sauren Gaswäsche für Abfall mit Ammoniaklösungen bis zu 20 Gew.-%
    b. Rückgewinnung des Ammoniaks in den Gaswäschern und Rückführung ins Verfahren vor der Absetzstufe
    c. Entfernung des in der Gasphase abgeschiedenen Ammoniaks durch eine Abgaswäsche mit Schwefelsäure, um Ammoniumsulfat zu erzeugen
    d. Erweiterung aller Probenahmen auf Ammoniak am Abgasschacht oder dem Filterpressenbereichen, um die VOCs bei der Filtration und Entwässerung zu erfassen[50] (siehe Abschnitt 4.3.1.12).

82. den Luftraum oberhalb der Filter und der Entwässerungsverfahren mit dem Haupt-Minderungssystem der Anlage zu verbinden (siehe Abschnitt 4.3.1.12)

83. dem Schlamm und dem zu behandelnden Abwasser Flockungsmittel zuzugeben, um den Sedimentationsprozess zu beschleunigen und die weitere Abtrennung von Feststoffen zu erleichtern (siehe Abschnitt 4.3.1.16 für identifizierte Anwendungsbeschränkungen). In den Fällen, in denen dies ökonomisch durchführbar ist, ist das Eindampfen besser, da dabei keine Flockungsmittel eingesetzt werden müssen (siehe Abschnitt 4.7.6.1)

[50] Anm. d. Übers.: Die hier möglicherweise vorliegende inhaltliche Unstimmigkeit wurde aus dem englischsprachigen Original übernommen.

84. eine Schnellreinigung und eine Dampf- oder Hochdruckwasserstrahlreinigung der Filteröffnungen der Siebverfahren durchzuführen (siehe Abschnitt 4.3.1.17).

Für die chemisch-physikalische Behandlung von festen Abfällen bestehen die BVT darin:

85. die Unlösbarkeit der amphoteren Metalle zu fördern, und die Auslaugung giftiger löslicher Salze durch eine geeignete Kombination von Waschen mit Wasser, Eindampfen, Rekristallisation und Säureextraktion zu verringern (siehe Abschnitte 4.3.2.1, 4.3.2.8, 4.3.2.9), wenn eine Immobilisierung als Behandlung angewendet wird um feste Abfälle mit gefährlichen Bestandteilen zu deponieren
86. die Auslaugbarkeit anorganischer Verbindungen unter Nutzung der standardisierten CEN-Auslaugverfahren, durch Anwendung eines angemessenen Testniveaus zu überprüfen: Grundlegende Charakterisierung, Übereinstimmungsuntersuchung oder Untersuchung vor Ort (siehe Abschnitt 4.3.2.2)
87. die Annahme von Abfällen zur Behandlung durch eine Verfestigung/Immobilisierung auf diejenigen zu beschränken, die keine hohen Konzentrationen an VOCs, geruchsintensiven Bestandteilen, festen Cyaniden, Oxidationsmitteln, Chelatbildnern besitzen, sowie keine Abfälle mit hohem TOC und Gasflaschen (siehe Abschnitt 4.3.2.3)
88. Kontroll- und Einhausungstechniken beim Be- und Entladen sowie eingehauste Förderbändersysteme anzuwenden (siehe Abschnitt 4.3.2.3)
89. Minderungssystem(e) zu besitzen, die in der Lage sind, die anfallende Luftmenge zu behandeln, sowie auch die Spitzenbelastungen, die mit der Aufgabe und dem Entladen verbunden sind, zu handhaben (siehe Abschnitt 4.3.2.3)
90. vor der Deponierung von festem Abfall mindestens ein Verfestigungs-, Verglasungs-, Schmelz- oder Sinterverfahren gemäß den Techniken in den Abschnitten 4.3.2.4 bis 4.3.2.7 zu nutzen

Für die chemisch-physikalische Behandlung von kontaminiertem Boden bestehen die BVT darin:

91. den Grad der Auskofferung, die Größe des betroffenen Areals, in dem Boden verunreinigt ist und die Dauer, in der Böden unbedeckt zurückbleiben, während des Auskofferns und der Entfernung des kontaminierten Bodens, zu kontrollieren (siehe Abschnitt 4.3.2.10)
92. einen Test im Labormaßstab durchzuführen, um die Eignung des geplanten Verfahrens und die besten Betriebsbedingungen für seine Nutzung zu bestimmen (siehe Abschnitt 4.3.2.11)
93. Geräte zur Erfassung und Kontrolle zu haben, wie etwa Nachbrenner, thermische Oxidationsanlagen, Gewebefilter, Aktivkohle, oder Kondensatoren für die Behandlung von Abgasen aus thermischen Behandlungen (siehe Abschnitt 4.3.2.11)
94. über die erzielten Wirkungsgrade der Verfahren bei der Reduzierung der verschiedenen Komponenten Bericht zu erstatten, auch für jene, die nicht durch das Verfahren beeinflusst wurden (siehe Abschnitt 4.3.2.3)

Rückgewinnung von Materialien aus dem Abfall

Für die Re-Raffination von Altöl bestehen die BVT darin:

95. eine sorgfältige Überprüfung der eingehenden Materialien mit Unterstützung von analytischen Geräten (Viskometrie, Infrarot, Chromatographie und Massenspektrometrie, wo angemessen), der Laboratorien und Hilfsmittel durchzuführen (siehe Abschnitt 4.1.1.1)
96. mindestens im Hinblick auf chlorierte Lösemittel und PCBs zu überprüfen (siehe Abschnitte 4.1.1.1 und 4.4.1.2)
97. die Kondensation in der Behandlung für die Gasphase der Vordestillation einzusetzen (siehe Abschnitt 4.6.8)
98. Dampfrückleitungen für das Be- und Entladen von Fahrzeugen zu besitzen, wobei alle Entlüftungen zu einer thermischen Oxidations/Verbrennungsanlage oder einer Aktivkohleadsorptionsanlage geleitet werden (siehe Abschnitte 4.1.4.6, 4.6.7 und 4.6.14)

99. eine direkte Entlüftung zu einer thermischen Oxidationsanlage mit Abgasbehandlung zu haben, falls chlorierte Verbindungen im Entlüftungsstrom vorhanden sind. Bei hohen Konzentrationen chlorierter Verbindungen ist die Kondensation mit anschließender alkalischer Gaswäsche und einem Aktivkohleschutzbett der bevorzugte Behandlungsweg (siehe Abschnitt 4.6)

100. eine thermische Oxidation bei 850 °C mit zwei Sekunden Verweilzeit für die Entlüftung der bei der Vakuumdestillation eingesetzten Vakuumerzeuger oder für die Luft aus Heizaggregaten einzusetzen (siehe Abschnitt 4.6)

101. ein hocheffizientes Vakuumverfahren einzusetzen (siehe Abschnitt 4.4.1.1)

102. die Rückstände aus der Vakuumdestillation oder den Dünnschichtverdampfern als Asphaltprodukte zu nutzen (siehe Abschnitt 4.4.1.15)

103. ein Re-Raffinationsverfahren für Altöl zu nutzen, dass eine höhere Ausbeute als 65 % Trockenbasis erreicht (siehe Abschnitte 4.4.1.1 bis 4.4.1.12)

104. die folgenden Werte im eingeleiteten Abwasser aus der Re-Raffinationsanlage zu erreichen (siehe Abschnitt 4.4.1.14):

Abwasserparameter	Konzentration (ppm)
Kohlenwasserstoffe	<0,01 – 5
Phenole	0,15 – 0,45
Für andere Abwasserparameter wird auf BVT Nummer 56 im Abschnitt “Allgemeine BVT“ verwiesen	

durch Nutzung einer geeigneten Kombination von prozessintegrierten Techniken und/oder primären, sekundären, biologischen und Endbehandlungen (siehe Abschnitte 4.4.1.14 und 4.7).

Für die Behandlung von Lösemittelabfällen bestehen die BVT darin:

105. eine sorgfältige Kontrolle der eingehenden Materialien mit Unterstützung der analytischen Geräte, der Laboratorien und Hilfsmittel durchzuführen (siehe Abschnitt 4.1.1.1)

106. den Rückstand aus den Destillationskolonnen einzudampfen und die Lösemittel zurückzugewinnen (sieh Abschnitt 4.4.2.4)

Für die Regeneration von Abfallkatalysatoren bestehen die BVT darin:

107. Beutelfilter einzusetzen, um die während des Regenerationsverfahrens erzeugten Partikel im Abgas zu mindern (siehe Abschnitte 4.4.3 und 4.6.5)

108. ein Entschwefelungsverfahren zu nutzen (siehe Abschnitt 4.4.3.3).

Für die Regeneration von verbrauchter Aktivkohle bestehen die BVT darin:

109. eine effektive Qualitätskontrolle zu haben, um sicherzustellen, dass der Betreiber zwischen dem Kohlenstoff, der für Trinkwasser benutzt wird oder lebensmitteltauglich ist und sonstigem verbrauchten Kohlenstoff (so genanntem „industriellen Kohlenstoff“) unterscheiden kann (siehe Abschnitt 4.4.4.2)

110. von Kunden eine schriftliche Garantie anzufordern, die angibt, wofür die Aktivkohle benutzt wurde (siehe Abschnitt 4.1.2.3 und dies steht auch im Zusammenhang mit BVT Nummer 12.c)

111. einen indirekt befeuerten Ofen für industrielle Kohlenstoffe einzusetzen – es könnte argumentiert werden, dass hier gleichermaßen Kohlenstoffe für Trinkwasser angewendet werden könnten. Allerdings können Kapazitätsbeschränkungen und Korrosionsprobleme dafür sprechen, das ausschließlich Etagenöfen oder direkt befeuerte Drehrohröfen genutzt werden (siehe Abschnitt 4.4.4.1)

112. einen Nachbrenner mit einer Mindesttemperatur von 1100 °C bei einer Verweilzeit von zwei Sekunden und 6 % Sauerstoffüberschuss zur Regeneration von industriellen Kohlen einzusetzen, bei denen die Wahrscheinlichkeit besteht, dass thermoresistente halogenierte oder sonstige thermisch resistente Stoffe vorhanden sind. In anderen Fällen genügen weniger strenge thermische Bedingungen (siehe Abschnitt 4.4.4.2)

113. einen Nachbrenner mit einer Mindestheiztemperatur von 850 °C bei einer Verweilzeit von zwei Sekunden und 6 % Sauerstoffüberschuss für trinkwasser- und lebensmitteltaugliche Aktivkohlen einzusetzen (siehe Abschnitt 4.4.4.2)

114. eine Abgasbehandlungskette einzusetzen, die aus einem Quench und/oder Venturiwäschern und wässrigen Gaswäschebereichen mit anschließendem induzierten Saugzug besteht (siehe Abschnitt 4.4.4.2)

115. alkalische oder Soda-Gaswäscherflüssigkeiten einzusetzen, um saure Gase aus Regenerationsanlagen für Industriekohlen zu neutralisieren (siehe Abschnitt 4.4.4.2)

116. bei der Behandlung von Kohlenstoff aus der Trinkwasseraufbereitung eine Abwasserbehandlungsanlage zu haben, die aus einer geeigneten Kombination von Flockung, Absetzen, Filtration und pH-Wert-Einstellung besteht. Für Abwässer von Industriekohlenstoff werden zusätzliche Behandlungen angewendet (z.B. Fällung von Metallhydroxiden, Sulfidfällung) die auch als BVT betrachtet werden (siehe Abschnitt 4.4.4.3)

Aufbereitung von Abfall zur Nutzung als Brennstoff

Für die Aufbereitung von Abfall zur Nutzung als Brennstoff bestehen die BVT darin:

117. eine enge Beziehung mit dem Nutzer des Brennstoffs aus Abfall anzustreben, damit Kenntnisse über die Zusammensetzung des Brennstoffs aus Abfall ordnungsgemäß weitergegeben werden (siehe Abschnitt 4.5.1)

118. ein Qualitätssicherungssystem zu besitzen, um Eigenschaften des erzeugten Brennstoffs aus Abfall zu garantieren (siehe Abschnitt 4.5.1)

119. unterschiedliche Brennstoffe aus Abfall herzustellen, je nach Art des Nutzers (z.B. Zementöfen, verschiedene Kraftwerke), der Art des Ofens (z.B. Rostfeuerung, Einblasen) und Art der Abfälle die genutzt werden für die Produktion (z.B. *gefährliche Abfälle*, feste Siedlungsabfälle) (siehe Abschnitt 4.5.2)

120. bei der Erzeugung von Brennstoff aus gefährlichen Abfällen eine Aktivkohlebehandlung für gering verschmutztes und eine thermische Behandlung für stark verschmutztes Wasser zu nutzen (siehe Abschnitte 4.5.6 und 4.7). In diesem Zusammenhang bezieht sich thermische Behandlung auf jede thermische Behandlung in Abschnitt 4.7.6 oder die Verbrennung, die nicht in diesem Dokument enthalten ist

121. bei der Erzeugung von Brennstoff aus gefährlichen Abfällen die korrekte Befolgung der Regeln hinsichtlich der Gefahren einer elektrostatischen Aufladung und der Entzündlichkeit aus Sicherheitsgründen sicherzustellen (siehe Abschnitte 4.1.2.7 und 4.1.7)

Für die Herstellung von festen Brennstoffen aus nicht gefährlichen Abfällen bestehen die BVT darin:

122. den eingehenden Abfall visuell zu begutachten, um sperrige metallische oder nichtmetallische Teile auszusortieren. Der Zweck hiervon ist, die Anlage gegen mechanische Beschädigung zu schützen (siehe Abschnitt 4.1.1.3 und dies steht auch im Zusammenhang mit BVT 8.e)

123. magnetische Abscheider für Eisen und Abscheider für NE-Metalle zu nutzen. Der Zweck dieser Maßnahme ist es, sowohl die Pelletierer zu schützen als auch die Anforderungen der Endnutzer zu erfüllen (siehe Abschnitte 4.5.3.3 und 4.5.3.10)

124. die NIR-Technik zur Aussortierung von Kunststoffen zu nutzen. Der Zweck dieser Maßnahme ist es, den Gehalt an organischem Chlor und den Gehalt einiger Metalle, als Bestandteil der Kunststoffe, zu reduzieren (siehe Abschnitt 4.5.3.10)

125. eine Kombination von Schredderanlagen und Pelletierern zu nutzen, die zur Erzeugung eines Brennstoffs spezifischer Größe aus Abfall geeignet ist (siehe Abschnitte 4.5.3.1 und 4.5.3.12)

    Für einige Anlagen, die feste Brennstoffe aus Abfall aus an der Quelle getrennt gehaltenen Abfallströmen herstellen, kann der Einsatz einiger oder aller der oben erwähnten Techniken nicht notwendig sein, um den BVT zu entsprechen (siehe Abschnitt 4.5.3.1)

Für die Herstellung von festem Brennstoff aus gefährlichen Abfällen bestehen die BVT darin:

126. Emissionen und die Entzündlichkeitsgefahren zu berücksichtigen, falls eine Trocknung oder Erwärmung erforderlich ist (siehe Abschnitte 4.1.2.7 und 4.5.4.1)

127. zu erwägen, Mischungs- und Vermengungsarbeiten in eingehausten Bereichen mit geeigneten Anlagen zur Kontrolle der Atmosphäre durchzuführen (siehe Abschnitte 4.1.4.5, 4.5.4.1 und 4.6)

128. Gewebefilter zur Abscheidung von Partikeln einzusetzen (siehe Abschnitt 4.6.26)

Für die Herstellung von flüssigen Brennstoffen aus gefährlichen Abfällen liegen die BVT darin:

129. Wärmetauschereinheiten außerhalb des Gefäßes zu nutzen, falls eine Erwärmung des flüssigen Brennstoffs erforderlich ist (Abschnitt 4.5.4.1)

130. den Gehalt an suspendierten Feststoffen anzupassen, um die Homogenität des flüssigen Brennstoffs sicherzustellen (siehe Abschnitt 4.5.4.1)

6 EMERGING TECHNIQUES

Emerging technique is understood in this document as a novel technique that has not yet been applied in any industrial sector on a commercial basis. This chapter contains those techniques that may appear in the near future and that may be applicable to the waste treatment sector.

[5, Concawe, 1996], [36, Viscolube, 2002], [30, Eklund, et al., 1997], [41, UK, 1991], [81, VDI and Dechema, 2002], [90, Rogut, 2003], [101, Greenpeace, 1998], [122, Eucopro, 2003], [132, UBA, 2003], [141, Magistrelli, et al., 2002], [150, TWG, 2004], [152, TWG, 2004], [154, UNEP, 2004]

On-line analysis

Description
The technique of the online-analysis is one of the latest developments on the field of analysis and quality assurance. It can be used for all applications in the field of preparation of solid recovered fuels.

On-line analysis is used for crushed and/or for non-crushed materials with automatically elimination of materials which do not comply with the quality criteria for e.g solid recovered fuels - especially when the chlorine- and/or bromine values are exceeded.

The mode of function is based on a new X-ray fluorescence-analysis with high speed analysis, so that a large quantity of crushed or not crushed materials (it depends on technical performance and determination) per hour can be analysed and/or detected and it can be automatically eliminate by overdraw nominal stock.

The configuration of the measuring unit and/or analyser takes place directly above a conveyor. A material stream as uniform as possible is directed under the measuring-unit and/or analyser and is analysed and/or measured.

If a limit-value is exceeded an electronically signal (digital or analogue) follows. There upon controlled through a software and/or electronics-unit the objectionable material is automatically (mechanically, hydraulically, pneumatically, electrostatically or magnetically magnetically) discharged. The measuring-unit and/or analyser can be equipped with one or more X-ray tubes or with one or more detectors.

As a additional control and quality assurance for the material input, also a handheld-unit can be used. The handheld-unit is also based on the X-ray fluorescence-method and it can ecspecially used for the analyse and/or detection from chlorine, bromine and heavymetals.

Achieved environmental benefits
Following elements can be analysed and detected with this tool (depending on equipment and software): Cl, Br, Cd, Hg, Pb, As, Se, Ni, Sb, Cu, Ba, Cr, Sn, Mo, Zn, Sr, Fe, Co, Ti, V, Rb, Ir, Pt, Au, Ag, Pd, Nb, W, Bi, Mn, Ta, Zr, Hf, Re.

Cross-media effects

Operational data
The tool is developed for the highest analyse quality under hardest attendance (dirt, rain, dust – are no problems!) The most fasted electronic deliver analyse quality as in the laboratory, nevertheless on the spot, measurement for measurement, equal what material, no standards or recalibrations.

Applicability
This tool seems to be now the fastest and exact handheld analysis tool for practically all recycling metal – plastic – oldwood – glass – ground – waste – mud – non-ferrous metal.

Reference literature
[150, TWG, 2004]

Biological degradation times in MBT processes
The minimal biological degradation times required to comply with the landfill criteria with sufficient operational reliability will have to be determined by future experience with the new optimised MBT plants.

Immobilisation of heavy metal chlorides
A method for the stabilisation of heavy metals wastes generated in the fly ashes vitrification process is based on the batch conversion of heavy metal chlorides with ammonium dihydrogenphosphate ($NH_4H_2PO_4$). Conversion of heavy metal chlorides into phosphate and its immobilisation in phosphate glass matrix.

Ferrous sulphate stabilisation of FGT waste

Description
This stabilization involves a five-step procedure, where the solid material are first mixed with a $FeSO_4$ solution and then aerated with atmospheric air at L/S 3 l/kg in order to oxidise Fe(II) to Fe(III) and precipitate iron oxides. This step also includes extraction of soluble salts. The pH of the suspension is then maintained at pH 10 - 11 for about 0.5 to 1 hour to allow dissolved heavy metals to bind to the precipitated iron oxides. The fourth step of the process is dewatering and finally a washing step to exchange remaining water and remove remaining salts. The final stabilised product has a water content of about 50 %.

Achieved environmental benefits
The main advantage of this stabilization process is the improved leaching properties of the final product. The leaching characteristics of waste OUT are shown to be very good, and it is expected that low release of heavy metals can be maintained for extended periods of time, as iron oxides are known to endure in geological time frames. The pollution potential of the waste OUT is documented rather detailed and the waste OUT are expected to be less prone to physical disintegration than cement stabilised products because of the fact that most salts are removed. This process stabilises FGT waste and typically have far better leaching properties than cement solidified wastes. This process reduces the amount of waste OUT by about 10 % per dry weight.

Cross-media effects
No reutilization strategies have yet been demonstrated, however it has been suggested that the waste OUT can be utilised in road construction after thermal treatment in the combustion chamber of the incinerator. Research activities are currently addressing this issue.

The process produces waste water with high content of salts and relatively low concentrations of metals because Fe(II) is present in the extraction step. The waste water can in most cases be discharged to a marine recipient after a simple treatment or can be deionised by crystallization.

Operational data
The process has been demonstrated in pilot scale at a batch plant of about 200 kg dry weight. Parameters like water consumption, mixing of water and materials, Fe(II) oxidation rate, reaction time, pH and pH controlling additive have been optimised. It has been demonstrated that the process is robust with respect to the properties of the waste IN, although some variations in process parameters arise. Typical process data are for one tonne of waste IN: 10 - 50 kg Fe, 20 - 50 minutes aeration, 30 - 60 minutes reaction time, H_2SO_4 or $FeSO_4$ as pH controlling additive, optimum pH of 10 - 11, and a water consumption of 3 - 4 m^3. In the current setup, dewatering of the treated material was done with a plate and frame filter press.

Applicability
The stabilization unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The technique has been demonstrated on semidry FGT waste as well as fly ash alone and fly ash combined with sludge from the wet scrubbers (Bamberg product); all with good results.

Economics
Treatment cost is estimated to about EUR 65/tonne with a plant capacity of 20000 tonne/year including investment costs.

Driving force for implementation
The main reason for implementing this technology is the very good leaching properties of the waste OUT and the fact that this is expected to last in a long-term perspective.

Example plants
The process has only been demonstrated in pilot scale, however it has also been designed in full-scale. No full-scale plants have yet been implemented.

Reference literature
[124, Iswa, 2003]

Carbon dioxide and phosphate stabilisation of FGT waste

Technical description
Chemical agents used here are CO_2 and/or H_3PO_4. This process involves a two-step procedure where the waste IN are first washed at L/S 3 l/kg in order to extract soluble salts. After this the material are dewatered and washed again in a plate and frame filter press at L/S 3 l/kg. The residues are then re-suspended, and CO_2 and/or H_3PO_4 is added. The stabilization reactions are allowed to occur for 1 - 1.5 hours while pH decreases, and another hour where pH is maintained around pH 7. Finally, the residues are dewatered again and washed at the filter press with another 3 l/kg. The final product has a water content of about 50 %. The use of CO_2 and H_3PO_4 as stabilizing agent ensures that heavy metals are bound as carbonates or phosphates.

Achieved environmental benefits
It shows very good leaching properties similar to the Ferrox stabilization. Metal carbonates and phosphates are known to generally have low solubilities, and the leaching characteristics of the waste OUT are expected to remain good for extended periods of time. The pollution potential of the waste OUT is documented rather detailed and physical disintegration of the waste OUT in a long-term perspective is expected to be less important than in the case of cement stabilization, because of the fact that most salts are removed. Waste OUTs typically have far better leaching properties than the ones treated with cement. The process reduces the amount of material by about 15 % per dry weight.

Cross-media effects
No reutilization strategies have yet been demonstrated. The process produces waste water from first dewatering step. All other process water is recycled in the process. The waste water needs to be treated for dissolved heavy metals in a standard unit, for example using pH adjustment and TMT addition.

Operational information
The process has been demonstrated in pilot scale at a batch plant of about 200 kg dry weight. Parameters like water consumption, mixing of water and solid material, CO_2 and H_3PO_4 addition, reaction time, pH and pH controlling approach have been optimised. It has been demonstrated that the process is robust with respect to the properties of the waste IN, although some variations in process parameters arise. Depending on waste IN composition, either CO_2 or

H_3PO_4 or both have been used. It has also been demonstrated that flue-gas can be used as CO_2 source.
Typical process data for 1 tonne of waste IN are: 5 - 20 kg of CO_2, 0 - 40 kg H_3PO_4 and 3 m^3 H_2O.

Applicability of technique
The stabilization unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The technique has been demonstrated on semidry FGT waste as well as fly ash alone and fly ash combined with sludge from the wet scrubbers (Bamberg product); all with good results.

Economics
Treatment cost for stabilization is estimated to about EUR 80/tonne with a plant capacity of 20000 tonne/year; including investment costs.

Driving force of implementation
The main reason for implementing this technology is the very good leaching properties of the waste OUT and the fact that this is expected to last in a long-term perspective.

Examples
The process has only been demonstrated in pilot scale, however it has also been designed in full-scale. No full-scale plants have yet been implemented.

References
[124, Iswa, 2003], [152, TWG, 2004]

Emerging techniques for soil vapour extraction for soil remediation
Approaches such as microwave, radio frequency, and electrical heating have been tested at the pilot scale, but full-scale results are not yet available.

Phytoextraction of metals from the soil
In the field of environmental reclamation through biological process, the methodology known as phytoremediation has recently received mounting attention from operators in the field. Phytoremediation encompasses various techniques used for cleaning up both soil and water. For metal contaminated soil, phytoextraction represents one of the best solutions from the eco-environmental point of view. Through this technique, metals are absorbed and transported from the soil to the harvestable tissues of plants.

Treatments of waste contaminated with POPs
Such type of waste is actually mostly treated by incineration. However other types of technique are emerging as shown in next Table 6.1.

Technique	Comment
Base catalyzed dechlorination	Organochlorines are reacted with an alkaline polyethylene glycol, forming a glycol ether and/or a hydroxylated compound, which requires further treatment, and a salt. Dioxins have been identified in process residues. Destruction efficiencies are not high
Catalytic hydrogenation	Organochlorines are reacted with hydrogen in the presence of noble metal catalysts, yielding hydrogen chloride and light hydrocarbons.
Electrochemical oxidation	At low temperature and atmospheric pressure, electrochemically-generated oxidants react with organochlorines to form carbon dioxide, water and inorganic ions with high destruction efficiencies. All emissions and residues can be captured for assay and re-processing, if needed. An electrochemical cell is used to generate oxidising species at the anode in an acid solution, typically nitric acid. These oxidisers and the acid then attack any organic compounds, converting most of them to carbon dioxide, water and inorganic ions at low temperature (<80 °C) and atmospheric pressure. Compounds that have been destroyed by this process include aliphatic and aromatic hydrocarbons, phenols, organophosphorous and organosulphur compounds, and chlorinated aliphatic and aromatic compounds. Data describing concentrations in gaseous, liquid and solid residues of dioxins and other POPs potentially formed by this process were not available for review. No industrial application is currently known
Electron beam oxidation	
Mediated electro-chemical oxidation by cerium	This technique uses electrochemical cells for the generation of the active Cerium(IV) oxidant at the anode, a liquid phase reactor for primary organic destruction, a gas phase reactor to destroy any fugitive emissions from the liquid reactor and an acid gas scrubber for removal of acid gases prior to venting to the air. The process operates at low temperature (90 – 95 °C) and at atmosphere pressure
Mediated electro-chemical oxidation by silver	This process uses silver (II) to oxidise organic waste streams. Reactions take place in an electro-chemcial cell similar to the type utilised in the chlor-alkali industry. Thre process operates at low temperature (~90 °C) and at atmospheric pressure
Molten metal	Organochlorines and other materials are oxidised in a vat of molten metal, yielding hydrogen, carbon monoxide, ceramic slag and metal by-products. There is currently designing facilities for four commercial customers in US
Molten salt	Organochlorines and other materials are oxidised in a vat of molten salt, yielding carbon dioxide, water, molecular nitrogen, molecular oxygen, and neutral salts. Destruction efficiencies may be high. It is suitable for the destruction of pesticides but not for treatment of contaminated soils
Photocatalysis	Use light to activate a catalyst that oxidise/reduce the compounds. A wide range of compounds can be destroyed. Useful for liquid and gaseous wastes
Ultraviolet oxidation	

Table 6.1: Emerging destruction techniques of POPs
[101, Greenpeace, 1998], [150, TWG, 2004], [154, UNEP, 2004]

Emerging techniques for treatment of waste oil

Presently, around the world, there are many activities to improve the existing used oil recycling technologies and to develop new ones. Next table sumarises those techniques under development:

Technique	Comment
FILEA Process by C.E.A.	Supercritical CO_2 filtration
MRD solvent extraction	Solvent extraction of used oil vaccum distillates produced by TFE with a high efficient and selective solvent (e.g. NMP). Complete waste free technology with high efficiency and flexibility and production of high quality base oils. Their major advanges are: • quantitative reduction of PNAs to a level not achievable by any other re-refining technology (ppb level) • complete retention of the high valued synthetic base oil components more and more present in used oils resulting in very high qualities of the produced base oils. It is expected that a unit will be in operation in Germany by March 2005
New Meinken technology	It has been developed a new process applying a novel absorbent to vacuum distillates. The catalyst absorbent seems to be an activated clay. No industrial application is currently known
Probex Process)	
ROBYS™ Process	Catalytic cracking and stabilisation for diesel production
Supercritical treatments	This technology applies to the deasphalting and also the fractionation. Pre-flash and hydrotreating do not change with respect to the standard assembly of a PDA unit. • *Supercritical Deasphalting:* the asphaltic fraction is separated by extraction with light hydrocarbons (C_2/C_3) under supercritical conditions. The clarified oil is separated from the extraction medium and fractionated in a standard column under vacuum conditions. • *Supercritical Fractionation:* the clarified oil from the supercritical deasphalting unit. still mixed with the extraction medium. is directly separated into two or more cuts by varying the physical conditions of the mixture. Both technologies reduce the investment and operating costs when compared with the standard PDA technologies (1 and 2 stages). Two independent pilot plant projects have been developed

Table 6.2: Waste oil treatment technologies under development
[5, Concawe, 1996], [36, Viscolube, 2002], [150, TWG, 2004]

Regeneration of activated carbon

	Stage of development
Activated carbon regeneration technologies	
Biological regeneration of spent activated carbon	Currently at the research and development stage
Oxidative regeneration	Currently at the research and development stage
Novel pollution control techniques for the abatement of emissions	
Circulating fluidised bed absorber	
Electrocatalytic oxidation of sulphur dioxide (the ELCOX process)	
Electrochemical processes	
Flue-gas irradiation	
Methanol injection	

Table 6.3: Emerging techniques that may be applied to activated carbon regeneration
[41, UK, 1991], [150, TWG, 2004]

Preparation of solid fuel from organic/water mixtures
The process consists in preparation of a fuel for the use in cement kilns. The process is the mixing of the organic-water mixtures with a lime hydrate porous structure in order to capture the organics and use such product as raw material in the cement industry. This technique is able to deal with clinical waste, municipal waste, hazardous/chemical waste and non-hazardous industrial and commercial waste.

Emerging techniques for hazardous waste preparation for energy recovery
New adsorbents for the preparation of solid waste fuel from hazardous waste. There is a permanent research for other absorbents in order to replace the fresh sawdust.

Cracking of polymer materials
Liquid or gaseous fuels like gasoils or heavy fuel oils can be also substituted with a prior step to crack the waste polymer into a liquid or a gas. Efforts in this field have mostly not progressed further than pilot scale tests.

7 CONCLUDING REMARKS

From the first meeting onwards, it has been difficult to have a common understanding within the TWG of which waste treatment activities need to be covered by this document. These different views on what should or should not be covered by this document have made the process more difficult and has probably restricted the development of the BAT chapter further (see 'Recommendations for future work' below).

There are some views that the scope of this document should cover all waste treatment installations now available in the waste sector. Their view was based on three rationales: first, the technical characteristics of such additional treatments are very similar if not equal to some of the treatments covered in this document; secondly they maintain that such issues may benefit the competitiveness of some waste treatments not covered by IPPC because such installations may be allowed to operate at less stringent environmental standards than required by BAT; and third it may be interpreted that because these treatments are not covered, no BAT can be determined and that they cannot run under BAT conditions. Scope of this document should not be interpreted as any attempt to interpret IPPC Directive or any waste legislation.

Annex I of the IPPC Directive lists the installations that are covered by the IPPC Directive. The installations are derived from the Recovery/Disposal (R/D) codes mentioned in the the Waste Framework Directive (75/442/EEC). However, it is difficult to distinguish between the R and the D codes ad they are so closely related. For example, there are waste treatments that are not covered when an 'R' treatment is carried out to a certain waste (e.g. aerobic digestion to produce compost) but covered when a 'D' treatment is carried out (e.g. aerobic digestion to landfill). This issue will create difficulties on the implementation of the Directive to certain waste treatment installations and may create market conflicts because some installations will be required to have an IPPC permit and others will not.

Some readers have tried to interpret the structure of the document as the tool to try to distinguish between some R and D codes. One example showing this can be the interpretation of R1, R9 and D10 codes for treatment of waste oils. There are two main options (see Section 2.4.1) for the treatment of waste oils. One is the re-refining of waste oil (covered in Section 2.4.1 under the section on recovery of materials) and the other one is the treatment of the waste oil to produce a material that will be mainly used as fuel. This latter option, in some cases, generates materials that can be used as naphthalene absorbant in coke oven gas cleaning, mould release oil or flotation oil. These treatments are covered in Section 2.5.2.4 when used as fuel. It must be stressed that this document does not in any way interpret any legislation.

Annex I of the IPPC Directive also makes the distintion for treatment of hazardous and non-hazardous waste. This issue creates an extra difficulty on a clear scope for this document as well as for the structure of this document. The point is that the same type of installations treating hazardous waste are included but not those treating non-hazardous waste.

Some information considered not to be within of the scope of this document has been included whereas other information provided has not been included at all (e.g. composting). In order to avoid confusion, it has been considered appropriate to maintain the information on these issues that were in the second draft but restricting such information from being included in Chapter 1 to Chapter 3. An example is the bottom ash (slag) treatment to be used as a construction material in Section 2.3.3.15. Some information provided was also agreed to be reviewed by some TWG members after the second TWG meeting. However, the TWG was not able to reach the deadline agreed at the meeting so the information is not available in this document. The information was related to pickling acid for waste water treatments, thermal purification sludge containing oil, thermal treatment of contaminated soil, treatment of blasting grit and treatment of asphalt containing tar.

Some information was given together with the comments to the second draft of this document (see timing of the work section below). As a consequence, there has not been enough time for a full peer review. This means that some techniques in Chapter 4 (e.g. Sections 4.1.4.11, 4.3.1.1, 4.3.1.19, 4.3.1.20, 4.3.1.21, 4.3.2.16, 4.3.3.3, 4.4.1.12, 4.4.2.1, 4.4.2.5, 4.5.2, 4.5.4.3) have not been properly peer reviewed and assessed to decide if they are elements of BAT for the sector. However, some of this new information is now included in the document. Some of this information was probably not provided earlier in the process because of the lack of clarity in the scope of the work. The information that is included in this category is some of the information that was provided by the Netherlands, Germany and Cefic.

This IPPC industrial sector is highly regulated and the terminology used is not the same throughout the EU. Moreover, there are different interpretations of the same wording in the different countries, especially that related to the qualification of Recovery and Disposal. To solve this difficulty, the glossary of this document plays an important role. It informs the user/reader in which sense each conflicting word identified by the TWG has been used in this document. This glossary should not be understood as an interpretation of any legislation and it may conflict with some national legislation definitions. To prevent some difficulties that have been encountered, this document has tried to use 'neutral' words with the intention to avoid waste related debates such as waste vs. non-waste, recovery vs. disposal, and hazardous vs. non-hazardous.

Techniques analysed in this document are the most relevant ones for the sector, however as is the case with all BREFs, they are restricted to the information provided.

Timing of the work
The work on this document started with the first plenary meeting of the TWG in February 2002. A first draft was issued in February 2003 followed by a second draft in January 2004. A final plenary meeting of the TWG was held in two sessions in Septerber and October 2004 after which the document was completed. All parts of this final document have thus been subjected to peer review by the TWG.

Sources of information
More than 150 items of information were used for the preparation of this document. Several reports from industry and MS authorities were used as main sources of information and assisted in the drafting, some of them were specifically prepared for this document. Only three Member States actively delivered documents. The others only provided some information when sending comments for the two drafts. The reports submitted mainly focused on specific waste treatments and some covered only some type of wastes, thus partially covering the WT sector. Complementary to that information, 35 site visits to eight EU countries (Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain), 10 meetings with permit writers and technology providers and attendance at six conferences were carried out. The formal consultations on drafts also prompted the submission of new and additional information, as well as providing opportunities for the TWG to verify information already submitted.

On the analysis of information provided, it needs to be emphasised that especially in the case of specific treatments, the core information came from one source. This issue meant that some of the sections of this document may be seen as representative for one country or as partial view of some TWG members. This has created criticism from a few TWG members that some conclusions are based on very little information or are not even representative of the entire EU sector. However, the BAT conclusions could only be achieved on information provided and rely on the expert judgement of the TWG.

110 experts form the TWG, 52 from EU Member States, 47 from Industry, two from Environmental NGO, two from non-Member States and seven from different services of the Commission. However, the attendance at the second TWG meeting was low considering the number of TWG members. Some MSs chose not to participate in the final meeting.

Degree of consensus reached

The conclusions of the work were agreed at the final plenary meeting in September – October 2004 and a high level of consensus was reached. There was full agreement on all the BAT conclusions as presented in this document. However, it needs to be emphasised that there is disagreement from Industry (except one Industry association) and one Member State on the scope of this document (see also first paragraphs of the Concluding remarks chapter). They claim that the coverage of this document should be enlarged to cover the entire WT sector ignoring whether the treatment is formally covered by IPPC or not. Their view was based on the developments on the waste sector since the Waste Framework and IPPC Directives were issued as well as market distorsions that may be generated because only a part of the sector is covered. Composting installations were mentioned as a good illustrative example on the previous points.

Recommendations for future work

The information exchange and the result of this exchange, i.e. this document, present an important step forward in achieving the integrated prevention and control of pollution from the waste treatment industry. On a few topics, however, the information is incomplete and did not allow BAT conclusions to be reached. As a consequence, this is considered as an important issue to focus on during the revision of this document. Future work could usefully focus on collecting the following information:

1. clarification and enlargement of the scope to include the majority, if not all, of the waste treatment activities. It would be advisable to clarify the installations to be covered by IPPC and to restrict the use of R/D codes as well as reference to hazardous and non-hazardous waste. Some waste treatments highlighted that may be good candidates for enlarging the scope of this document have been composting, end-of-life materials (including vehicles, fridges, electronic waste, cathode ray tubes, glass preparation, fluorescents containing mercury, batteries, switches) and treatment of slag from combustion processes (e.g. from incineration) to be used for example as construction material. As a consequence of such a decision, this actual document does not contain specific BAT for such processes. However, it needs to be noted that some of these processes are relatively similar to some of the processes already covered

2. on-site remediation is not included in this document because it was seen to be outside the scope of IPPC. Clarification as to whether on-site remediation needs to be covered by this document has been proposed.

3. the document does not give guidance of what 'dilution' is considered to be. A better analysis of what is understood by 'dilution' is required as this can have a big impact on other waste policies. However, at the same time it should be determined whether this guidance is possible to be given under the framework of the IPPC Directive because, as is mentioned in the Scope chapter, IPPC focuses on installations and not the full chain of waste management. It may be possible that when analysing 'dilution', other considerations outside the scope of IPPC may be taken into account

4. there is a shortage of current consumption and emission levels and on the performance of techniques to be considered in the determination of BAT. This was generally true throughtout the whole document. Thus, it is proposed to collect data on this issue to generate a better base document and enlarge the BAT chapter

5. this document does not include emission levels associated with the use of BAT for physico-chemical treatment of waste waters. These waste streams have some of the largest volumes in Europe, however there is a lack of identification of values for these treatments. The number of generic waste water parameters identified (i.e. COD, BOD and heavy metals) for this sector are considered to be insufficient for this particular treatment

6. some lack of information have been identified on some issues covered by this document and some have limited the BAT conclusions. These are:

   - off-site remediation treatments
   - mixing and blending treatments. This issue is identified as very important in the sector but it has not been well developed. The BAT chapter lacks further conclusions on this issue
   - emission levels when biogas is used as the fuel (some information is actually available in the LCP BREF for installations larger than 50 MWth)
   - waste water emission levels from biological treatments
   - dioxins, nitrous oxide and mercury emission levels to the air from mechanical biological treatments. One member state considered important to include the dioxins parameter in table of BAT 70 of Chapter 5
   - destruction of POPs. Basel convention provides technical guidelines for environmental sound management of waste consisting of, containing or contaminated with PCBs, PCTs and PBBs
   - treatments of waste containing mercury
   - treatment of asbestos
   - recovery of components from abatement techniques.

Suggested topics for future R&D projects
The information exchange has also exposed some areas where additional useful knowledge could be gained from research and development projects. These relate to the following subjects:

- studies to build on the knowledge of the definition of dilution
- clarify the distinction between Recovery and Disposal of waste and to define, if possible, the stage where recovery is completed and when the waste turns into a tradeable product.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

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GLOSSAR

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Dieser IVU-Industriesektor ist gesetzlich stark reglementiert, und die benutzte Terminologie ist in der EU nicht einheitlich. Darüber hinaus gibt es verschiedene Auslegungen derselben Bezeichnungen in den verschiedenen Staaten, insbesondere im Zusammenhang mit der Einstufung von Verwertung und Beseitigung. Die TWG hat versucht, drei Regeln zu verwenden, um auszuwählen, welches Wort in diesem Dokument verwendet werden muss. Diese Regeln sind:

1. externe Übereinkommen. Manche in diesem Dokument verwendete Wörter werden in derselben Bedeutung z.B. in der EU-Gesetzgebung verwendet. In diesem Fall können diese Wörter übernommen werden, und stehen im Einklang mit der bestehenden Gesetzgebung. Diese Option ist wegen verschiedener Auslegungen und nicht präziser Bedeutungen mancher Wörter nicht immer anwendbar.
2. BREF Übereinkommen. Mit dem BREF Übereinkommen wird in der Regel versucht, die Verwendung problematischer Wörter mit verschiedenen Bedeutungen für verschiedene Anwender zu vermeiden. Diese Wörter werden im Glossar erläutert und in diesem Dokument verwendet. Zu dieser Kategorie gehören 'Abfall IN', 'Abfall OUT', 'Output' usw.
3. Bezugnahme auf die Wortgebung der vorliegenden Informationen. Wegen der Schwierigkeiten bei der Auslegung der von der TWG zur Verfügung gestellten Informationen ist es für einige Wörter manchmal nicht möglich, sie richtig in die in den Gesetzestexten verwendeten Wörter zu „übersetzen". In manchen Fällen interpretieren verschiedene Staaten dieselben Wörter unterschiedlich, also ist es schwierig für das EIPPCB, eine solche Wortgebung zu verändern.. Einige Beispiele auf diesem Gebiet sind 'Produkt', 'Materialien', 'Chemikalie', 'Verwertung', 'Beseitigung', usw. In diesem Fall respektiert das EIPPCB die in der vorliegenden Information benutzte Wortgebung.

Deutscher Begriff	Englischer Begriff	Erläuterung
~	~	Ungefähr
€	€	Euro, EUR (Europäische Währung)
	AD	Vergärung
A		
ADR	ADR	Europäisches Übereinkommen über die internationale Beförderung gefährlicher Güter auf der Straße
	APME TEC	Association of Plastic Manufacturers in Europe, Technical Centre
AOX	AOX	Adsorbierbare organisch gebundene Halogene
	API	American Petroleum Institute
AT_4	AT_4	Atmungsaktivität nach vier Tagen (gemessen in mg O_2/g Trockenmasse)
B		
Biologischer Abbau	Biological degradation	Bezieht sich auf die – meist aeroben - biologischen Prozesse, denen Biomasse in natürlicherweise in der Atmosphäre unterworfen ist. In manchen Ländern wird zur Definition dieses Begriffs der Begriff „Rotte/Verrottung" verwendet
Vermengung	Blending	Mischung flüssiger oder halbflüssiger Abfälle
BSB	BOD	Biochemischer Sauerstoffbedarf
Verbrennungsschlacke	Bottom ash	Feste Rückstände aus dem Verbrennungsprozess
Brightstock	Brightstock	Fraktion von Schmieröl
BVT-Merkblatt	BREF	BVT-Referenzdokument / BAT-Referenzdokument
BTEX	BTEX	Benzol, Toluol, Ethylbenzol (Phenylethan) und Xylol

Deutscher Begriff	Englischer Begriff	Erläuterung
Auffangvorrichtung	Bund	Die Auffangvorrichtung (oder der Damm) eines Tanklagers ist dafür ausgelegt, große Verschüttungen, wie sie bei einem Bruch der Hülle oder einer Überfüllung entstehen können, zurückzuhalten. Die Auffangvorrichtung besteht aus einer Mauer um die Außenseite des oder der Tanks, um im unwahrscheinlichen Fall eine Freisetzung aller Materialien zurückzuhalten. Die Auffangvorrichtung besteht in der Regel aus gut verdichteter Erde oder verstärktem Beton. Das Volumen ist normalerweise so ausgelegt, dass die Inhalte des größten Tanks in der Auffangvorrichtung Platz finden. Für weitere Informationen siehe BVT-Merkblatt „Lagerung“.
CEN	CEN	Europäisches Komitee für Normung
FCKW	CFC	Fluorchlorkohlenwasserstoffe
KWK	CHP	Kraft-Wärme-Kopplung
CSB	COD	Chemischer Sauerstoffbedarf
Koksrückstand nach Conradson	Conradson	Messung des Koksrückstands (in Gew.-%). Messung der Tendenz einer organischen Verbindung zur Koksbildung
Fraktionsschnitte	Cuts	Begriff aus der (fraktionierten) Destillation zur Benennung der durch die Destillation erhaltenen Fraktionen
C_x	C_x	Kohlenwasserstoff mit x Kohlenstoffatomen
D	D	Beseitigungscode, D-Code (Code der EU-Gesetzgebung für Beseitigungsverfahren)
	DAF	Entspannungsflotation
DCH	DCH	Direktkontakt Hydrierung für Altölverfahren
DCM	DCM	Dichlormethan
Diffuse Emissionen	Diffuse emissions	Emissionen aus dem direkten Kontakt flüchtiger oder leichter staubförmiger Stoffe mit der Umwelt unter normalen Betriebsbedingungen (siehe BVT-Merkblatt “Monitoring”)
Gärrückstand	Digestate	Fester Rückstand nach der Vergärung
DIN	DIN	Deutsches Institut für Normung
Auslieferung	Dispatch	Auslieferung an die nachfolgende Tätigkeit oder den Kunden
Beseitigung	Disposal	Definiert durch die EG-Abfallrahmenrichtlinie
TS	DM	Trockensubstanz. Das Material nach Entfernung der enthaltenen Feuchtigkeit
	DRE	Zerstörungs- und Entfernungswirkungsgrad. Er berücksichtigt nur Emissionen aus dem Schornstein, jedoch keine anderen Freisetzungen und Reststoffe
TS	DS	Trockensubstanz. Die Masse eines Materials, das nach Trocknung durch die Standard-Testmethode übrig bleibt
	EC	Europäische Kommission
EDTA	EDTA	Ethylendiamintetraacetat
UMS	EMS	Umweltmanagementsystem
	EOP	“End-of-Pipe”-Technik
Äqu.	eq.	Äquivalent (z. B. Rohöläquivalent)
EU	EU	Europäische Union
EU+	EU+	Europäische Union + EFTA (Europäische Freihandelsvereinigung) + Beitrittsstaaten
EUR	EUR	Euro, EUR, (Europäische Währung)
EAV	EWL	Europäisches Abfallverzeichnis zur EG-Abfallrahmenrichtlinie
F		
ARA	FGT	Abgasreinigungsanlage. Techniken (z.B. Entstaubung, Entstickung; Entschwefelung), die in der Regel zur Reinigung der Abgase aus Verbrennungsprozessen angewendet werden

Deutscher Begriff	Englischer Begriff	Erläuterung
ARA-Abfall	FGT waste	Bezieht sich auf den in der Abgasreinigung von Verbrennungsprozessen erzeugten Abfall und wird in diesem Dokument als „Abfall-IN" betrachtet. Zur Beachtung: Dieser Begriff wird mit einer anderen Bedeutung als „Reststoff aus ARA" (s.u.) benutzt. Für nähere Informationen siehe Abschnitt 8.3.7
Reststoff aus ARA	FGT residue	Bezieht sich auf die bei der Anwendung von Abgasreinigung in Abfallbehandlungsanlagen erzeugten Reststoffe. Zur Beachtung: Dieser Begriff wird – wie oben erwähnt - zur Abgrenzung von "ARA-Abfall" verwendet
FID	FID	Flammenionisationsdetektor
Flüchtige Emissionen	Fugitive emissions	Durch undichte Bauteile/Lecks verursachte Emissionen: Emission in die Umwelt wegen allmählichem Verlust der Dichtheit eines Bauteils, welches Gase oder Flüssigkeiten enthält, grundsätzlich durch eine Druckdifferenz und ein daraus folgendes Leck verursacht. Beispiele von Leckverlusten: Leck in einem Flansch, einer Pumpe, in versiegelten oder verschraubten Bauteilen...(s. BVT-Merkblatt „Monitoring")
G		
GB21	GB21	Gasbildungsrate (Gärtest zur Messung der Bildung anaerober Gase)
	GAC	Granulierte Aktivkohle
GE	GE	In Deutschland: Geruchseinheit
	GNP	Great Northern Processing Inc.
H		
	H&S	Gesundheits- und Sicherheitsprogramm
KW	HC	Kohlenwasserstoffe
HFCKW	HCFC	teilhalogenierte Fluorchlorkohlenwasserstoffe
	HF	Hydrofinishing
	HMIP	Her Majesty's Inspectorate of Pollution (UK)
	HRT	Hydraulische Verweilzeit
I		
IBC	IBC	Intermediate bulk container
IEF	IEF	Information Exchange Forum (siehe Vorwort)
IFP	IFP	Institut Français du Pétrole
	IRR	Interner Zinsfuß
L		
	L/S	Flüssig/fest-Verhältnis
Laborkleinmengenabfälle	Lab smalls	Begriff zur Definition von Abfall aus Laboratorien, der in der Regel in kleinen Mengen anfällt und stark in seiner Zusammensetzung schwankt.
	LDAR	Lecksuch- und Reparaturprogramm
H_u	LHV	Unterer Heizwert
Leichtsieder	Light ends	Begriff aus der (fraktionierten) Destillation zur Benennung der leichtflüchtigen Bestandteile, die am oberen Ende der Kolonnen landen
Flüssiger Brennstoff aus Abfall	Liquid waste fuel	Flüssiger oder halbflüssiger aus Abfall erzeugter Brennstoff. In der Regel aus gefährlichen Abfällen hergestellt
	LPG	Flüssiggas
	LSHV (h^{-1})	Raumgeschwindigkeit einer Flüssigkeit
M		
M	M	Million (10^6), Mega
MBA	MBT	Mechanisch-biologische Behandlungsanlage
MEK	MEK	Methylethylketon
MIBK	MIBK	Methylisobutylketon
Vermischen	Mixing	Mischung fester Abfälle
NMVOC	NMVOC	VOC-Emissionen ohne Methan
MS	MS	Mitgliedstaat (Einer der 25 Mitgliedstaaten der EU)

Deutscher Begriff	Englischer Begriff	Erläuterung
	MSW	Siedlungsabfall
N		
n.v.	n.a	Nicht vorhanden/nicht verfügbar
n/a	n/a	Nicht anwendbar
	ndM	Analytische Methode
NF	NF	Nanofiltration
NIR	NIR	Nah-Infrarotspektrometrie
	NPV	Net payback value
NTA	NTA	Nitrilotriacetat
O		
GE	ouE	Europäische Geruchseinheit (EROM). Die Menge eines Geruchsstoffs, in 1 m³ eines neutralen Gases unter Standardbedingungen gelöst, die eine physiologische Reaktion bei einem Prüfgremium hervorruft
Output	Output	Enthält den Abfall-OUT (Hauptoutput) und die anderen Arten fester Rückstände, Emissionen, Abwasser usw., die während einer Abfallbehandlung erzeugt werden
P		
PAG	PAG	Polyalkylenglykol
PAH/PAK	PAH	Polyzyklische aromatische Kohlenwasserstoffe
PBB	PBB	Polybromierte Biphenyle
PCB	PCB	Polychlorierte Biphenyle
PCB/PCT	PCB/PCT	Polychlorierte Biphenyle und -terphenyle
PCDD/PCDF	PCDD/PCDF	Polychlorierte Dibenzodioxine und polychlorierte Dibenzofurane
	PDA	Propan de-Asphaltimng (für Altöl)
	PF	Vordestillation oder Preflash (in der Regel für die Nutzung bei Altöl)
C-P	Ph-c	Chemisch-physikalische Behandlung. In diesem Dokument für die Behandlung von Abwässern oder festen Abfällen verwendet
PM	PM	Partikelförmige Emissionen
PM_x	PM_x	Partikel von weniger als x Mikrometern aerodynamischem Durchmesser
POP	POP	Persistente organische Schadstoffe
ppm	ppm	Parts per million (mg/kg. Bei Konzentrationen in Wasser annähernd gleich mit mg/l)
ppmv	ppmv	Parts per million in Bezug auf das Volumen (Millionstel Liter pro Liter)
Prozessbedingter Abfall	Process generate	Nicht verwertbarer Abfall (z.B. Abfall-Kalk, Sümpfe von Lagertanks, Schlämme) wird im Prozess erzeugt und ist nicht gleich dem Abfall-OUT. Der Grund, waum zwischen den Abfällen zu differenziert wird, ist dass der Abfall-OUT für verschiedene Zwecke genutzt werden kann, doch prozessbedingter Abfall in der Regel nicht verwertet wird. Siehe auch die Einführung zu Kapitel 3 undFigure 3.1 für weitere Informationen.
R		
R	R	Verwertungscode, R-Code (Code der EU-Gestzgebung für Verwertungsverfahren)
R/D	R/D	Verwertung und Beseitigung
F+E	R&D	Forschung und Entwicklung
EBS oder SBS	RDF	Brennstoff aus Abfall (Sekundärbrennstoff)
Recyceln	Recycle	betriebsexternes Recycling oder Recycling innerhalb der Abfallbehandlungsanlage (in diesem Dokument meistens das Letztere)
Verwertung	Recovery	Definiert durch die EU-Abfallrahmenrichtlinie. In diesem Dokument auch Behandlung von (Teilen von) Materialien aus Abfall zum Zweck der Verwertung

Deutscher Begriff	Englischer Begriff	Erläuterung
Redox	Redox	Die grundlegenden Reaktionen in der Chemie sind die Redoxreaktionen. Dazu zählen alle Reaktionen, bei denen Atome ihre Oxidationszahl ändern.
	REF	Sekundärbrennstoffe
Raffinerie	Refinery	Mineralölraffinerie (siehe BVT-Merkblatt Raffinerien)
Regeneration	Regeneration	In diesem Dokument für die Behandlung von flüssigen und festen Abfällen mit dem Ziel der Verwertung des größten Teils des Abfallstoffs verwendet. Es besteht jedoch eine Ausnahme, da im Fall der Regeneration von Altöl zu Basisöl der Begriff "Re-Raffination" verwendet wird
Sanierung	Remediation	Behandlung von kontaminierten Böden
Re-Raffination	Re-refining	Behandlung von Altöl zur Umwandlung in Basisöl
UO	RO	Umkehrosmose
	RTD	Rahmenprogramme für Forschung und technologische Entwicklung der EU
S		
SCR	SCR	Selektive katalytische Reduktion. Katalytische Abgasreinigungstechnik zur Reduzierung von NO_x -Emissionen
	Selectopropane	PDA unit
Schlacke/Asche	Slag	Feste Rückstände aus Verbrennungsprozessen
SNCR	SNCR	Selektive nicht katalytische Reduktion. Nicht katalytische Abgasreinigungstechnik zur Reduzierung von NO_x -Emissionen
Verfestigung	Solidification	Behandlungsmethode, die Additive zur Veränderung der physikalischen Eigenschaften des Abfalls einsetzt (siehe Abschnitt 2.3.3.5).
Sekundärbrennstoff	Secondary fuel	In diesem Dokument jegliche Art von Brennstoff (aus Abfall oder nicht), der zum Ersatz von Primärbrennstoffen in einer Verbrennungsanlage verwendet wird
Fester Sekundär-brennstoff	Solid waste fuel	Fester aus Abfall erzeugter Brennstoff. Er kann aus gefährlichem oder nicht gefährlichem Abfall erzeugt werden
Anforderungen oder Spezifikationen	Specification	Gesetzliche Grenzwerte für die Konzentration mancher Verbindungen (z.B. in Schmierstoffen)
	SRF	Fester Sekundärbrennstoff. Fester Brennstoff aus Abfall, der bestimmte Standards erfüllt
T		
t/a	t/yr	Tonnen pro Jahr
TCE	TCE	Trichlorethylen
	TCT	Thermisches Cracken
	TDA	Thermische Entasphaltierung (Technik zur Behandlung von Altölen)
TEQ	TEQ	Toxizitätsäquivalent. Einheit zur Messung der Toxizität von PCDD und PCDF
	TFE	Dünnschichtverdampfung (Technik zur Behandlung von Altölen)
Umladestation	Transfer station	Umladestation
TOC	TOC	Gesamter organischer Kohlenstoff
	TPH	Gehalt an Mineralöl-Kohlenwasserstoffen
	TRI	Toxic release inventory der USA(http://www.epa.gov/tri/)
	TS	Gesamtfeststoffgehalt
TWG	TWG	Technical Working Group for Waste Treatments (zusammengesetzt aus Experten der Mitgliedstaaten, Anlagenbetreiber/Verbände, Umwelt-NGOs, korrdiniert durch das EIPPCB)
U		
GB	UK	Großbritannien
Gebrauchte Öle	Used oil	Gebrauchte SChmieröle
	USAEPA	Umweltbehörde der USA
	US DOE	US department of Energy

Deutscher Begriff	Englischer Begriff	Erläuterung
V		
Frischöl	Virgin oil	nicht benutztes Schmieröl
VOC	VOC	Flüchtige organische Verbindungen. In der Regel als Kohlenstoffmasse gemessen
Vol.-%	vol-%	Verhältnis von Volumen zu Volumen. (z.B. bedeutet Y Vol.-% Y Liter der Verbindung X pro 100 Liter Gas)
vs.	vs.	Versus/Gegen
W		
Gew.-%	w/w-%	Gewichtsprozent
Mit PCBs und Dioxinen verunreinigter Abfall	Waste contaminated with PCBs and dioxins	COM (2001) 593 erwähnt, dass das BVT-Merkblatt "Abfallbehandlungsanlagen" auch die Behandlung dieser Art Abfall umfasst. Dieser Begriff wird hier in derselben Bedeutung wie in dieser Gesetzgebung verwendet.
Brennstoff aus Abfall	Waste fuel	Dieser Begriff bezieht sich in diesem Dokument auf alle Arten von Abfällen oder aus Abfall hergestellten Materialien, die als Brennstoff in beliebigen Verbrennungsprozessen eingesetzt werden
Altöl	Waste oil	Umfasst gebrauchte Schmieröle und andere Altöle aus Entwässerungssystemen, der Brennstofflagerung, aus Raffinerien usw.
Abfall-IN	Waste IN	Abfall, der in einer Abfallbehandlungsanlage behandelt werden kann. Zur näheren Erläuterung siehe die Einführung zu Kapitel 3
Abfall-OUT	Waste OUT	Bezieht sich auf den Abfalloutput (sei es Abfall oder ein Produkt) einer Abfallbehandlungsanlage. Dennoch hat es in diesem Dokument eine andere Bedeutung als „prozessbedingter Abfall". Zur weiteren Erläuterung siehe die Einführung zu Kapitel 3
Weiße Ware	White goods	Große, üblicherweise weiß lackierte Haushaltsgeräte wie Kühlschränke, Waschmaschinen usw..
Abfallbesitzer	Waste holder	Anlage von der der Abfall stammt. Manchmal ist es die Anlage des Abfallerzeuger, wenn es keinen Mittler zwischen der Abfallbehandlungsanlage und dem Abfallerzeuger gibt. Manchmal ist diese Anlage die Umladestation.[51]
Betreiber	Waste operator	Unternehmer der die Abfallbehandlungsanlage betreibt
Abfallerzeuger	Waste producer	Anlage, in der Abfall erzeugt wird.
Umladestation	Waste transfer	Anlagen, deren Hauptaufgabe die Sammlung verschiedener Abfallarten ist, um die vergrößerte Menge zur Behandlung zu schicken
Abfallbehandlung	Waste treatment	Alle Einrichtungen, die eine Behandlung von Abfällen im Sinne des Dokuments ausführen
	WI	Abfallverbrennung
	WO	Altöl
	WT	Abfallbehandlung
AWR	WWT	Abwasserreinigung
	WWTP	Abwasserreinigungsanlage

[51] Anm.d.Übers.: Sinngemäße Übersetzung des Originaltextes.

	Ländernennung	Abkürzung	Währung ISO Code
EU-25 EU Mitgliedsstaaten	Belgien	BE	EUR
	Tschechien	CZ	CZK
	Dänemark	DK	DKK
	Deutschland	DE	EUR
	Estland	EE	EEK
	Grichenland	EL	EUR
	Spanien	ES	EUR
	Frankreich	FR	EUR
	Irland	IE	EUR
	Italien	IT	EUR
	Zypern	CY	CYP
	Lettland	LV	LVL
	Litauen	LT	LTL
	Luxemburg	LU	EUR
	Ungarn	HU	HUF
	Malta	MT	MTL
	Niederlande	NL	EUR
	Österreich	AT	EUR
	Polen	PL	PLN
	Portugal	PT	EUR
	Slovenien	SI	SIT
	Slowakei	SK	SKK
	Finnland	FI	EUR
	Schweden	SE	SEK
	Großbritanien	UK	GBP
Beitrittsländer	Bulgarien	BG	BGN
	Rumänien	RO	ROL
	Türkei	TR	TRL
Andere Staaten	Australein	AU	AUD
	Kanada	CA	CAD
	Island	IS	ISK
	Japan	JP	JPY
	Neuseeland	NZ	NZD
	Norwegen	NO	NOK
	Schweiz	CH	CHF
	USA	US	USD

Tabelle 7.1 Ländernennungen und Währungen
Anmerkung: Information from http://eur-op.eu.int/code/en/en-5000500.htm

8 ANNEXES

Five annexes have been prepared to complement the information provided in this document, each relating to a specific topic, i.e.:

Annex I. Environmental legislation and emission limit values applied to the waste treatment sector

Annex II. Questionnaire used to gather environmental information of European waste treatment plants

Annex III: Types of waste and waste production in the EU

Annex IV. Quality assurance systems for secondary recovered fuel

8.1 Annex I. Environmental legislation and emission limit values applied to the waste treatment sector

[5, Concawe, 1996], [6, Silver Springs Oil Recovery Inc., 2000], [7, Monier and Labouze, 2001], [36, Viscolube, 2002], [37, Woodward-Clyde, 2000], [55, UK EA, 2001], [86, TWG, 2003], [95, RAC/CP, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

8.1.1 Waste Directive

Table 8.1 shows the classification of waste treatment operations. Such a classification of waste treatment operations according to these entries is used for several purposes (e.g. statistics, export of waste). The table also contains examples of the type of installations that may be included in each type of operation. However, these examples do not represent any definition of those terms. It is recognised that some of these definitions may be technically ambiguous but they correspond to existing legal definitions, which are outside the scope of this document.

Disposal (D) operations		**Examples of installations**
D1	Deposit into or onto land (e.g. landfill, etc.)	
D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)	
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)	
D4	Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)	
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)	Hazardous landfill: typically used to landfill hazardous waste from third parties. Mono landfill: where only one type of waste is landfilled. Typically if more than one type of waste is landfilled, segregation is used.
D6	Release into a water body except seas/oceans	
D7	Release into seas/oceans including sea-bed insertion	
D8	Biological treatment not specified elsewhere in this list which results in final compounds or mixtures which are discarded by means of any of the operations numbered D1 to D12	Operations that include the use of biological processes or use micro-organisms for the treatment of waste.
D9	Physico-chemical treatment not specified elsewhere in this list which results in final compounds or mixtures which are discarded by means of any of the operations numbered D1 to D12 (e.g. evaporation, drying, calcination, etc.)	Operations carried out for the treatment of waste prior disposal by means of physico or chemical processes or a combination of both. Some operations are stabilisation, dehydratation, solidification, sterilisation, autoclave, disinfection of hospital waste, etc.
D10	Incineration on land	Operations for the destruction of waste by incineration, with the main objective being to destroy the waste, with or without energy recovery.
D11	Incineration at sea	
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)	
D13	Blending or mixing prior to submission to any of the operations numbered D1 to D12	
D14	Repackaging prior to submission to any of the operations numbered D1 to D13	
D15	Storage pending any of the operations numbered D1 to D14 (excluding temporary storage, pending collection, on the site where it is produced)	
Recovery (R) operations		
R1	Use principally as a fuel or by other means to generate energy	Large combustion plants, cement and lime kilns, ceramic installations or similar (e.g. cogeneration).
R2	Solvent reclamation/regeneration	Operations aimed at regeneration of solvent independent of the type of process used
R3	Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)	Operations aimed at regeneration of, for example, plastic containers, refrigerant gases, combustibles. It also includes cleaning activities. Operations for the recovery of PCB contaminated waste.

R4	Recycling/reclamation of metals and metal compounds	Operations aimed at recycling metal wastes or reclamation of metals and metal compounds. Waste as slags, metal powders, metalic containers, lead batteries, copper wires, mercury from batteries, fluorescents, scrap metals, metal salts from metalurgic processes. Vehicles, end-of-life fridges, and toners may also be included here. Cleaning activities before the recycling of metal containers are also included.
R5	Recycling/reclamation of other inorganic materials	Operations aimed at the recycling of inorganic materials which are not metal or the reclamation of inorganic material from waste (e.g mineral materials from construction and demolition waste, flocculants from acids (ferric chloride)).
R6	Regeneration of acids or bases	Operations aimed at the regeneration of acid or bases independent of the process used.
R7	Recovery of components used for pollution abatement	
R8	Recovery of components from catalysts	Operations aimed at the recovery of components as metals or ceramics from catalysts
R9	Oil re-refining or other re-uses of oil	Operations aimed at the regeneration of waste oils
R10	Land treatment resulting in a benefit to agriculture or ecological improvement	
R11	Use of wastes obtained from any of the operations numbered R1 to R10	
R12	Exchange of wastes for submission to any of the operations numbered R1 to R11	
R13	Storage of wastes pending any of the operations numbered R1 to R12 (excluding temporary storage, pending collection, on the site where it is produced)	

Table 8.1: Type of waste treatments installations and examples of installations included in each different category of waste operation
Annex II A and B of Council Directive 91/156/EC

8.1.2 EU legislation applicable to waste oils

Directive	Name
75/439/EEC	About waste oils
75/442/EEC	About wastes and the definition of wastes
87/101/EEC	Amendment to Directive 75/439 giving priority to re-refining
89/369/EEC	About preventive measures of air pollution of incinerating plants and emissions
89/429/EEC	Control of special wastes
91/156/EEC	To encourage clean technologies and the recovering of wastes without a risk to the environment and human health
91/689/EEC	About hazardous wastes
91/689/EEC	List of dangerous wastes Article 1, paragraph 4, Directive 91/689 EEC
91/692/EEC	Standardisation and realisation of some environmental directives
92/12/EEC	About the excise duties on mineral oils
92/81/EEC	Harmonisation of excise duties on mineral oils
92/82/EEC	Rates of excise duties on mineral oils
92/108/EEC	Amendment of Directives 92/12 and 92/81
94/62/EC	About packing and wastes from packing
94/67/EC	About the incineration and co-incineration of wastes and emission limits
96/61/EC	About preventive measures and integral reduction of the pollution
2000/76/EC	Directive on waste incineration

Table 8.2: EC Directives in force affecting waste oils
[36, Viscolube, 2002], [150, TWG, 2004]

8.1.3 Other EU waste legislation

There are different types of legislation important for holders of waste products, which need to be known for the treatment of waste. Some of the most important ones are summarised in the Table 8.3:

Reference	Name
	Waste sector regulations
94/62/EEC	Packaging issued - PWD
2000/53/EC	Automotive issued - ELV, End of Life Vehicle Directive
13/6/2000	Electrical & Electronics - WEEE, Proposal for a Directive on Waste Electrical and Electronic Equipment
	Horizontal issue regulations
2000/2037EC	Ozone depleting substances - ODP, Ozone Depleting Substances
1999/31/EC	Landfill disposal - LWD, Landfill of Waste Directive
2000/76/EC	Waste incineration - WID, Waste Incineration Directive
2000/53L/EC	Waste List - EWL, Commission decision of May 2000
67/548/EEC	Dangerous Substances Directive - DSD, Dangerous Substance Directive
1999/45/EC	Dangerous Preparation Directive - DP, Dangerous Preparation Directive
	Solvents Emissions Directive (SED)
	Landfill Directive
	Seveso Directive
	Water Framework Directive
	Industrial Safety, VawS (s.a.), others...

Table 8.3: EU legislation related with waste treatment installations

8.1.4 Legislation in some EU countries

8.1.4.1 France

France has adopted the main European regulations on hazardous waste management. Decree (2002 - 540) has been recently adopted to adapt the classification of hazardous wastes to new European regulations (Decision 2000/532/CE) [95, RAC/CP, 2003].

8.1.4.2 Germany

The legislation applied in Germany according to waste treatment may be summarised by the following legislation:

- Technical Instruction on Waste management (Technische Anleitung zur Lagerung, chemisch/physikalischen, biologischen Behanlung, Verbrennung und Ablagerung von besonders überwachungsbedürftigen Abfällen – TA Abfall)
- Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste treatment facilities of 20 February 2001
- Ordinance on Requirements for the discharge of waste water into water/waste water ordinance (Abwasserverordnung – AbwV) of 15October 2002
- TA Luft
- 30. BImSchV.

Requirements for waste water treatment are set in: Annex 23 ‘Facilities for Biological Treatment of Waste’ and, Annex 27 ‘Treatment of Waste by Chemical and Physical Processes (Ph-c facilities) and processing of used oil’ of the ‘Ordinance on Requirements for the Discharge of Waste Water into Waters (Waste Water Ordinance - AbwV) of 15 October 2002’.

Waste water discharges or blending

The Ph-c plants in Germany are subject both to control relating to waste and water legislation. The waste water may be discharged into water bodies only insofar as process water from process and waste-air treatment in mechanical-aerobic-biological treatment facilities cannot be used completely in internal processes.

According to the ordinance, the generated waste water is often used for a waste gas cleaning process, e.g. for humidification of the bio filter or for the operation of the bio scrubber. In some cases it is applied for cooling processes with an open evaporation. Because of the small volumes of waste water, filter techniques are the main applied operations.

Emission limit values (ELV) for MBTs

	Emission limit values	Units
Daily mean values (continuous measurement):		
total dust	10	mg/m^3
organic substances, given as total carbon	20	mg/m^3
Half hour mean values (continuous measurement):		
total dust	30	mg/m^3
organic substances, given as total carbon	40	mg/m^3
Monthly mean values, determined as mass ratio[1]:		
nitrous oxide	100	g/t
organic substances, given as total carbon	55	g/t
Single measurements		
odours	500	GE/m^3
dioxins/furans (total value)	0.1	ng/m^3

[1] Gram TOC or N_2O per tonne of treated waste

Comment to 5 % of oxygen. The reference to oxygen has proven not to be practical because oxygen content in the MBT exhaust gas is similar to atmospheric oxygen content. Insufficient accuracy of the oxygen measurement causes large uncertainties in the reference calculation. An appropriate combination of load limits and concentration limits is the better alternative for the prevention of dilution effects.

Table 8.4: German emission limit values applied to MBTs
[150, TWG, 2004]

8.1.4.3 Greece

Despite the fact that a hazardous waste 'National Plan' is still being developed in Greece, mechanisms to manage industrial and hazardous wastes are already in place. The main regulations with regard to the management of industrial waste are:

- Law 1650/86 on Environmental Protection
- Law 3010/02 on Environmental Protection
- CMD 69728/96 on Solid Waste Management
- CMD 114218/97 on Technical Specifications on Solid Waste Management
- CMD 113944/97 National Plan on Solid and Hazardous Waste Management.

Specific regulations on hazardous industrial waste management are the following

- CMD 72751/85 and CMD 19396/97 on Hazardous Waste management
- CMD 98012/97 on Used Oils Management
- CMD 73537/95 on Lead Batteries and CMD 19817/00 on Batteries
- CMD 8243/91 on Asbestos Waste and CMD 7589/00 on PCBs/PCTs
- CMD 2487/99 on Pollution Prevention from Incineration of Hazardous waste.

8.1.4.4 Italy

The legal framework concerning the management of industrial and hazardous waste is well developed in Italy.

The national framework law on waste issued in 1997 (Legislative decree 22/97) transposed the European Waste Framework Directive 75/442/EEC, the Directive on Hazardous waste 91/689/EC and the Directive on packaging and packaging waste 94/62/EC (73) to national legislation.

Law 22/97 introduces an integrated waste management policy, as set up by the European hierarchy: waste minimisation and prevention at source followed by recovery in its triple dimension of re-use, recycling and energy recovery and, finally safe disposal. This law represents a reform in the field of waste management in Italy. It promotes clean technologies, Ecolabel, the EMAS certification system, integrated networks of recovery and disposal facilities, and voluntary agreements between public administrators and economic operators in order to create real opportunities for waste recycling.

Wastes are classified according to the European Waste List (decision 2000/532/EC). The waste information system is based on the National Register of Waste, which was first established by law in 1994 and reorganised in 1998.

Recently Directive 99/31/EC has been transposed into Italian legislation by the Legislative Decree 13 January 2003 for the provision of technical and operational tools for a better landfilling management and measures/procedures to minimise the environmental impact and effect on human health. Furthermore, Directive 2000/53/EC concerning the end of life vehicles, is in the process to be transposed into Italian legislation.

Table 8.5 shows the emission limit values applied to a waste oil refinery.

Air parameter	**Emission limit values**	**Units**
Fume temperature	150	ºC
PM	30	mg/Nm^3
Heavy metals	5	mg/Nm^3
TOC	10	mg/Nm^3
HCl	10	mg/Nm^3
HF HBr	3	mg/Nm^3
HCN	0.5	mg/Nm^3
P	5	mg/Nm^3
PAH	0.05	mg/Nm^3
PCDD + PCDF	0.01	$\mu g/Nm^3$
TCDD + TCDF	0.05	$\mu g/Nm^3$
PCB + PCN + PCT	0.1	mg/Nm^3
Notes: Values referred to a percentage of O_2 of 10 %		

Table 8.5: Air emission limit values for a waste oils refinery [36, Viscolube, 2002]

Water parameter	Emission limit values	Units
Temperature	25	ºC
Acidity	5.5/9.5	pH
COD	160	mg/l
Phenols	0.5	mg/l
NH_4^+	15	mg/l
P (total)	10	mg/l
Anionic tensioactives		mg/l
Non-anionic tensioactives		mg/l
Total tensioactives	2	mg/l
Al	1	mg/l
Fe	2	mg/l
Colour	Not detectable	
Suspended solids	80	mg/l

Table 8.6: Water discharge emission limit values from a waste oils refinery [36, Viscolube, 2002]

8.1.4.5 Spain

A legal framework with regard to the management of industrial and hazardous wastes has been developed in Spain. The main regulations on hazardous waste are the following:

- Law 10/98 of 21 April, on Waste
- Decree 833/1988 of 20 July that develops Law 20/1986, on Hazardous Wastes. (Modified by Royal Decree 952/1997)
- Ordinance MAM/304/2002 on Hazardous Waste Classification
- Hazardous Waste National Plan (1995 - 2000)
- Hazardous Waste National Plan (2002 - 2008) (being developed).

Specific regulations exist on the management of used oils, PCB, PCT, and batteries.

8.1.4.6 United Kingdom

England and Wales	Scotland	Northern Ireland
PPC Regulations (England and Wales) 2000	PPC (Scotland) Regulations 2000; SI 200/323	
Waste Management Licensing Regulations SI 1994 1056	Waste Management Licensing Regulations SI:1994 1056	No NI equivalent
The Water Resources Act 1991	COPA 1974 (S30A-30E equiv to Part III WRA91) Natural Heritage (Scotland) Act 1991(Part II equiv to Part I WRA91)	The Water (NI) Order 1999
SI 1989 No 317: Clean Air, The Air Quality Standards Regulations 1989	SI 1989/317: Clean Air, The Air Quality Standards Regulations 1989	The Air Quality Standards Regulations (Northern Ireland) 1990. Statutory Rules of Northern Ireland 1990 No 145
SI 1997 No 3043: Environmental Protection, The Air Quality Regulations 1997	SSI 2000/97 The Air Quality (Scotland) Regs	No NI equivalent
SI 1989 No 2286 and 1998 No 389 the Surface Water (Dangerous Substances Classification) Regulations. (Values for List II substances are contained in SI 1997/2560 and SI 1998/389)	SI 1990/126 Surface Water (Dangerous Substances) (Classification) (Scotland) Regs	Surface Waters (Dangerous Substances) (Classification) Regulations 1998. Statutory Rules of Northern Ireland 1998 No 397 SI 1991/1597:
SI 1991/1597: Bathing Waters (Classification) Regs.	SI 1991/1609 Bathing Waters (Classification) (Scotland) Regs	The Quality of Bathing Water Regulations (NI) 1993
SI 1992/1331 and Direction 1997 Surface Waters (Fishlife) (Classification) Regs.	SI 1997/2471 Surface Waters (Fishlife) (Classification) Regs	The Surface Water (Fishlife) (Classification) Regulations (NI) 1997
SI1997/1332 Surface Waters (Shellfish) (Classification) Regs.	SI 1997/2470 Surface Waters (Shellfish) (Classification) Regs	The Surface Water (Shellfish) (Classification) Regulations (NI) 1997
SI1994/2716 Conservation (Natural Habitats etc) Regulations 1994	SI 1994/2716 Conservation (Natural Habitats etc) Regs	Conservation (Natural Habitats etc) Regulations (Northern Ireland) 1995
Control of Major Accident Hazards Regulations 1999 (COMAH)	SI 1999/743 Control of Major Accident Hazards Regs	Control of Major Accident Hazard Regulations (Northern Ireland) 2000
Special Waste Regulations 1996		The Special Waste Regulations (Northern Ireland) 1998

Table 8.7: UK related waste legislation and correspondence [55, UK EA, 2001]

8.1.4.7 Belgium

The burning of used oils in asphalt mixing plants has been illegal since January 1999 in the Flemish region of Belgium [11, Jacobs and Dijkmans, 2001].

8.1.4.8 The Netherlands

The risk of use of materials in agriculture and diffusion of toxic substances, especially heavy metals, in the environment and in crops have been legislated in the Netherlands. Standards are set for the application of anaerobic digestate into farmlands, set in the Quality and Use of Other Organic Fertilisers Decree: Cd <1.25 mg/kg, Cr <75 mg/kg, Cu <75 mg/kg, Hg <0.75 mg/kg, Ni <30 mg/kg, Pb <100 mg/kg, Zn <300 mg/kg, As <15 mg/kg (concentrations in mg/kg dry matter).

8.1.4.9 Austria

Emission limit values for MBTs

Parameters	Emission Limit Value	Units
1. organic substances, as total organic carbon		
half hourly average values	40	mg/m^3
daily average values	20	mg/m^3
mass ratio[1]	100	g/t_{waste}
2. nitrogen dioxide (as NO_2)[2]		
half hourly average values	150	mg/m^3
daily average values	100	mg/m^3
3. ammonia	20	mg/m^3
4. dioxins/furans[3] (2-, 3-, 7-, 8-TCDD-equivalent (I-TEF))	0.1	ng/m^3
5. total dust	10	mg/m^3
6. odour	500	GE/m^3
7. other parameters[4]		

[1] see Chapter 7.2.2.2, paragraph. 2 of 'MBA-Richtlinie'.
[2] if the applied technique of waste gas treatment precludes the formation of nitrogen dioxides
[3] if the applied technique of waste gas treatment precludes the formation of polychlorinated dibenzo-pdioxins (PCDD) and/or dibenzofurans (PCDF)
[4] depending on the treatment technology and the type of waste which will be treated, the possibility of green-house gases emissions (e.g. N_2O) has to be taken into consideration, which has to be limited as the case may be. Therefore, special provisions for IPPC installations according to the Austrian Waste Management Act.
In this table, the levels for emissions from MBT relate to an oxygen concentration of 5 %

Table 8.8: Austrian emission limit values for air emissions in MBTs
[150, TWG, 2004]
Note: Emission limit values according to the Austrian 'MBA-Richtlinie' (Guideline for the mechanical-biological treatment of wastes, 2002, Republic of Austria, Federal Ministry of Agriculture, Forestry, Environment and Water Management, Band 2/2002, March 2002)

8.1.5 Waste legislation in some other countries

Canada
In Canada, used oils containing more than 2 ppm PCBs have to be taken to an incinerator.

US
The USEPA has regulations for Standards for the Management of Used Oil. Within these regulations the burning of used oil is subject to a comprehensive set of process controls unless it can be shown that the used oil falls within set specifications related to contaminant levels. USEPA, United States Code of Federal Regulations, CFR64 Part 279, United States used oil Specification give a specification for a waste not be considered as a hazardous waste. Table 8.9 shows the specifications of waste to not be named as a hazardous waste.

Compound	Maximum value in mg/kg
Arsenic	5
Cadmium	2
Chromium	10
Lead	100
Total halogens	4000

Table 8.9: Specification of waste oil not to be named as a hazardous waste
US EPA

8.2 Annex II. Questionnaire used to gather environmental information of European waste treatment plants

PURPOSE OF THE QUESTIONNAIRE
Requested by the Technical Working Group on Waste Treatments (WT) and with the aim of standardising the type of information that is needed for the WT BREF

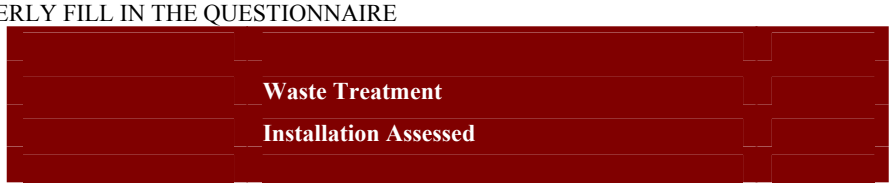
WHAT IS GOING TO BE DONE WITH THIS INFORMATION?
The information that will be gathered will be used only for the purpose of the WT BREF

IF ANY PART OF THE QUESTIONNAIRE IS CONFIDENTIAL, PLEASE SPECIFY
Confidential data will be treated by EIPPCB as such and will not be openly discussed in the BREF

BUT, I DO NOT HAVE ALL THE INFORMATION REQUESTED
Partial information is also important because it is equally important to know why certain information does not exist

WHICH CELLS DO I HAVE TO FILL IN?
Those that allow you to put information in, and which are coloured in blue

THIS FIGURE SUMMARISES HOW YOUR INSTALLATION NEEDS TO BE SEEN
TO PROPERLY FILL IN THE QUESTIONNAIRE



Person completing the questionnaire
Name
e-mail
This information will be used only if any further clarification is needed.

CREATED BY: Miquel A. Aguado-Monsonet (EIPPCB)
Ludwig Ramacher (FEAD)

FOR QUESTIONS: Miquel A. Aguado-Monsonet (EIPPCB)
at miguel.aguado@cec.eu.int

ONCE COMPLETED PLEASE SEND TO:
Miquel A. Aguado-Monsonet (EIPPCB)
at miguel.aguado@cec.eu.int

GENERAL INFORMATION ABOUT THE WT INSTALLATION		
1	Country	
2	Operator	
3	Name and site of the plant	
4	Plant operating since	
5	The data provided in this questionnaire corresponds to year. . . (year of reference)	
6	Additional remarks	

THIS WORKSHEET CONTAINS DATA ON THE INPUTS TO THE INSTALLATION

WASTE TREATED

Amount of waste treated in the year of reference		tonnes/yr													Number of hazardous codes that you treat	Annual percentage for each type of waste treated
Types of waste treated	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**			%
01														0		
02																
03																
04																
05																
06																
07																
08																
09																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																

UTILITIES INPUT

Type of fuel used		(fossil fuel (gas, liquid, solid) and waste (e.g. RDF))
Fuel consumption		MJ/yr
Electricity consumption		MWh/yr
Heat consumption		MWh/yr
Water		m^3/yr
Cooling		MJ/yr

OTHER INPUTS (e.g. Chemicals)

		tonnes/yr

THIS WORKSHEET CONTAINS A BRIEF EXPLAINATION OF THE PLANT AND THE ACTIVITIES/PROCESSES INVOLVED

TYPE OF PLANT

	production of fuel from non-hazardous waste
	production of fuel from hazardous waste
	mechanical/biological treatment of non-hazardous waste
	anaerobic digestion
	treatment of spent catalysts
	treatment of flue-gas cleaning residues and ashes
	treatment of waste oils
	treatment of waste solvents
	physico-chemical treatment for oil water mixtures and emulsions
	treatment of contaminated soil

BRIEF SUMMARY OF THE INSTALLATION

(Please mention the list of processes/activities carried out in your installation (note: storage is already included). Please add a flow sheet of the plant (in the next worksheet) to assist in the understanding of your process)

		Number	Remarks
1	Gas storage		
2	Liquid storage		
3	Solid (including waste) storage		
4			
5			
6			

AIR ABATEMENT PROCESSES

Please mention in the following table which types of flue-gas cleaning system are used

	Type of system in use	abatement efficiency	basis of the efficiency	Remarks
A1	dry electrostatic precipitator		PM	
A2	wet electrostatic precipitator		PM	
A3	cyclone		PM	
A4	quench			
A5	bag filter		PM	
A6	bag house filter with active carbon injection		PM	
A7	acidic wet scrubber			
A8	alkalic wet scrubber			
A9	additional scrubber system			
A10	dry scrubber with lime injection			
A11	non selective catalytic reduction		NO_x	
A12	selective catalytic reduction for NO_x		NO_x	
A13	selective catalytic reduction for NO_x and dioxins			
A14	active carbon filter (steady)			
A15	VOC incinerator		VOC	
A16	biofilter			
A17				

Are you planning to implement any other air abatement technique in the short term (2 years?)

	If yes, please specify which.

WASTE WATER TREATMENT PLANT (WWTP)

	Does your installation generate waste water?			
If yes, please respond below				
	Is the waste water generated by your installation treated in a WWTP?			
If yes, please respond below				
	The WWTP only treats waste water generated by your installation			
	Overall efficiency		%	In TOC terms
			%	

	Type of treatments contained in the WWTP	**remarks**
W1	sedimentation	
W2	neutralisation	
W3	chemical treatment with	
W4	separation of emulsions	
W5	filtration	
W6	dewatering	
W7	filterpress	
W8	ion exchange	
W9	flocculation	
W10		

Are you planning to implement any other water treatment in the short term (2 years?)

	If yes, please specify which.

PASTE HERE AN IMAGE OF THE FLOW SHEET OF THE INSTALLATION

THIS WORKSHEET CONTAINS QUESTIONS ABOUT THE CURRENT EMISSIONS OF THE INSTALLATION

PRODUCTS					
Name of products with positive market price					
Annual amount of products made (tonnes/yr)					
Electricity (MWh/yr)					
Heat (MWh/yr)					

Notes: C:Continuous, D:Discontinuous, IM: Indirect measurement, E:estimated

If an emission parameter is not applicable for the process include N/A in the table. If you know that may be some emission but you don't have it please leave the cell blank.

AIR EMISSIONS	Types of measurement				
Parameter	**(C, D, IM, E)**	**Concentration**	**Units**	**Load**	**Units**
Fumes generated					Nm^3/yr
Oxygen percentage used for the data below			%		
Averaging time period					
CO_2					kg/yr
Dust			mg/Nm^3		kg/yr
SO_2			mg/Nm^3		kg/yr
NO_x			mg/Nm^3		kg/yr
N_2O			mg/Nm^3		kg/yr
TOC			mg/Nm^3		kg/yr
CO			mg/Nm^3		kg/yr
HCl			mg/Nm^3		kg/yr
HF			mg/Nm^3		kg/yr
Total metals			mg/Nm^3		kg/yr
Hg			mg/Nm^3		kg/yr
Cd + Tl			mg/Nm^3		kg/yr
PAH			mg/Nm^3		kg/yr
PCB			mg/Nm^3		kg/yr
Chlorobenzenes			mg/Nm^3		kg/yr
PCDD/PCDF			$(ngTEQ/Nm^3)$		g/yr
CFC			mg/Nm^3		kg/yr
Odour					
Noise					

Note: N means normal conditions (0 °C and 1 atm). Please give the data in dry conditions.

WATER EMISSIONS	Types of measurement				
Parameter	**(C, D, IM, E)**	**Concentration**	**Units**	**Load**	**Units**
Averaging time period					
Waste water generated					m^3/yr
SS (Suspended Solids (dried 105 °C))			mg/l		kg/yr
TOC (Total Organic Carbon)			mg/l		kg/yr
BOD_5 (Biological Oxygen Demand 5 days)			mg/l		kg/yr
COD (Chemical Oxygen Demand 2 hours)			mg/l		kg/yr
Hydrocarbons			mg/l		kg/yr
Phenols			mg/l		kg/yr
AOX			mg/l		kg/yr
BTX			mg/l		kg/yr
Total Nitrogen (as N)			mg/l		kg/yr
Nitrit N (NO_2 - N)			mg/l		kg/yr
CN (free)			mg/l		kg/yr
Sulphide (free)			mg/l		kg/yr
F, total			mg/l		kg/yr
P, total			mg/l		kg/yr
Total metals			mg/l		kg/yr
Al (mg/l)			mg/l		kg/yr
Fe (mg/l)			mg/l		kg/yr
As			mg/l		kg/yr
Cr, total			mg/l		kg/yr
Cr (VI)			mg/l		kg/yr
Cu			mg/l		kg/yr
Hg			mg/l		kg/yr
Ni			mg/l		kg/yr
Pb			mg/l		kg/yr
Zn			mg/l		kg/yr

RESIDUES GENERATED BY THE PROCESS					
Residues produced by the process					
Annual amount of residues (tonnes/yr)					
Composition					
Subsequent fate					

Please include in this worksheet those techniques implemented or that will be implemented shortly in your installation and that you think are Good Environmental Practices (GEP). For each techniques please give the following information

	Information
Description	
Achieved environmental benefits	
Cross-media effects	
Operational data	
Applicability	
Economics	
Driving force for implementation	
Example plants	
Reference literature	

8.3 Annex III: Types of waste and waste production in the EU

[7, Monier and Labouze, 2001], [39, Militon, et al., 2000], [40, Militon and Becaud, 1998], [41, UK, 1991], [42, UK, 1995], [53, LaGrega, et al., 1994], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003] [124, Iswa, 2003], [125, Ruiz, 2002], [126, Pretz, et al., 2003], [150, TWG, 2004].

This Annex summarises the types of waste produced in the EU and its classification in the EU, as well as summarising the production of waste in individual EU countries and some other European countries. As stated in Chapter 1, waste treatment installations are designed to manage waste. This waste is the input (called raw material in other industrial sectors) to these installations. Viewing the waste treatment sector, as a whole, it can be seen that the physico-chemical properties of such inputs can vary widely. Waste can be liquid to solids (e.g from a physical properties perspective), to organic or to inorganic in character (e.g. from a chemical properties perspective).

The European Waste Framework Directive classifies waste according to the activities that generate the waste, categorising the waste into twenty different groups as listed below.

EWL Code	Groups of waste as mentioned in EWL
01	Wastes resulting from exploration, mining, dressing and further treatment of minerals and quarry
02	Wastes from agricultural, horticultural, hunting, fishing and aquacultural primary production, food preparation and processing
03	Wastes from wood processing and the production of paper, cardboard, pulp, panels and furniture
04	Wastes from the leather, fur and textile industries
05	Wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal
06	Wastes from inorganic chemical processes
07	Wastes from organic chemical processes
08	Wastes from the manufacture, formulation, supply and use of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks
09	Wastes from the photographic industry
10	Inorganic wastes from thermal processes
11	Inorganic metal-containing wastes from metal treatment and the coating of metals; non-ferrous hydro-metallurgy
12	Wastes from shaping and surface treatment of metals and plastics
13	Oil wastes (except edible oils, 05 and 12)
14	Wastes from organic substances used as solvents (except 07 and 08)
15	Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified
16	Wastes not otherwise specified in the list
17	Construction and demolition wastes (including road construction)
18	Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)
19	Wastes from waste treatment facilities, off-site waste water treatment plants and the water industry
20	Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions
Note: EWL stands for European Waste List	

Table 8.10: European classification of waste
Council Decision 2000/532/EC

In order to give a snapshot of the waste situation in Europe, the following tables (Table 8.11 to Table 8.13) show the amount of waste generated in each Member State (MS) and some other European countries, for each category of waste mentioned above. It should be noted that a waste with the same physico-chemical characteristics may appear with different codes.

	AT		BE		DE		DK		ES		EL		FR		FI		IT		IE		LU		NL		PT		SE		UK		IS		NO		CH	
EWL Code	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N
01	7		0				0		28						0	432			21						0	16971										
02	22		92				0		60						3,1	831	0						0		0	1483										
03			1				0		0						0,2	8525	0		0				0		0	2594										
04	0		0				1		7						< 0.1	13	1		0				0		0	3114										
05	38		3				9		61		15				32	3	29		6				10		8	4										
06	11		13				5		110						137	656	261		3				266		11	6										
07	1		29				11		215		1				46	47	842		146				2		32	35										
08	15		8				15		21						7	4	37		2				3		5	63					0					
09	5		2				10		4						1,4	0	164		0				1		1	1					0					
10	64		90				34		290		109				534	2095	367		1				51		10	1212										
11	5		57				7		132						272	71	298		0				82		5	3										
12	41		12				2		74		1				6	273	233		0				1		2	457										
13	33		33				35		42						42	1	392		28				50		122	0					5					
14	0		8				4		99						2,8	< 0.1	137		4				2		28	0					0					
15	32		7				1		48						9	146			0				0		0	327										
16	67		57				11		22		4				55	968	318		6				117		15	123					1					
17	66		18				5		1						2	897	21		0				2		0	1283										
18	3		4				10		0						2	< 0.1	133		3				0		0	0					0					
19	140		40				91		136		36				24	2301	164		4				11		14	605										
20	26		0				12		12						2	826	5		0				2		0	630										
SUB TOTAL	576	47059	474	48371	9093	39068	263	13229	1362	11096	450	3197	7000	623600	1177	18088	3401	28364	248	6179	180	2548	1520	54090	254	28908	500	3200	1844	248415	7		645	6847		2600
TOTAL	47635		48845		48161		13492		12458		3647		630600		19265		31765		6427		2728		55610		29162		3700		250259				7492			

Table 8.11: Amount of each type of waste generated by European country
Note: Data in kilotonnes per year. H: hazardous, N: non-hazardous

	AT		BE		DE		DK		ES		EL		FR		FI		IT		IE		LU		NL		PT		SE		UK		IS		NO	
EWL Code	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N
01	1.2		0.0				0.0		2.1		0.0				0.0	2.2	0.0		9.4				0.0		0.0	58.7					0.0			
02	3.8		19.4				0.0		4.4		0.0				0.3	4.3	0.0		0.0				0.0		0.0	5.1					0.0			
03	0.0		0.2				0.0		0.0		0.0				0.0	44.3	0.0		0.0				0.0		0.0	9.0					0.0			
04	0.0		0.0				0.4		0.5		0.0				0.0	0.1	0.0		0.0				0.0		0.1	10.8					0.0			
05	6.6		0.6				3.4		4.5		9.0				2.7	0.0	0.9		2.7				1.7		3.0	0.0					0.0			
06	1.9		2.7				1.9		8.1		0.0				11.6	3.4	7.7		1.3				44.3		4.3	0.0					0.0			
07	0.2		6.1				4.2		15.8		0.6				3.9	0.2	24.8		65.2				0.3		12.8	0.1					0.0			
08	2.6		1.7				5.7		1.5		0.0				0.6	0.0	1.1		0.9				0.5		2.1	0.2					0.0			
09	0.9		0.4				3.8		0.3		0.0				0.1	0.0	4.8		0.0				0.2		0.2	0.0					0.0			
10	11.1		19.0				12.9		21.3		65.7				45.4	10.9	10.8		0.4				8.5		4.0	4.2					0.0			
11	0.9		12.0				2.7		9.7		0.0				23.1	0.4	8.8		0.0				13.7		2.1	0.0					0.0			
12	7.1		2.5				0.8		5.4		0.6				0.5	1.4	6.8		0.0				0.2		0.9	1.6					0.0			
13	5.7		7.0				13.3		3.1		0.0				3.6	0.0	11.5		12.5				8.3		48.0	0.0					83.3			
14	0.0		1.7				1.5		7.3		0.0				0.2	0.0	4.0		1.8				0.3		11.0	0.0					0.0			
15	5.6		1.5				0.4		3.5		0.0				0.8	0.8	0.0		0.0				0.0		0.0	1.1					0.0			
16	11.6		12.0				4.2		1.6		2.4				4.6	5.0	9.3		2.7				19.5		6.0	0.4					16.7			
17	11.5		3.8				1.9		0.1		0.0				0.2	4.7	0.6		0.0				0.3		0.0	4.4					0.0			
18	0.5		0.8				3.8		0.0		0.0				0.1	0.0	3.9		1.3				0.0		0.1	0.0					0.0			
19	24.3		8.4				34.6		10.0		21.7				2.0	11.9	4.8		1.8				1.8		5.3	2.1					0.0			
20	4.5		0.0				4.6		0.9		0.0				0.2	4.3	0.1		0.0				0.3		0.1	2.2					0.0			
SUB TOTAL	1.3	98.7	1.6	98.4	18.9	81.1	2.1	97.9	23.4	76.6	12.3	87.7	1.1	98.9	6.1	93.9	10.7	89.3	3.9	96.1	6.6	93.4	2.7	97.3	0.9	99.1	13.5	86.5	0.7	99.3			8.6	91.4
TOTAL	100		100		100		100		100		100		100		100		100		100		100		100		100		100		100				100	

Table 8.12: Percentage of each type of waste generated by European country
Note: Data in percentages per year. The raw subtotal corresponds to the percentage of hazardous and non-hazardous waste generation for each country
[10, ANPA and ONR, 2001], [19, Brodersen, et al., 2002], [21, Langenkamp and Nieman, 2001], [86, TWG, 2003], [127, Oteiza, 2002], [150, TWG, 2004]

	Municipal	Industrial	Agricultural	Mining	Demolition	Sewage sludge	Hazardous
Belgium	3.5	27.0	53.0	7.1	0.7	0.7	0.9
Denmark	2.4	2.4	-	-	1.5	1.3	0.1
France	1.7	50.0	400.0	10.0	-	0.6	3.0
Germany	19.5	61.0	-	9.5	12.0	1.7	6.0
Greece	3.1	4.3	0.09	3.9	-	-	0.4
Ireland	1.1	1.6	22	1.9	0.2	0.6	0.02
Italy	17.3	40.0	30.0	57.0	34.0	3.5	3.8
Luxembourg	0.17	1.3	-	-	4.0	0.02	0.004
Netherlands	6.9	6.7	86.0	0.1	7.7	0.3	1.5
Portugal	2.4	0.7	0.2	3.9	-	-	0.16
Spain	12.5	5.1	45.0	18.0	-	10	1.7
UK	35.0	70.0	250.0	25.0	32.0	1.0	4.5
US	209.0	760.0	150.0	14.0	32.0	10	275.0 [a]
Japan	48.0	312.0	63.0	26.0	58.0	2	6.6
Units in million tonnes [a] Includes waste water							

Table 8.13: Estimated waste arisings in selected countries
OECD (1991) and Department of the Environment (1992) in [80, Petts and Eduljee, 1994]

The following sections cover more specific information, classified by type of waste. Not all types of waste are covered as in some cases the sector is minor or no information has been provided.

8.3.1 Municipal solid waste (MSW)

Table 8.14 shows a gross summary of the different components of MSW in the Member States as well as the total production of MSW in some European countries.

Country	Paper	Textiles	Plastics	Glass	Metals	Biodegradable waste		Others	Total
Austria	670	63	340	284	166	750	*29 %*	236	2509
Belgium									5014
Czech republic									3200
Cyprus									370
Denmark	505		122	94	42	923	*36 %*	894	2580
Estonia									560
Finland	536			116	53	662	*32 %*	735	2102
France	6250	750	2750	3250	1000	7250	*29 %*	3750	25000
Germany									40017
Greece	640	144	272	144	160	1568	*49 %*	272	3200
Hungary									4300
Ireland									1503
Italy	3300		1050	900	450	6450	*43 %*	2850	15000
Luxembourg	36	4	15	13	5	83	*44 %*	33	189
Netherlands	1785	230	395	445	230	2630	*38 %*	1220	6935
Poland									11800
Portugal	1074	154	503	254	109	1627	*36 %*	811	4532
Slovenia									1020
Spain	3025	689	1511	984	589	6303	*44 %*	1195	14296
Sweden	1408	64	224	256	64	960	*25 %*	224	3200
UK	7400	400	2000	1800	1400	3800	*19 %*	3200	20000
Norway									2722
Data in ktonnes and correspond to years between 1993 and 1997									

Table 8.14: Municipal solid waste composition in the EU and production in different European countries
[59, Hogg, et al., 2002], [92, EEA, 2002], [150, TWG, 2004]

Table 8.15 shows the metals that might be present in municipal solid wastes.

Metal	Present due to
Cd	Plastic pigments, batteries
Cr	Colours, pigments in plastics, textile dyes and leather tanning

Table 8.15: Metals in municipal solid waste
[113, COWI A/S, 2002]

8.3.2 Contaminated waters

Table 8.16 shows the amount of contaminated water generated in France.

Type of waste water	Amount (kt/yr)
Mix of water, hydrocarbons and sediments	10

Table 8.16: Amount of polluted water generated in France
[40, Militon and Becaud, 1998]

Table 8.17 describes efforts to reduce the quantities of waste, illustrated with the aid of statistics from the German federal state of North Rhine Westphalia.

	Quantities of waste (m^3/yr)		
Governmental districts of NRW (Germany)	In 1990	Projected quantity for 2005	
		Projection of 1994 [1]	Projection of 1996 [2]
Arnsberg	278300	204000	102600
Detmold	78300	66000	35300
Duesseldorf	337800	251200	140700
Cologne	264400	206000	98700
Münster	83400	69500	59600
Total	**1042200**	**796700**	**436900**
Valuation	**100 %**	**76 %**	**42 %**

NRW: North Rhine Westphalia
[1] Strategic Concept for Special Waste Disposal in NRW, 4th Edition, 1994, WAZ Press, Duisburg
[2] Strategic Concept for Special Waste Disposal in NRW, 5th Edition, 1996, WAZ Press, Duisburg

Table 8.17: Waste treated by Ph-c plants in North Rhine Westphalia/Germany in 1990 and projected quantity for 2005
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

The changes in projected quantities of waste to be treated by Ph-c plants indicate which measures are most successful in achieving effective reductions in quantities of waste. These measures consist of production-integrated measures as well as improvements in production processes and, especially, auxiliary substances and additives.

Despite these measures to avoid and reduce the quantities of waste, waste which arises in the course of production still has to be contended with. However, reductions in the quantities of waste can frequently lead to a build up associated with a more expensive treatment procedure. Physico-chemical plants constantly adapt to these changes technically, operationally and organisationally.

8.3.3 Sewage sludge

Table 8.18 and Table 8.19 show the amount of sewage sludge produced in some European countries and the European average composition of sewage sludge.

Country	Quantity (kt dry matter)
Austria	211.9
Belgium	113
Denmark	200
Finland	158
France	878
Germany	2661
Greece	86
Ireland	43
Italy	
Luxembourg	13
Netherlands	349
Portugal	239
Spain	787
Sweden	236*
UK	1193
Norway	93
Data corresponding to year 1998, except * that correspond to year 1995	

Table 8.18: Amount of sewage sludge produced in some European countries [92, EEA, 2002], [150, TWG, 2004]

Compound	Concentration (mg/kg dry matter)
N	3500 – 46000
P	10400 – 45000
Cd	0.7 – 3.8
Cr	16 – 840
Cu	220 – 641
Hg	0.6 – 4
Ni	8 – 85
Pb	20 – 325
Zn	290 – 2580

Table 8.19: Ranges of contamination and content of sewage sludge [92, EEA, 2002]

8.3.4 Waste acids and bases

The European Waste List (EWL) specifies several waste acids and bases (e.g. sulphuric, hydrochloric, hydrofluoric, phosphoric, nitric acids, calcium hydroxide, soda and ammonia). HF is not regenerated; it is only neutralised. Bases are not typically regenerated; they are typically neutralised. An exception may be represented by the regeneration of black liquors in the pulp industry (covered in Pulp and Paper BREF)

8.3.5 Waste adsorbents

The adsorption of pollutants onto activated carbon, charcoal and ion exchange resins has been a common treatment technique for removing contaminants (e.g. COD, POPs, inorganics) from waste water and gaseous emissions for many years. Activated carbon is also used for the removal of VOCs from gaseous emissions (e.g. pesticide manufacture/formulation). Regeneration procedures for the spent carbon have been primarily limited to thermal reactivation technologies. Resins have found selective uses where recovery and re-use of the organic contaminant is an important objective, or where the contaminants are in reasonably high concentrations. They can also be used for inorganic removal and recovery (e.g. colour removal in the sugar industry, dyestuff and paper mill industries, for phenol removal, for processing new antibiotics, and for polishing high purity waters). Charcoal is primarily used as a fuel. As it is destroyed by combustion processes, charcoal is typically not reactivated.

8.3.6 Waste catalysts

Catalytic methods are used extensively in the production of inorganic and organic chemicals, in petroleum technology, in the processing of synthetic gaseous and liquid fuels, in pollution control, and in energy conversion. Some examples of the use of catalysts are shown in Table 8.20.

Industrial sector	Examples
Production of inorganic chemicals	Hydrogen, ammonia, sulphuric acid, etc.
Production of organic chemicals	Organic synthesis, hydrogenation, dehydrogenation, acid catalysed dehydration reactions, oxychlorination
Petroleum refining	Reforming, desulphurisation, hydrocracking, cracking, isomerisation, lube oil hydrofinishing
Pollution control techniques	NO_x abatement SCR, off-gas combustion purification

Table 8.20: Industrial sector where catalysts are used
[125, Ruiz, 2002]

The type of compounds used as catalysts depends on the process but metals, metal oxides and acids are the ones most commonly used, as shown in Table 8.21.

	Importance	Examples
Metals	They are among the most important and widely used industrial catalyst components	Ag, Au, and the platinum group metals Transition metals: Fe, Co, Ni, Mo, Ru, Rh, Pd, W, Re, Os, Ir and Pt. Nontransition metals: Cu, Zn, As, Se, Ag, Cd, Sn, Sb, Te, Au, Hg, Pb and Bi.
Metal oxides	They are common catalyst supports and catalysts.	Al_2O_3, SiO_2- Al_2O_3, V_2O_5, ZnO, NiO, MoO_3, CoO, WO_3.
Metal sulphides		MoS_2, WS_2
Acids	Insulators that show the transition from basic to amphoteric and acidic character	Na_2O, MgO, Al_2O_3 , SiO_2 , and P_2O_5
Bases	Limited industrial applications	$Ba(OH)_2$, $Ca(OH)_2$, Na
Multifunctional catalysts		$Bi_2O_3.MoO_3$
Ion exchangers		
Organometallic complexes		
Others		$Co(acetate)_2$, amines, benzoil peroxide, etc

Table 8.21: Overview of the types of catalysts used for industrial purposes
[125, Ruiz, 2002]

Theoretically, a catalyst remains unchanged after its use. However, when a catalyst may lose its activity because of deactivation (by, e.g. poisoning (by, e.g. P, S, As, Se, Te, Bi, C), fouling or sintering) and re-dispersion of the active centres of the catalysts. As a consequence, waste catalysts are mainly composed of the same materials as the native catalyst but contaminated with some additional components.

8.3.7 Wastes from combustion processes

Combustion wastes are generated during the combustion of coal, (heavy) liquid fuels or waste in large combustion plants, industrial heaters and boilers, and incinerators. Two types of wastes are produced in combustion processes. One type is the bottom ashes (slags) generated in the combustion chamber and the second corresponds to the flue-gas treatment (FGT) waste (sometimes so-called 'air pollution control' (APC) residues), regulated according to the European Legislation as hazardous waste. FGT waste can come from any combustion process (e.g. incinerators, large combustion plants, industrial boilers) and they are typically treated before re-use or being landfilled.

The term 'APC residue' is used with slightly differing meanings in the literature: strictly speaking the term only covers the solid residues (i.e. sludge and gypsum from wet systems, and excess reagent and reaction products from dry/semi-dry systems) generated to minimise emissions of acidic components in the flue-gas. Considering this definition, fly ashes should not be included. However, from a management point of view, all these solid residues (the fly ash, which is the major component, (most important by amount and even boiler ash in some MSs) are usually handled in combination (notably in the dry and semi-dry systems).

FGT waste is used as including all types of solid residues produced in or after the heat recovery systems (boiler/economiser). This includes fly ash, boiler ash, excess lime and reaction products (dry/semi-dry), sludge from scrubber solution treatment and gypsum (wet). No special emphasis is placed on managing sludge and gypsum separately, as the amounts are relatively small compared to fly ash. Table 8.22 and Table 8.23 indicate the waste generated by coal fired power plants and the total in some European countries.

Country	Fly ash	Slag and bottom ash	Gypsum	Other products from gas cleaning	Sludge	Total[1]
Austria	334.5	24.9	74.5	2.0	0.3	436.2
Belgium						1135
Denmark	1158	152	374	100	n.a.	1784
Finland						1274
France	1840 - 1940					2100
Germany						25310
Greece	10					10080
Ireland						450
Italy	872	182	4	3	2	1063
Luxembourg						
Netherlands						1525
Portugal	272	30				302
Spain	531					531
Sweden						600
UK	5100	1400				6500
Norway						
Data in kt/yr correspond to years from 1993 to 1999 depending on the country. Data contains ashes (bottom and fly) as well as residues from flue-gas cleaning (gypsum). [1] Corresponds to waste from energy production plants						

Table 8.22: Waste from coal-fired power plants
[40, Militon and Becaud, 1998], [92, EEA, 2002], [95, RAC/CP, 2003]

Data in ktonnes		Type of FGT system			
Country		**Dry/semi-dry**	**Wet**	**Not specified**	**Total**
Austria	Residues	0	8.1	0	8.1
	Waste	0	450.0	0	450.0
Belgium	Residues	2.7	0	4.4	7.1
	Waste	90.1	0	101.2	191.3
Denmark	Residues	26.6	30.9	5.1	62.6
	Waste	745.6	1348.8	234.6	2329.0
Germany	Residues	284.4	377.4	13.2	675.0
	Waste	3807.0	10027.0	247.0	14081.0
France	Residues	83.2	122.4	5.9	211.5
	Waste	551.7	1971.4	121.6	2644.7
Hungary	Residues	11.1	0	0	11.1
	Waste	352.2	0	0	352.2
Italy	Residues	0	0	50.2	50.2
	Waste	0	0	1109.4	1109.4
Netherlands	Residues	0	54.0	30.4	84.4
	Waste	0	1492.0	887.0	2379.0
Norway	Residues	0.4	3.4	0	3.8
	Waste	17.5	126.7	0	144.2
Portugal	Residues	27.4	0	0	27.4
	Waste	321.8	0	0	321.8
Spain	Residues	58.8	0	0	58.8
	Waste	817.9	0	0	817.9
Sweden	Residues	43.0	29.0	14.8	86.8
	Waste	699.8	901.8	327.4	1929.0
United Kind-dom	Residues	30.9	0	0	30.9
	Waste	1074.1	0	0	1074.1
Switzerland	Residues	0	65.7	0	65.7
	Waste	0	2462.6	0	2462.6
Total	Residue	396.3	530.3	148.0	1074.6
	Waste	6266.2	12819.5	3787.9	22873.6

Table 8.23: Amounts of FGT waste in some European countries
[124, Iswa, 2003], [152, TWG, 2004]

An overview of the main components of solid FGT waste is given in Table 8.24.

Solid component	Dry/semi-dry systems	Wet systems
Fly ash/boiler ash	Always	Always
Excess reagent + reaction products	Always: can be mixed with fly ash; contain Cl salts and/or gypsum	-
Dioxin sorbent	Optional: usually included	Optional: usually handled separately or re-used as a neutralisation agent in Waste Water Treatment Plant
Sludge	-	Always: sometimes mixed with fly ash/boiler ash (Bamberg model)
Gypsum	Included in reaction products	Obtained if no liquid effluent: handled separately if recovery is intended
Cl salts	Included in reaction products; re-covery possible in some cases	Obtained if no liquid effluent: recovery possible in some cases

Table 8.24: Main components of the FGT waste
[124, Iswa, 2003], [150, TWG, 2004]

8.3.8 Waste oil

Waste oil (WO) is a term defined by European law as any mineral-based lubrication or industrial oils which have become unfit for the use for which they were originally intended, and in particular used combustion engine oils and gearbox oils, and also mineral lubricating oils, oils for turbines and hydraulic oils (Council Directive 85/101/EEC). WOs are classified as hazardous waste by European law and should be collected so that they can be safely treated. Waste oil contaminated with more than 50 ppm of PCBs is not included in this category because they are treated differently by EU legislation.

WOs cover a wide range of materials, with further differences arising from their previous use under differing conditions. In this document, the term 'used oil' is understood to include only those WOs which arise from the use of lubricating oils. Slop oils recovered from drainage systems, refineries, fuel storage sites, etc. are another type of waste oil. They may end up in used oil collection systems, where they can decrease the value of the used oil. Oil filters and carburetor filters contain around 30 % hydrocarbons.

Used oils can be categorised according to market considerations as follow:

- (black) engine oils: these represent more than 70 % of used oil. The largest potential source of used oils is from vehicle use, particularly engine oils
- black industrial oils: these represent about 5 % of used oil
- light industrial oils: these represent about 25 % of used oil. They are relatively clean and their market value is high. Their market is very specific and independent from the classical supply routes of regeneration.

Used oil composition is becoming more and more complex due to different factors:

- the increasing use of dispersants, as well as esters and polyalphaolefins, e.g. to increase the life of the oil. However, as a result, the resulting WO has become more complex and dirty over time
- the progressive displacement of conventional mineral based auto lubricants by 'synthetic' products which have enhanced performance characteristics. Whereas some of these synthetic products can be regenerated along with mineral oils, others (those based upon esters for instance) are less suitable to regeneration because they tend to be less stable in the presence of caustic (often used by regeneration processes) and less stable to the hydro-finishing step.

A low proportion of base oil (less than 2 % of the total consumption) originates from agricultural sources, being produced from either sunflower or rape-seed. These bio-lubricants are used in applications where their characteristics represent a real advantage, in particular:

- their good biodegradability. This is important when lubrication losses into the environmental media, e.g. soil and water, can occur during use (woodcutting with motor saws, boats, cutting oils, etc.)
- their high viscosity index and low volatility for instance.

The fate of 1.1 million tonnes of used oils generated in Europe in 1993 was unrecorded. This represents approx. 20 % of the total virgin lubricating oils market. The following Figure 8.1 shows that the amount of waste oil recovered in EU has increased to ~50 %. In 1995, the Australian Industry Commission [13, Marshall, et al., 1999] estimated that, of the world's total available waste oil, only 44 % was collected.

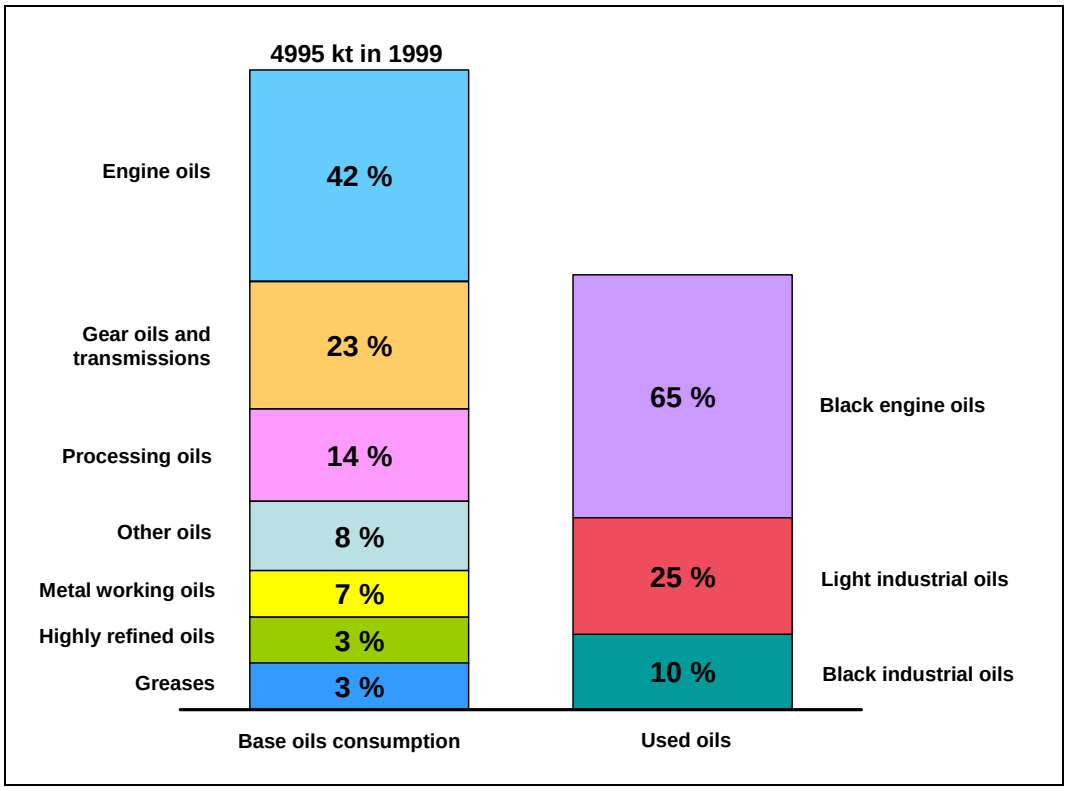


Figure 8.1: Base oils consumed and used oils generated in the EU [7, Monier and Labouze, 2001]

More information on the amount collected in each MS and on issues related to the waste oil market can be found in [7, Monier and Labouze, 2001]. More information about the typology of lubricants and the different types of WO is given below.

Lubricants and waste oils
Table 8.25 details:

- the typology of lubricants and a split of the lubricant consumption according to this typology
- the average ratio to be considered for each category of lubricant to assess the WO generated during their use
- the type of WO, black oils (from engine origin or industrial origin) or light oils, generated in each case.

Lubricants Consumption					*WO*		
Category	**Application**	**Use**	**European Consumption 1999 (kt)**	**% of consumption**	**Ratio (oil consumed/WO generated)**	**WO 1999 (kt)**	**Type of WO**
Engine oils	Engine oils for passenger cars	To diminish friction between moving parts of engine	2098	42 %	59 %	1238	Black oils
	First fill oils for passenger cars						
	Engine oils for commercial vehicles						
	First fill oils for industrial vehicles						
	Multipurpose diesel oils						
	Two-stroke engine oils						
	Other engine oils						
Gear oils & transmissions	Automatic transmission fluids	To inhibit wearing out of gears and bearings and also to inhibit oxidation and corrosion	1149	23 %	24 %	276	Black oils
	Automotive gear oils						
	Industrial gear oils						
	Hydraulic transmission oils						
	Shock absorber oils						
Greases	Automotive greases	To diminish friction between moving parts of engine	150	3 %	27 %	40	Black oils
	Industrial greases						
Metal working oils	Quenching oils	In metal working for lubricating and cooling of both tools and the metals to be worked	350	7 %	0 %	0	Lost
	Neat oils for metalworking						
	Soluble oils for metalworking						
	Rust prevention products						
Highly refined oils	Turbine oils		150	3 %	48 %	72	Light oils
	Electrical oils						
Other oils	Compressor oils	To inhibit wearing out of gears and bearings and also to inhibit oxidation and corrosion	400	8 %	61 %	244	Black oils
	General machine lubricants						
	Other oils for non-lubricating uses						
Processing oils	Process oils		699	14 %	77 %	538	Light oils
	Technical white oils						
	Medical white oils						
TOTAL			**4996**	**100 %**	**50 % on average**	**2408**	

Table 8.25: EU lubricant collectable waste oil [7, Monier and Labouze, 2001]

End Use	Sales 1999 (tonnes)	% recoverable[1]	Potentially collectable (tonnes)
Gasoline and diesel engines	249488	65	162167
Agricultural engines	15000	65	9750
Other engines	7288	0	0
Marine engines	37728	25	9432
Aviation and turbine oils	2214	50	1107
Total engine oils	311718		182456
Hydraulic and transmission	96352	80	77082
Other gear oil	53815	80	43052
Total gear/transmission oils	150167		120134
Total greases	11815		1177
Total metal working oils	35548		7110
Turbine and electrical oils	27070	95	25717
General machine lubricants	15219	50	7610
Non-lubricating industrial oils	11792	10	1179
Other industrial oils	10939	20	2188
Total other oils	65020		36693
Total processing oils	129908		0
Deliveries to blenders	86151	50	43075
Total all lubricants	**790327**	**(49.4)**	**390646**
[1]Estimates based on CONCAWE WQ/STF-26 study			

Table 8.26: UK lubricant collectable waste oil estimates (tonnes)
[7, Monier and Labouze, 2001]

8.3.9 Waste solvents

In this document, the term 'waste solvent' is to be understood as including all those wastes from organic substances used as solvents, also including those used in organic chemical processes and from manufacture, formulation, supply, and those used in coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks.

Country	Annual production (kt/yr)	Treated (kt/yr)
ES		127
FR	800	90.7
IT		58.3

Table 8.27: Production of solvents and treatment of waste solvents
[40, Militon and Becaud, 1998], [95, RAC/CP, 2003]

8.3.10 Waste plastics

Plastics are mainly organic polymers with different compositions. Typical polymers are polystyrene (PS), polyethylene terephthalate (PET), polypropylene (PP), polyurethane (PU), polyacrylonitrile-butadiene-styrene (ABS), polycarbonate (PC), polyamides (PA), polybutylene terephthalate (PBT), polyethylene (PE), polyvinyl chloride (PVC), etc. Waste plastics can be differentiated according to its type of use as shown below:

Sectors	Polymers contained in the plastic waste
Packaging	PE, PP, PS, PET, etc.
Automotive	PP, PU, ABS, etc.
Electrical	PS, ABS, PP, etc.
Electronics	PC, PA, PBT, etc..
Building + Construction	Foams: PU, Expanded PS, Mix of PS, etc., Pipes: PE, PVC, etc.
Agricultural (films)	PE

Table 8.28: Waste plastics
[58, CEFIC, 2002], [150, TWG, 2004]

The requirements for each type of use greatly differs and the choice of plastic is made by the user, typically a downstream producer, on a cost performance ratio. Table 8.29 shows some examples of metals that are present in plastics.

Metal	Use	Comment
Pb	PVC stabiliser	About 0.7 – 2 % Pb as stabiliser in many types of rigid PVC for outdoor use
	Pigment in plastic	Lead chromate for yellow and red colours contains 64 % lead
Cd	Stabilisers (e.g. PVC)	About 0.2 %, up to a maximum of 0.5 % cadmium used as stabiliser in rigid PVC for outdoor applications (window profiles, sidings).
	Pigment	
Cr (Cr (III) and Cr (VI))	Colours and pigments	

Table 8.29: Presence of metals in plastics
[113, COWI A/S, 2002], [150, TWG, 2004]

8.3.11 Waste wood

Contaminated wood can arise from electrical and telephone fence posts, supports in railways and from all wood treated for use outdoors. This type of wood is typically treated and some of the product for treatment may contain metals. The treatments that they receive are based on creosote and pentachlorophenol, metallic salts, copper sulphate, CFK treatment (Cu, F, Cr treatment), CCB treatment (Cu, Cr, B treatment) or CCA treatment (Cu, Cr, As treatment). Table 8.30 shows some data on the amount of this type of waste generated in one MS (France).

Type of contaminated wood	Amount of waste generated per year	
	(m^3/yr)	(t/yr)
Wood treated with creosote	150000	75000
Wood treated with CCA	80000	40000

Table 8.30: Amount of contaminated wood generated
[40, Militon and Becaud, 1998]

8.3.12 Cyanide wastes

Cyanide wastes typically arise in solutions that have been used for a variety of operations in the metals/electroplating industries, such as cleaning, de-tarnishing, printing and electroplating solutions. Typically, the waste consists of solid or liquid cyanide salts. Cyanide wastes also arise as fused solids within a container or in block form when molten salts have been used for heat treatment purposes.

The volume of cyanide wastes arising has significantly decreased in recent years, mostly due to the replacement of cyanide based cleaners by surface active agents and the use of copper pyrophosphate plating solutions in place of copper cyanide.

8.3.13 Other inorganic waste

Waste containing silver mainly arises from film processing, but to a lesser degree also some from the custome sector and the dental sector, which also produces waste contaminated with mercury.

8.3.14 Refractory ceramics waste

The level of contamination of refractory ceramics depends on its utilisations. For example, it is known that ceramics used in the combustion of heavy fuel contain cadmium, vanadium, nickel and sulphur and that sulphur is common in refractory ceramics used in petrochemistry. The amount of waste generated per year in France is 200 kt [40, Militon and Becaud, 1998].

8.3.15 Hazardous waste from the construction and demolition sector

Table 8.31 shows the amount of hazardous waste produced from the construction and demolition sector in some European countries.

Country	Quantity (kt)
AU	8.4
DE	490.0
DK	8.4
EL	0.9*
ES (Region of Catalonia)	185.5
IE	159.0
Data from 1996 except for DE that corresponds to 1993 * Data refer only to asbestos	

Table 8.31: Amount of hazardous waste generated from the construction and demolition sectors in some European countries
[92, EEA, 2002], [95, RAC/CP, 2003]

8.3.16 Waste contaminated with PCBs

Some types of waste contaminated with PCBs are electrical transformers, capacitors, transformer oils and waste oils (waste oil contaminated with more than 50 ppm of PCB is considered by European Legislation to be a special waste which cannot be treated in the same way as waste oils). Some commonly found materials may also become polluted with PCBs (soils, building materials, waste clothing, other debris, etc.). These can typically be decontaminated by treatment with a solvent, and the resulting solvent and PCBs mixture may then be processed.

The uses of PCBs can be classified into three categories:

Closed applications
As the name implies, closed uses are those in which the PCBs are enclosed and cannot escape during normal use. The main examples are transformers and capacitors, which are sealed pieces of electrical equipment. Apart from accidents (fire, mechanical damage, etc.) the PCB will remain in a safe environment, at least until the end of the working life of the equipment in which it is enclosed.

Partially closed applications
In these, oil containing PCB is employed as a fluid which is called upon to move during use, for example as a heat transfer fluid or as a hydraulic fluid, in pumps or in switches. This movement implies the presence of joints and seals in the equipment, offering the possibility that these items of equipment can release small amounts of fluid during normal operation.

Open applications
In open applications, the PCBs are generally incorporated into a formulation, usually in small or very small quantities. Such products can be lubricants, adhesives, paints, inks, etc. The PCBs can become very dispersed depending on each application, and it is virtually impossible to destroy them. The solution to this problem is instead found further upstream, i.e. to ban the incorporation of PCBs in such products; this of course is already done in most countries, although many products manufactured earlier may still be in use.

This classification is useful since it indicates the likelihood with which the PCB can be released, intentionally or unintentionally, thereby leading to a PCB contamination problem.

8.4 Annex IV. Quality assurance systems for secondary recovered fuel (SRF)

[126, Pretz, et al., 2003]

There are several initiatives to characterise and set in place quality assurance systems for solid waste fuels (e.g. SRF). These can be divided into initiatives based either on a European wide level or on a national level. Some have been described in Section 3.5.4.4 of this document.

Quality assurance systems

Part of the description of the best available technique concerns the logistics of the SRF processing. By choosing and using specific waste materials, SRF producers set a kind of quality assurance themselves. Quality assurance systems already exist and further regulations are currently under development.

In the past, SRF was mainly produced from process related wastes as mono-batches which were easier to handle because of their constant qualities. Nowadays high calorific fractions of municipal solid wastes and of other mixed wastes are also used in the production of SRF, which makes the need for a quality assurance system more urgent. The aim of a quality assurance system for SRF is to attain and ensure constant qualities, to increase acceptance of SRF by end users and permitting authorities. The requirements mainly concern product quality. The following sections present the results of a survey about existing quality assurance systems and ongoing developments.

RAL

In early 1999, the German Bundesgütegemeinschaft für Sekundärbrennstoffe e.V. (BGS e.V.) initiated the quality label GZ 724. The label is awarded to SRF producers which comply with certain quality and consistency requirements. The standards initially applied relate to the cement industry and power stations, where SRF now have to fulfil the criteria given in Annexes 1 and 2 of GZ 724. Annex 1 contains a list of all the allowed wastes which can be used as a basis for the SRF. In Annex 2 values are given which have to be met. These values are shown in Table 8.32. Checks are made in two phases in the approval as well as in the supervision procedures.

Phase 1:

Three samples taken by an independent supervisor, and seven samples taken out of a pool of samples resulting from self monitoring are analysed according to certain standards. For the heavy metal contents:

- the median value of the ten samples must not exceed the allowed median values given in Table 8.32
- the “80 the percentile” values in Table 8.32 must not be exceeded by eight out of the ten samples (Application of the ‘4 out of 5 regulation’).

Phase 2:

If in phase 1, the median or the “4 out of 5 regulation” does not comply, another ten samples are chosen out of the sample pool of the self monitoring and examined for the parameter(s) that did not comply. The analysis follows the some procedures as that used in level 1:

- the median values of the 20 samples must not exceed the allowed median values given in Table 8.32 and
- the ‘80th percentile’ values of Table 8.32 must not be exceeded by 16 out of 20 the samples (Application of the “4 out of 5-Regulation”).

Further parameters need to be documented as follows: the calorific value, the humidity, the ash content, and the chlorine content.

These values should not be regarded as strict thresholds. The conditions are kept if four of five outliers is still below the 80th percentile. Outliers often appear in waste analysis and this regulation is specific to the character of wastes. The guideline value used is the median because of the obvious low concentrations in waste and environmental analysis. Heavy metal contents are established applying the DIN or DIN EN ISO test methods. The digestion method is applied with aqua regia in a closed microwave system.

	Content of heavy metals [4]			
	median (mg/kgDM)		**80th percentile (mg/kgDM)**	
Cadmium	4		9	
Mercury	0.6		1.2	
Thallium	1		2	
Arsenic	5		13	
Cobalt	6		12	
Nickel	25 [1]	80 [2]	50 [1]	160 [2]
Selenium	3		5	
Tellurium	3		5	
Antimony	25		60	
Lead	70 [1]	190 [2]	200 [1]	- [3]
Chromium	40 [1]	125 [2]	120 [1]	250 [2]
Copper	120 [1]	350 [2]	- [3]	- [3]
Manganese	50 [1]	250 [2]	100 [1]	500 [2]
Vanadium	10		25	
Tin	30		70	
Beryllium	0.5		2	

[1] For solid recovered fuel from production specific waste
[2] For solid recovered fuel from the high calorific fractions from municipal waste
[3] Restricted not until a secured database is given by the fuel processing
[4] The mentioned heavy metal contents are valid up to a calorific value NCV_{DM} of ≥ 16 MJ/kg for the high calorific fractions from municipal waste and up to a calorific value NCV_{DM} of ≥ 20 MJ/kg for production specific waste. For calorific values falling below, the mentioned values need to be lowered accordingly, an increase is not allowed.

Table 8.32: Heavy metal contents which have to be complied with according to BGS [126, Pretz, et al., 2003]

Furthermore the BGS e.V. demands an approval procedure (first inspection) and a monitoring procedure, which incorporates self-monitoring and independent supervision. A re-inspection is also scheduled. Moreover, Annex 2 of GZ 724 defines sampling procedures, covering all the analytical examinations and regulations.

Acknowledging procedure (first inspection)
To attain the quality label the applicant has to pass the approvals procedure. This first inspection is conducted by a neutral inspection institute which assesses the applied techniques and workforce and facilities. The SRF have to meet the regulations in Annex 2. Furthermore, the applicant has to verify his practice and expert knowledge, reliability and the official permission for operating the plant. Furthermore, he has to prove that he is able to conduct a continuous self-monitoring system. Parts of this self-monitoring can be sub-contracted to a neutral inspection institute in arrangement with the BGS e.V., but this inspection institute is then not allowed to carry out the independent supervision at the same time.

Self-monitoring
The self-monitoring concerns the production process control and is carried out by the enterprise itself or sub-contracted out as explained above. The input material has to be documented using mass balance according to the European Waste List Code (EWL), e.g. also listing mass, derivation, physico-chemical parameters and the output as produced SRFs. The produced SRFs have to be approved in line with the requirements from Annex 2.

Independent supervision
The independent supervision is conducted by a dedicated inspection institute which is nominated by the BGS e.V. The quality of the produced SRF is controlled and the completeness and the reasonableness of the self-monitoring documentation are reviewed. The ascertained personal situation from the approval proceeding is also appraised. The monitoring intervals depend on the amount of SRF produced yearly.

Re-inspection
A re-inspection is carried out within a period of four weeks if, in the framework of the independent supervision, the supervisor detects any faults in the quality assurance. If the re-inspection fails, the enterprise is deemed to have failed the independent supervision as a whole. What further action is needed is laid down in the implementation instructions for awarding and using the BGS e.V quality label.

The BGS e.V. can set penalties depending on the irregularity. This may be an admonishment or even cancellation of the rights to use the label.

SFS 5875
The Finnish waste disposal system is based on a separate collection of wastes for recycling and for SRF production. Different solid wastes are used in Finnish boilers with a high technical standard, ensuring highly efficient energy production together with low emission levels. The application of SRF in the Finnish multifuel boiler is considered to be 'well suited'. The regulations concern separate collected, dry solid, high calorific fractions or for dry, high calorific fractions derived from household wastes. The regulation defines operations and demands to control the production of SRF. The regulation refers to the complete waste management chain, from the waste recovered paper source up to the disposal. For each part of the disposal chain, the standard requires a person to be in charge and to take responsibility for monitoring the technical and quality requirements.

Similar to the BGS e.V. standard, the annexes of the Finnish standard define concrete requirements concerning the threshold limits for heavy metals, as well as for the framework of the analysis, sampling, etc. The thresholds need to be set and kept to, as well as regulations covering contracts.

Supervision operation
Compliance with the standard needs to be guaranteed by contracts and stipulated delivery specifications between the respective groups within the disposal string. Regulations concerning self-monitoring, independent supervision or approvals procedures are not newly defined in this standard. Therefore, the regulations of the standardisation institute will need to be followed.

Quality requirements and classes
In comparison to the BGS e.V. standard, the Finnish standard is split into three quality classes. For categorisation of SRF in Finland seven elements are analysed. Limiting values for heavy metals are given for cadmium and mercury. Furthermore, the classification into one class requires an analysis for the contents of chlorine, sulphur, nitrogen, potassium and sodium. Table 8.33 presents the criteria for the classification into quality classes. Metallic aluminium is not allowed for in quality class I (1) but is accepted within the limits accuracy (two decimal places). The metallic aluminium content of SRF of quality class II (2) is already reduced by the sorting and further processing steps. For SRF of quality class III (3) it is necessary to satisfy the content of metallic aluminium separately. The given thresholds refer to a volume of SRF of ≤1000 m³ or to the volume which is produced or delivered in one month.

Parameter	Unit	Quality classes		
		I	II	III
Chlorine	weight -%	<0.15	<0.5	<1.5
Sulphur	weight -%	<0.2	<0.3	<0.5
Nitrogen	weight -%	<1.0	<1.5	<2.5
Potassium and sodium	weight -%	<0.2	<0.4	<0.5
Aluminium (metallic)	weight -%	- [1)]	- [2)]	- [3)]
Mercury	mg/kg	<0.1	<0.2	<0.5
Cadmium	mg/kg	<1.0	<4.0	<5.0
[1)] Metallic aluminium is not allowed, but is accepted within the limits of reporting precision. [2)] Metallic aluminium is minimised by source-separation and by the fuel production process. [3)] Metallic aluminium content is agreed separately.				

Table 8.33: Quality classes according to SFS 5875/13/ [126, Pretz, et al., 2003]

In principle, the SRF quality is specified by means of Table 8.33 above. A second possibility for an arrangement about the characteristics of SRF is the possibility of fixing it on the content and amount of parameters. The amount of parameters may need further thresholds and characters to extend to the defined quality classes. Concerning the analysis of the physico-chemical parameters, the respective ISO standards apply.

CEN/BT/TF 118

The CEN Task Force 118 'Solid Recovered Fuels' was established in April 2000. It was set up to prepare a technical report about the production and application of SRF within the EU, as well as to develop a work programme as a basis for a future European standard. The European classification model will be based on SRF characteristics, source material and origin.

The report concluded that it was indeed necessary to develop a European standard. CEN has been given the mandate to develop, as a first step, a set of technical specifications concerning the use of SRF for energy recovery in waste incineration or co-incineration plants. Secondly, CEN has been given a mandate to transform this set of technical specifications into European Standards.

ÖG SET

In a joint project of the 'Österreichische Gütegemeinschaft für Sekundärenergieträger (ÖG SET)', a quality assurance concept has been worked out. The work started in May 2001 and it was finished on May 2003. The result ought to be a basis for a label like the one generated by the BGS e.V.

Others

Internal quality assurance systems already exist, e.g. the generated quality assurance system used by Trienekens AG whose successor is RWE Umwelt AG. Table 8.34 gives an overview about this system.

Process step	Measures	Supplementary measures
Origin (waste producer, sorting plant, mechanical biological processing)	Collection of wastes, avoidance of impurities, contractual arrangements about allowed qualities of wastes, declaration analysis, documentation of disposed amounts	Instruction courses for waste producers, periodic controls of the waste producing company by the disposer
Processing plant (delivery)	(Regular) sampling and analysis, reserve samples, documentation of input and processed amounts	Regular sampling and analysis of the outgoing materials by a external official expert
Processing plant (output)	Regular sampling and analysis, reserve samples, documentation of the delivered amounts	
Cement and lime kilns, power plants	Regular sampling and analysis, reserve samples, documentation of the input amounts	

Table 8.34: Quality assurance system of RWE Umwelt AG
[126, Pretz, et al., 2003]

Comparison of quality assurance systems

The regulations of the German Bundesgütegemeinschaft für Sekundärbrennstoffe e.V. should complement internal quality assurance systems. The regulations according to RAL-GZ 724 are a completion of ISO 9000 and are specific to SRF. The Finnish regulation aims at incorporation of existing systems, opening the possibility for agreements to be made concerning the SRF quality between the producer and the consumer. The BGS e.V. actually defines two classes, whereas the Finnish system separates into three different quality classes. It has already been decided for the new EU regulations that the quality classes will be expanded. The result may be a classification system as shown in Table 8.35, with additional parameters for fuel technology and process engineering.

		Codification of the columns				
Parameter	**Units**	**A**	**B**	**C**	**.....**	**X**
NCV	MJ/kg					
H_2O	% o.s.					
Chlorine	% o.s.					
Ash	% o.s.					
Hg	mg/MJ					
Cd	mg/MJ					
Sum of As, Co, Cr, Cu, Mn, Ni, Pb, Sb, V	mg/MJ					
Biogenic part	% o.s.					

Table 8.35: Classification system
[126, Pretz, et al., 2003]

The BGS e.V. standard requires documentation of the chlorine content whereas the Finnish standard defines thresholds for each quality class.

The Finnish standard seems to be less widely applied in practice than the German quality label GZ 724. The approach of the Finnish standard is quite different in comparison to the German quality label. The German system is based upon an extensive data basis and considers the complete process chain. The Finnish standard regulates high calorific fractions derived from separate collected wastes and defines procedures and requirements for SRF quality control.