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Identification of potentially POP-containing Wastes and Recyclates – Derivation of Limit Values

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Identification of potentially POP-containing Wastes and Recyclates – Derivation of Limit Values

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Kurzbeschreibung

Das Stockholmer Übereinkommen über persistente organische Schadstoffe (POPs) und das POP-Protokoll zum Übereinkommen über weiträumige grenzüberschreitende Luftverunreinigung (CLRTAP) sind dynamische Instrumente, deren Substanzlisten ständig erweitert werden. Wenn neue Stoffe/Stoffgruppen in den Übereinkommen als POPs eingestuft worden sind, werden sie nachfolgend in die Verordnung (EG) 850/2004 (POP-Verordnung) aufgenommen.

Das Vorkommen dieser Schadstoffe in Abfällen und in Erzeugnissen hat entsprechend den Anhängen I, IV und V der POP-Verordnung Konsequenzen für die Abfallbehandlung und für das Maß ihrer Ausschleusung aus dem Wirtschaftskreislauf. In einer effizienten, gemeinwohlverträglichen und zugleich ressourcenschonenden Kreislaufwirtschaft muss demzufolge ein vernünftiger Kompromiss zwischen Schadstoffentfrachtung und Recycling gefunden werden. Auf europäischer Ebene werden deshalb Grenzwerte, unterhalb derer das Recycling von POP-haltigen Abfällen möglich ist, sowie Höchstwerte für die Konzentration der Schadstoffe bei bestimmten zulässigen Entsorgungsverfahren, verbindlich definiert.

Eine Voraussetzung für die Festlegung von Grenzwerten ist die detaillierte Kenntnis über das Vorhandensein der Schadstoffe in Abfällen, Erzeugnissen sowie Recyclingprodukten. In dem Vorhaben wurden Daten über das Vorkommen von Hexabromcyclododekan (HBCD), Hexachlorbutadien (HCBD), Polychlorierten Naphtalinen (PCN), Pentachlorphenol (PCP) und kurzkettigen chlorierten Paraffinen (SCCP) in relevanten Abfällen, Erzeugnissen und Recyclingprodukten in Deutschland erhoben und eine Schätzung über die Mengen an POP-haltigen Abfällen und Recyclingstoffen vorgenommen.

Auf der Grundlage der Daten wurden Vorschläge für die Grenzwerte des Anhangs IV der POP-Verordnung sowie für bestimmte Entsorgungswege abgeleitet, die einerseits eine möglichst weitgehende Ausschleusung von Schadstoffen gewährleisten und andererseits umweltgerechte Recyclingprozesse ermöglichen.

Abstract

The Stockholm Convention on Persistent Organic Pollutants (POPs) and the Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) are dynamic instruments, whose substance lists are amended continuously. As soon as new substances/substance groups are classified in the Convention as POPs, they are subsequently included in the Regulation EC (No) 850/2004 (EU POP Regulation).

The presence of these pollutants in waste and products has, according to Annexes I, IV and V of the POP Regulation, consequences for the waste treatment and for the degree of their removal from the economic cycle. In an efficient and resource-saving recycling economy, which considers at the same time common welfare, a reasonable compromise between pollutant removal and recycling has to be found. Therefore, limits values, below which recycling of POP-containing waste is possible, as well as maximum values for the concentration of pollutants for specific permitted disposal operations, are bindingly defined at European level.

A condition for the setting of limit values is the detailed knowledge of the presence of pollutants in waste, products as well as recyclates. In the present project data were collected on the presence of Hexabromocyclododecane (HBCD), Hexachlorobutadien (HCBD), Polychlorinated naphthalenes (PCN), Pentachlorophenol (PCP) and short chain chlorinated paraffins (SCCP) in relevant waste, products and recyclates in Germany. In addition, an estimation of the quantities of POP-containing waste and recyclates was carried out.

On the basis of these data proposals for limit values to be defined in Annex IV of the POP Regulation as well as for certain disposal pathways were derived, which enable a maximised removal of pollutants on the one hand and environmentally sound recycling processes on the other hand.

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(P)NEC	(Predicted) No Effect Concentration
ABANDA	Waste Samples Database of the German Federal State North Rhine-Westphalia (German: Abfallanalysendatenbank des Landes Nordrhein-Westfalen)
AltholzV	German Waste Wood Ordinance of 15 August 2002 (Original title in German: Verordnung über Anforderungen an die Verwertung und Beseitigung von Altholz (BGBl. I S. 3302))
ASE	Accelerated Solvent Extraction
ASN	Waste Code (German: Abfallschlüsselnummer)
BImSchG	German Federal Immission Control Act (Original title in German: Bundesimmissionsschutzgesetz)
BImSchV	Ordinance for the Implementation of the German Federal Immission Control Act (Original title in German: Bundesimmissionsschutzverordnung)
BLV	Biological Limit Value
CBA	Cost-Benefit Analysis
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution of 13 November 1979
CP(s)	Chlorinated Paraffin(s)
DepV	German Landfill Regulation (Original title in German: Deponieverordnung of 27 April 2009 (BGBI. I S. 900))
DM	Dry Matter
ECHA	European Chemicals Agency
EGS	Ecosystem Goods and Services
E-PRTR	European Pollutant and Release Transfer Register
EPS	Expanded Polystyrene Foam
HBCD	Hexabromocyclododecane
HCBD	Hexachlorobutadiene
HELCOM	Convention on the Protection of the Marine Environment of the Baltic Sea Area
HIPS	High Impact Polystyrene
IPA	Information Portal on Waste Assessment (German: Informationsportal Abfallbewertung)
LCCP(s)	Long Chain Chlorinated Paraffin(s)
LPCL	Low POP Concentration Limit in accordance with Article 7(4)a of the EU POP Regulation
LPVC	Low Production Volume Chemical
MCCP(s)	Medium Chain Chlorinated Paraffin(s)
MPCL	Maximum POP Concentration Limit in accordance with Article 7(4)b of the EU POP Regulation
MRL	Minimal Risk Level

n.r.	not relevant
ODS	Ozone Depleting Substances
OEL	Occupational Exposure Limit
PBDD/F(s)	Polybrominated Dioxins/Furans
PBT	Persistent, bioaccumulative and toxic
PCB(s)	Polychlorinated Biphenyls
PCDD/F(s)	Polychlorinated Dioxins/Furans
PCN(s)	Polychlorinated Naphthalene(s)
PCP	Pentachlorophenol
PD	Polymer Dispersion
PER	Tetrachloroethene
POP(s)	Persistent Organic Pollutant(s)
PS	Polystyrene
PS-E	Polystyrene, Expanded (Polystyrene hard foams, including EPS and XPS)
PUR	Polyurethane
PVC	Polyvinyl Chloride
REACH	Regulation (EC) No 1907/2006 (REACH Regulation)
SCCP(s)	Short Chain Chlorinated Paraffin(s)
SVHC	Substance of Very High Concern
TDI	Tolerable Daily Intake
TETRA	Tetrachloromethane
TICS	Thermal Insulation Composite System
TRI	Trichloroethene
UBA	German Federal Environment Agency (German: Umweltbundesamt)
UFOPLAN	Environmental Research Plan (German: Umweltforschungsplan)
WEEE	Waste of Electrical and Electronic Equipment
WFD	Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008)
XPS	Extruded Polystyrene Foam

Note:

Apart from those explained in the list of abbreviations, further common abbreviations are used in this report, inter alia for different units (mg, kg, t, ppm, ppb, etc.).

1 ppm = 1 mg/kg = 0.0001%;

1 ppb = 1 µg/kg = 0.0000001%

Zusammenfassung

Hintergrund und Ziele

Persistente organische Schadstoffe (engl. Persistent Organic Pollutants, kurz POPs) sind chemische Substanzen, die nach ihrer Freisetzung lange in der Umwelt verbleiben und über Nahrungsketten – insbesondere im Fettgewebe – stark akkumulieren und so schließlich Konzentrationen erreichen, die schädliche Auswirkungen auf die menschliche Gesundheit und die Umwelt haben. POPs haben darüber hinaus das Potential zum weiträumigen Transport und können sich über Luft und Meeresströmungen weltweit verbreiten.

Das Stockholmer Übereinkommen und das POP-Protokoll zum Übereinkommen über weiträumige grenzüberschreitende Luftverunreinigung sind dynamische Instrumente, deren Substanzlisten ständig erweitert werden. Fünf Stoffe bzw. Stoffgruppen sind derzeit als sogenannte POP-Kandidaten zur Aufnahme in das Stockholmer Übereinkommen vorgeschlagen bzw. wurden im Mai 2013 aufgenommen (HBCD):

- Hexabromcyclododekan (HBCD),
- Hexachlorbutadien (HCBD),
- Polychlorierte Naphthaline (PCN),
- Pentachlorphenol (PCP) und
- Kurzkettige Chlorierte Paraffine (SCCP).

Erklärtes politisches Ziel europäischer und nationaler Abfallpolitik ist einerseits die Förderung der Kreislaufwirtschaft zur Schonung der natürlichen Ressourcen, andererseits zielt die Abfallpolitik genauso auch auf die Sicherstellung des Schutzes von Mensch und Umwelt bei der Bewirtschaftung von Abfällen. Die Vorgaben zur Zulässigkeit von Beseitigungsmaßnahmen im Rahmen der Abfallhierarchie verdeutlichen den grundsätzlich gewollten Ausgleich beider Ziele: Dort, wo Recycling letztlich zu einem aus Umwelt- und Gesundheitsperspektive unerwünschten Kreislauf von Schadstoffen führt und damit die Vorteile der Ressourcenschonung überwiegen, gilt der hierarchische Vorrang des Recyclings nicht. Dort können und sollen Abfälle bzw. die darin enthaltenen Schadstoffe im Sinne des Umwelt- und Gesundheitsschutzes aus dem Wirtschaftskreislauf ausgeschleust werden.

Das Spannungsverhältnis zwischen den beiden dargestellten grundsätzlichen Zielen der Abfallpolitik ist speziell im Bereich des Gehalts von POPs in Abfällen sowie Gemischen und Erzeugnissen als Ergebnis von Recyclingprozessen, namentlich durch Festlegung von schadstoffspezifischen Grenzwerten auszugleichen. Diese Grenzwerte haben dem Gebot der Verhältnismäßigkeit genauso zu entsprechen wie dem umweltpolitischen Vorsorgeprinzip. Dabei ist für eine sachgerechte Festlegung der Grenzwerte essentiell, dass eine solide Fakten- und Datenbasis für jeden einzelnen Schadstoff existiert. Das rechtliche Instrument hierzu sind die Anhänge der EU POP-Verordnung.

Vor diesem Hintergrund ist das Ziel des Vorhabens,

- Daten über das Vorkommen der fünf POP-Kandidatenstoffe/-stoffgruppen in relevanten Abfällen und Recyclingprodukten zu erheben;
- eine Abschätzung über die Mengen an POPs/POP-Kandidatenhaltigen Recyclingstoffen vorzunehmen, die im Wirtschaftskreislauf verbleiben; und
- auf Grundlage der Daten, Vorschläge für die Grenzwerte des Anhangs IV der POP-Verordnung sowie für bestimmte Entsorgungswege abzuleiten, die einerseits eine möglichst weitgehende Ausschleusung von Schadstoffen gewährleisten und andererseits umweltgerechte Recyclingprozesse ermöglichen.

Herangehensweise/Methodik

Herangehensweise

Nach einer Recherche zum möglichen Vorkommen der POP-Kandidaten in Erzeugnissen und Abfällen wurden gezielte Laboranalysen zur Verbesserung der bestehenden Datengrundlage durchgeführt. Im Anschluss wurden Vorkommen und Verbleib der relevanten Stoffe und Stoffgruppen in Deutschland auf einer möglichst umfassenden und präzisen Datengrundlage geschätzt und es wurde dargestellt, welche Risiken von den aus diesen Erzeugnissen entstandenen Abfällen und Recyclingprodukten ausgehen. Für die einzelnen Stoffe/Stoffgruppen wurden Vorschläge für Grenzwerte nach Anhang IV der POP-Verordnung abgleitet und Empfehlungen für geeignete Entsorgungswege und Behandlungstechnologien gegeben.

Es wurden umfangreiche Recherchen durchgeführt, um die Datengrundlagen zum Vorkommen der relevanten Substanzen in Erzeugnissen und Abfällen zu erheben. Im Rahmen der Recherchen wurden Stoff- und Massenflüsse auf Grundlage der verfügbaren Informationen erstellt. Zu diesem Zweck wurden für alle Stoffe/Stoffgruppen folgende Informationen soweit verfügbar analysiert:

- Chemische Charakterisierung
- Gesetzlicher Hintergrund
- Herstellung und Trends
- Verwendung und Trends
- Auswahl relevanter Anwendungsbereiche (in welchen Anwendungsbereichen wird der Stoff/Stoffgruppe in erheblichen Mengen eingesetzt/generiert)
- Detailinformationen zu ausgewählten Anwendungsbereichen

Die Recherchen fokussierten auf die Anwendungen/Produkte/Abfälle, in denen das Vorkommen der relevanten Stoffe/Stoffgruppen aufgrund der Literaturauswertung zu erwarten ist und/oder wo ein besonders großer Eintrag in die Umwelt zu erwarten ist.

Aufbauend auf den Ergebnissen der Recherchen wurden in enger Abstimmung mit dem Umweltbundesamt (UBA) spezifische Erzeugnisse/Abfälle/Recyclate zu den fünf Stoffen/Stoffgruppen ausgewählt und ein entsprechender Probenbeschaffungs- und Analysenplan erstellt. Die analytischen Messungen und Laboruntersuchungen erfolgten gezielt bei Erzeugnissen, Abfällen und Recyclingprodukten, um gezielt Wissenslücken zu schließen. Es wurden insgesamt 45 analytische Messungen durchgeführt, um das Vorhandensein der relevanten Stoffe/Stoffgruppen in Erzeugnissen, Abfällen sowie Recyclingprodukten zu prüfen und zu quantifizieren.

Im Bericht werden die angewandten sowie verfügbare Analyseverfahren und Untersuchungsparameter eingehend beschrieben, sowie die Ergebnisse der Laboranalysen vor dem Projekthintergrund diskutiert.

Die Ergebnisse der Analysen und weitere Recherchen dienten dazu, die Daten aus der Vorrecherche zu erweitern und zu präzisieren. Anhand von präzisierten Stoff- und Massenflüssen und zusätzlichen Informationen zum Vorkommen der POP-Kandidaten in Produkten und Abfällen und deren Behandlung wurde eine Übersicht erstellt, in welchen Bereichen die Stoffe/Stoffgruppen typischerweise vorkommen und welche Risiken aus entsprechenden Abfällen und Recyclingprodukten ausgehen. Die Gebrauchsdauer der Artikel und die derzeit praktizierten Entsorgungswege wurden dabei berücksichtigt.

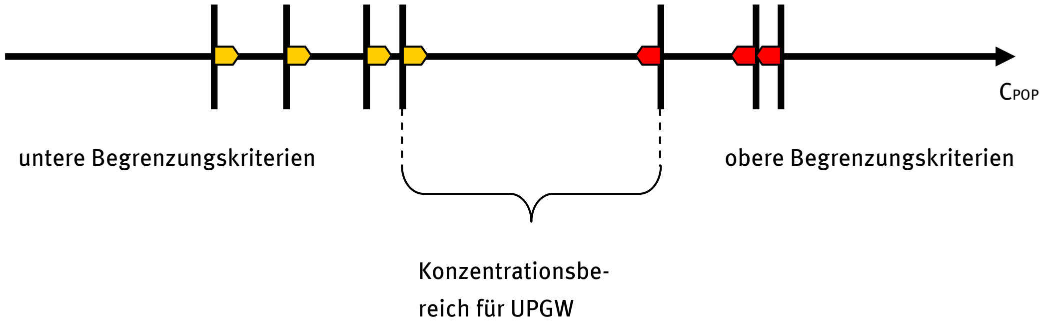
Ableitung von Grenzwertvorschlägen nach Artikel 7(4)a der POP-Verordnung, Entsorgungswege und Behandlungstechnologien

Auf der Grundlage der vorhergehenden Arbeiten wurden Art und Menge der derzeit im Wirtschaftskreislauf befindlichen und in Zukunft verbleibenden Mengen an POP-haltigen Materialströmen abgeschätzt. Für die jeweiligen Stoffe/Stoffgruppen wurden Vorschläge für Grenzwerte nach Anhang IV der POP-Verordnung abgleitet, die einerseits eine möglichst weitgehende Ausschleusung von Schadstoffen gewährleisten und andererseits umweltgerechte Recyclingprozesse ermöglichen.

Abfälle mit einem POP-Gehalt oberhalb des unteren POP Grenzwerts (UPGW) unterliegen den Vorschriften des Stockholmer Übereinkommens zur Zerstörung oder unumkehrbaren Umwandlung nach Artikel 6. 1. (d) (ii). Abfälle unterhalb des UPGW unterliegen sonstigen einschlägigen Rechtsvorschriften zur Beseitigung oder Verwertung von Abfällen. Erwägungen zum Umwelt- oder Gesundheitsschutz etc. sind ggfs. dort zu berücksichtigen.

Die Methode zur Ableitung von Grenzwerten beruht darauf, den Konzentrationsbereich eines möglichen Grenzwerts für jede der zu untersuchenden Substanzen, anhand verschiedener Kriterien nach unten und oben zu begrenzen. Ein Teil dieser Kriterien, wirkt dabei (z.B. durch die Bestimmungsgrenze analytischer Verfahren) nach unten begrenzend, der andere Teil der Kriterien (z.B. durch die möglichen Auswirkungen auf Umwelt und Gesundheit) nach oben begrenzend. Abbildung 1 stellt die Einschränkung der Bandbreite für UPGW durch untere und obere Begrenzungskriterien grafisch dar:

Abbildung 1: Eingrenzung des Konzentrationsbereichs für UPGW durch untere und obere Begrenzungskriterien



Für jede Substanz ist ein Grenzwert innerhalb des eingegrenzten Konzentrationsbereichs möglich. Damit soll einerseits erreicht werden, dass der Grenzwert unter Berücksichtigung der verfügbaren Daten realistisch implementierbar ist, andererseits die menschliche Gesundheit und die Umwelt aber auch möglichst weitgehend vor persistenten organischen Schadstoffen geschützt werden.

Um die Bandbreite möglicher Grenzwerte für jede Substanz einzuschränken, werden vier untere sowie zwei obere Begrenzungskriterien herangezogen. Die Optionen für UPGWs ergeben sich dann aus der Zusammenführung der innerhalb aller Einzelkriterien jeweils ermittelten Grenzwerte.

Untere Begrenzungskriterien:

- **(A) Analyseverfahren**: Grenzwerte sollen analytisch kontrollierbar sein
- **(H) Hintergrundkontamination**: Grenzwerte sollen oberhalb von bestehenden Hintergrundkontaminationen in der Umwelt liegen
- **(BV) Beseitigungs- und Verwertungskapazitäten**: Grenzwerte sollen so liegen, dass für die erforderliche Verwertung und Beseitigung benötigten (neuen) Entsorgungswege und Kapazitäten realistisch verfügbar sind
- **(W) Wirtschaftliche Auswirkungen**: Grenzwerte sollen so liegen, dass erforderliche zusätzliche Entsorgungskosten wirtschaftlich vertretbar sind

Obere Begrenzungskriterien:

- **(GW) Grenzwerte**: Grenzwerte sollen nicht im Widerspruch zu bestehenden Grenzwerten stehen
- **(UG) Mögliche Umwelt- und Gesundheitsauswirkungen**: Grenzwerte sollen so liegen, dass mögliche Auswirkungen auf Umwelt und Gesundheit vermieden werden

Im Bericht erfolgt eine ausführliche Evaluierung der unteren und oberen Begrenzungskriterien, die es ermöglicht, den Bereich für den UPGW für die jeweiligen Stoffe/Stoffgruppen konkret einzugrenzen.

Material- und Stoffflüsse

Hexabromcyclododekan (HBCD)

Derzeit wird HBCD innerhalb der EU ausschließlich in den Niederlanden hergestellt mit einer Jahresproduktion von rund 6.000 t. HBCD wird außerdem in die EU sowie nach Deutschland als Chemikalie, in Zubereitungen und in flammgeschützten Artikeln im- und exportiert. In Deutschland wird HBCD nicht hergestellt.

Global wird HBCD seit den 1960er Jahren verwendet. HBCD wurde in vier relevanten Produkttypen in erheblichen Mengen eingesetzt.

In Deutschland ist die einzige verbleibende Anwendung, in der erhebliche Mengen an HBCD eingesetzt werden, die Verwendung für EPS und XPS im Baubereich. Schätzungen zufolge dürften die verwendeten Mengen in 2012 bei ca. 2.700 t liegen. Seit 2013 wird HBCD auch in dieser Anwendung substituiert und soll bis August 2015 vollständig ersetzt werden. In HIPS (High Impact Polystyrol) im Elektrobereich findet aktuell keine Verwendung mehr statt. Im Textilbereich wurde die Verwendung 2007 eingestellt.

Auf Grundlage früherer, aktueller und prognostizierter Verwendungsmengen und Emissionen lässt sich schätzen, welche HBCD Mengen bereits als Abfall angefallen sind bzw. künftig als Abfall anfallen werden. Berechnungen und Abschätzungen für Deutschland zeigen, dass der weitaus größte Anteil HBCD-haltigen Abfalls erst in Zukunft anfallen wird. Insbesondere sind hier die Anwendung im Baubereich, mit vergleichsweise hohen Verwendungsmengen und sehr langen Produktlebenszeiten, entscheidend. In anderen EPS und XPS relevanten Anwendungen, die vom Verpackungsbereich dominiert werden, wird HBCD in Deutschland bereits nicht mehr eingesetzt. Aufgrund der kurzen Produktlebensdauer in diesem Bereich könnte HBCD hier möglicherweise durch Importe nach Deutschland in Abfallströme gelangen. Ähnliches gilt für die Verwendung von HBCD in HIPS für den Elektrobereich. Es liegen keine konkreten Informationen vor, dass HBCD hier noch verwendet wird.

Es ist davon auszugehen, dass HBCD in Deutschland schon seit 2007 nicht mehr im Textilbereich eingesetzt wird. Bereits in den Jahren davor sind die Verwendungsmengen zurückgegangen. Entsprechende Produkte dürften daher im Abfall mittelfristig von sehr begrenzter Relevanz sein.

Abschätzungen zum Aufkommen von HBCD-Mengen in Abfällen verdeutlichen, dass die überwiegende Menge des verwendeten HBCDs noch in Produkten im Umlauf ist und in Zukunft in die Abfallströme gelangen wird (siehe Tabelle 1). Insbesondere gilt das für EPS- und XPS-Schäume, die im Baubereich eingesetzt wurden: einerseits aufgrund ihrer hohen Lebensdauer (50 +/- 25 Jahre) und andererseits aufgrund der hohen Verwendungsmengen von HBCD für diesen Bereich (bis 2015 insgesamt über 60.000 t).

Aufgrund durchschnittlicher Konzentrationen von HBCD in relevanten Produkten lassen sich die entsprechenden Abfallmengen darstellen:

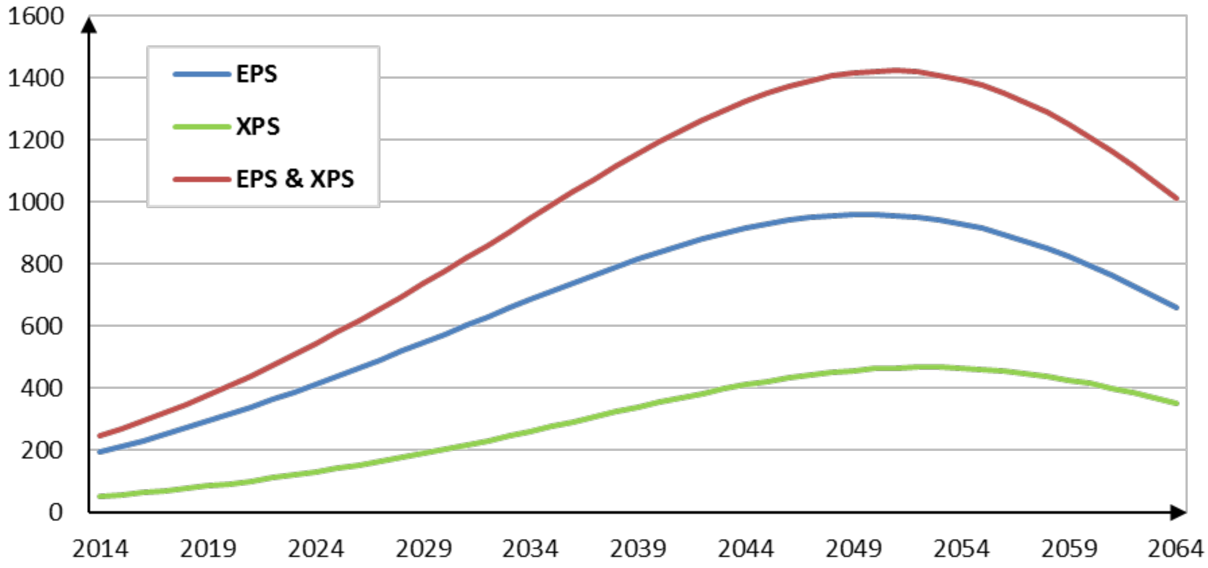
Tabelle 1: Kumulierte HBCD-haltige Abfallmengen aus den geschätzten Verwendungsmengen (in Tonnen) für die relevanten Anwendungen

Abfälle	Menge HBCD in Abfällen (in t)	HBCD Konzentration (in %)	Abfallmenge (in t)	Anfall nach 2012 (in t)	Anfall bis 2012 (in t)
EPS Produkte Bau	42.829	0,70	6.118.429	5.921.665	196.764
XPS Produkte Bau	19.102	1,5	1.273.470	1.252.026	21.444
EPS/XPS andere	3.719	0,70*	531.286	0	531.286
HIPS Produkte	1.306	4,00*	32.650	16.200	16.450
Textilien	4.114	8,00*	51.425	11.563	39.863
Summen	71.070		8.007.259	7.201.453	805.806

* aktuell keine Verwendung mehr

Die mit Abstand größten HBCD Abfallmengen werden künftig aus dem Baubereich anfallen (siehe Abbildung 2). Je nach Lebensdauer behandelter Produkte und dem Zeitpunkt des Einsatzes lässt sich schätzen, wie sich der jährliche Anfall an HBCD im Laufe der Zeit verändert und in welchen Mengen HBCD in entsprechenden Abfällen in Zukunft anfallen wird. Eine Abschätzung für den jährlichen Anfall von HBCD in EPS und XPS Abfällen aus dem Baubereich ist in der folgenden Abbildung grafisch dargestellt.

Abbildung 2: Abschätzung des künftigen jährlichen Anfalls (in t) von HBCD in EPS und XPS Abfällen aus dem Baubereich von 2014 bis 2064



Selbst wenn HBCD nicht mehr eingesetzt wird, kann das Vorkommen der entsprechenden Produkte in den Abfallströmen je nach Lebensdauer noch lange in der Zukunft von Bedeutung sein. Die Bedeutung von EPS/XPS Anwendungen außerhalb des Baubereichs, HIPS im Elektrobereich und Polymerdispersionen im Textilbereich ist allerdings irrelevant bzw. vergleichsweise gering, verglichen mit den EPS/XPS Anwendungen im Baubereich.

Die Schlussfolgerungen aufgrund der Projektergebnisse zeigen, dass HBCD insbesondere aus EPS und XPS Materialien aus dem Baubereich relevant ist (siehe Tabelle 2).

Hexachlorbutadien (HCBD)

Anthropogene Quellen von HCBD sind die gezielte Produktion, die unbeabsichtigte Herstellung sowie Abfälle aus historischen Anwendungen. Es gibt keine natürlichen Quellen für die Entstehung von HCBD. Seit Ende der 1970 er Jahre wird HCBD in Europa weder gezielt hergestellt noch verwendet.

In der Vergangenheit wurde HCBD zu unterschiedlichen Zwecken verwendet. HCBD kann als unerwünschtes Nebenprodukt bei der Synthese von chlororganischen Verbindungen, bei Verbrennungsprozessen oder der Produktion von Magnesium unbeabsichtigt entstehen.

In Deutschland wurde HCBD zu keiner Zeit gezielt hergestellt. Allerdings sind Ende der 70 er Jahre etwa 4.500 t/a HCBD als Nebenprodukt der Niederdruck-Chlorolyse zur Herstellung von Tetrachlorethen (PER) oder Tetrachlormethan (TETRA) angefallen.

Unabhängig von historischen Anwendungen und Freisetzungen von HCBD erscheint heutzutage die unbeabsichtigte Herstellung von HCBD als größte Emissionsquelle.

Möglicherweise relevante Vorkommen wurden untersucht. Die Projektergebnisse lassen schlussfolgern, dass HCBD in Deutschland in Produkten, Abfällen und Recyclaten keine relevante Bedeutung hat (siehe Tabelle 2).

Polychlorierte Naphthaline (PCN)

Bis in die 1970er Jahre wurden PCN als „High Production Volume“ Chemikalie hergestellt. Seit 1989 werden in Deutschland keine PCN mehr produziert. PCN wurden in der Vergangenheit in unterschiedlichen Anwendungen eingesetzt, sie können aber auch unerwünscht bei verschiedenen thermischen Prozessen entstehen. Verbrennungsprozesse, insbesondere die Abfallverbrennung, werden als die wichtigsten aktuellen Quellen erachtet. Man geht davon aus, dass PCN unter ähnlichen Bedingungen wie Dioxine und Furane entstehen.

Möglicherweise relevante Vorkommen wurden untersucht. Aufgrund der Projektergebnisse lässt sich schließen, dass PCN in Deutschland in Produkten, Abfällen und Recyclaten keine relevante Bedeutung hat (siehe Tabelle 2).

Pentachlorphenol (PCP)

Über die aktuelle globale Produktion von PCP lassen sich keine genauen Angaben machen. In 1981 wurden etwa 90.000 t PCP weltweit hergestellt. Aktuellen Literaturangaben zufolge wird in der gesamten UNECE-Region PCP nur noch in den USA produziert. In 2011 wurden weltweit etwa 10.000 t PCP hergestellt. In Deutschland wurde die Herstellung in 1985/86 eingestellt.

PCP fand Einsatz in der phenolischen Form (PCP), als Salz (Natriumpentachlorphenolat, NaPCP) und als Ester (Pentachlorphenollaurylester, PCPL). Aufgrund hervorragender bakterizider und fungizider Eigenschaften eignen sich PCP und seine Derivate für eine Reihe unterschiedlicher Anwendungsgebiete. Es wurde in erster Linie für den Holz- und Bautenschutz und die Schnittholzbehandlung verwendet, aber auch für Textil- und Lederimprägnierung sowie zur Zellstoff-, Papier- und Pappeherstellung. PCP wurde zudem in Fugendichtungsmitteln, Spachtel- und Vergussmassen, Klebern, Lacken und Farben eingesetzt.

Die industrielle Holzimprägnierung wird als die einzige, noch aktuelle Verwendung, in der gesamten UNECE-Region aufgeführt. In Deutschland wurde PCP hauptsächlich für die Holzimprägnierung (ca. 61% in 1983) und zur Behandlung von Spezialtextilien eingesetzt (ca. 13% in 1983). Die Verwendung von PCP in Deutschland wurde jedoch bereits in 1989 eingestellt.

In Deutschland wurde in 1979 etwa 500 t PCP verbraucht. Im Gegensatz zur EU ging der PCP Verbrauch schon Anfang der 80er Jahre deutlich nach unten. In 1983 beispielsweise wurde nur noch die Hälfte der Gesamtmenge von 1979 verbraucht und zwei Jahre später nur noch etwa 80 t PCP. Der Hauptanteil der PCP Gesamtmenge wurde zur Imprägnierung von Holz verwendet.

Aufgrund der z.T. sehr hohen Lebensdauer von imprägnierten Holzprodukten, insbesondere im Baubereich, ist davon auszugehen dass PCP behandelte Hölzer weiterhin als Abfall anfallen und in den nächsten Jahren entsorgt werden müssen. PCP tritt beispielsweise im Rahmen des Vollzuges immer noch als Problemstoff im Zusammenhang mit dem Recycling von Bauabfällen auf.

Möglicherweise relevante Vorkommen wurden untersucht. Aufgrund der Projektergebnisse lässt sich schließen, dass PCP in Deutschland in Abfällen (möglicherweise auch in Recyclaten) eine relevante Bedeutung hat (siehe Tabelle 2).

Kurzkettige chlorierte Paraffine (SCCP)

Die hergestellten und verwendeten SCCP Mengen gingen in Deutschland, ähnlich wie in der gesamten EU in den letzten Jahren deutlich nach unten, insbesondere nach dem Inkrafttreten der EU-Richtlinie 2002/45/EG und der damit verbundenen Anwendungsbeschränkung für die zwei wichtigsten Anwendungsgebiete von SCCP in Deutschland (ca. 74% des deutschen Gesamtverbrauchs wurden in der Metallbearbeitung und zum Fetten von Leder eingesetzt).

Angaben zur derzeitigen Produktion von SCCP und verfügbaren Produktionskapazitäten in der EU sind nur beschränkt verfügbar. Es ist daher davon auszugehen, dass nur noch ein Hersteller SCCP in größeren Mengen herstellt (>1.000 t pro Jahr). Aufgrund geringer Nachfrage, besonders in den letzten Jahren, ist nicht klar ob weitere Hersteller noch SCCP auf den Europäischen Markt bringen. In Deutschland werden SCCP seit Mitte der 90er Jahre nicht mehr hergestellt. Importe von SCCP und anderen Chlorparaffinen können nicht grundsätzlich ausgeschlossen werden.

SCCP kommen in Deutschland, wie auch in der gesamten EU in unterschiedlichsten Verwendungen zum Einsatz. Aktuellen Literaturangaben zufolge werden SCCP z.B. als Weichmacher, Bindemittel, Flammschutzmittel und in Kunststoffen, Lacken und Farben, Gummierzeugnissen, Papier, Textilien, Fugen und Dichtungsmassen und Klebern angewandt. Der aktuelle SCCP Verbrauch in Deutschland kann grob auf etwa 85 t/a geschätzt werden.

Die derzeit wichtigsten Einsatzgebiete für SCCP sind als Flammschutzmittel für in Förderbändern in der mineralgewinnenden Industrie verwendeten Gummi (ca. 26 t) und die Verwendung als Weichmacher und Flammschutzmittel in Dichtungsmassen für die Bauindustrie (ca. 38 t). Die EU Kommission schlägt jedoch vor, den Anhang I der POP-Verordnung an den technischen Fortschritt anzupassen, d.h. die genannten Verwendungen aus dem Anhang der Verordnung zu entfernen. Ob und wann dies umgesetzt werden soll steht derzeit noch nicht fest. Grundsätzlich ist zu erwarten, dass die Verwendung von SCCP eingestellt werden wird und die jährlich anfallenden Abfallmengen zunehmend sinken werden. Für beide Verwendungen gibt es mittlerweile geeignete Alternativen auf dem Markt. Einige Firmen konnten SCCP bereits erfolgreich substituieren.

Möglicherweise relevante Vorkommen wurden untersucht. Aufgrund der Projektergebnisse lässt sich schließen, dass SCCP in Deutschland in Abfällen und möglicherweise auch in Recyclaten eine relevante Bedeutung haben (sieheTabelle 2).

Relevante Produkte, Abfälle, Recyclate

Übersicht über relevante Bereiche

Anhand der Stoff- und Massenflüsse und zusätzlicher Informationen zu Vorkommen in Produkten und Abfällen zeigt Tabelle 2, in welchen Bereichen die Stoffe/Stoffgruppen typischerweise vorkommen und möglicherweise relevante Risiken verursachen können.

Tabelle 2: Übersicht über POPs, relevante Bereiche und entsprechende Mengen der Stoffe/Stoffgruppen in Produkten, Abfällen und Emissionen (in Deutschland in 2012); hervorgehobene Bereiche werden in der Risikoabschätzung berücksichtigt.

Potentieller Quellsektor	Substanz	Einschätzung der Relevanz im Projektzusammenhang	Emission (t/a)	Produkt (t/a)	Abfall (t/a)
Aufgeschäumtes Polystyrol (EPS) für die Bauindustrie	HBCD	Bis 2015 hohe Relevanz in Produkten und künftig aufgrund der hohen Lebensdauer über viele Jahrzehnte in Abfällen (ca. 161 t HBCD/a in 2012; ca. 960 t HBCD/a um 2050)	n.r.	1.708	161
Extrudiertes Polystyrol (XPS) für die Bauindustrie	HBCD	Bis 2015 hohe Relevanz in Produkten und künftig aufgrund der hohen Lebensdauer über viele Jahrzehnte in Abfällen	n.r.	979	41
EPS/XPS außerhalb der Baubranche	HBCD	Aktuell in Produkten nicht mehr relevant; Auch in Abfällen aufgrund begrenzter Lebensdauer der Produkte nicht mehr relevant	n.r.	0	0,4
High Impact Polystyrol (HIPS) für Elektro- und Elektronikgeräte	HBCD	Aktuell nicht mehr relevant in Produkten; früher Verwendung im Elektrobereich; Importe könnten für Abfälle eine gewisse Rolle spielen.	n.r.	0	70
Polymerdispersionen für Textilien	HBCD	Seit 2007 nicht mehr relevant in Produkten	n.r.	0	290
Klärschlamm	HBCD	Nicht relevant	n.r.	n.r.	0,1
Verbrennungsrückstände Abfallverbrennung	HBCD	Nicht relevant	n.r.	n.r.	0,01
Produkte aus historischen Anwendungen	HCBD	Nicht relevant	n.r.	n.r.	n.r.
Unbeabsichtigte Entstehung - Produktion von chlororganischen Verbindungen	HCBD	Nicht relevant	n.r.	n.r.	n.r.
Unbeabsichtigte Entstehung – Verbrennungsprozesse Abfall	HCBD	Nicht relevant	n.r.	n.r.	n.r.
Unbeabsichtigte Entstehung - Kunststoffherstellung	HCBD	Nicht relevant	n.r.	n.r.	n.r.

Potentieller Quellsektor	Substanz	Einschätzung der Relevanz im Projektzusammenhang	Emission (t/a)	Produkt (t/a)	Abfall (t/a)
Klärschlamm	HCBD	Nicht relevant	n.r.	n.r.	n.r.
Frühere Verwendung in diversen Bereichen	PCN	Nicht relevant	n.r.	n.r.	n.r.
Elektrobereich	PCN	Nicht relevant	n.r.	n.r.	n.r.
Abfallverbrennung	PCN	Nicht relevant	n.r.	n.r.	n.r.
Sekundäre Kupferherstellung	PCN	Möglicherweise relevant			
Sekundäre Aluminiumherstellung	PCN	Nicht relevant	n.r.	n.r.	n.r.
Chlor-Alkali Elektrolyse	PCN	Nicht relevant	n.r.	n.r.	n.r.
Holzimprägnierung	PCP	Relevanz in Abfällen und evtl. auch in recycelten Erzeugnissen	n.r.	n.r.	140
Textilindustrie	PCP	Im Vergleich zu Holzimprägnierung von untergeordneter Relevanz	n.r.	n.r.	«
Metall- und Lederbearbeitungsmittel	SCCP	Nicht relevant	n.r.	n.r.	n.r.
Gummiindustrie	SCCP	Relevanz in Produkten, Abfällen und evtl. auch in recycelten Erzeugnissen	n.r.	26	176
Dicht- und Klebstoffe	SCCP	Relevanz in Produkten und Abfällen	n.r.	38	66
Farben und Lacke	SCCP	Nicht relevant	n.r.	n.r.	n.r.
Textilindustrie	SCCP	Langlebige Textilprodukte aus Militärbeständen könnten noch eine Rolle spielen	n.r.	n.r.	«
Lederindustrie	SCCP	Nicht relevant	n.r.	n.r.	n.r.
PVC und andere Kunststoffe	SCCP	Nicht relevant	n.r.	n.r.	n.r.
Spezialpapiere	SCCP	Nicht relevant	n.r.	n.r.	n.r.
Sekundärquelle (Klärschlamm)	SCCP	Nicht relevant	n.r.	n.r.	n.r.

Risikoabschätzung

Die als relevant identifizierten Bereiche wurden einer Risikoabschätzung unterzogen. Bei der Risikoabschätzung wurden insbesondere folgende Fragen berücksichtigt:

1. Sind die nach Anhang V, Teil 1 der EU POP-Verordnung erlaubten Beseitigungs- und Verwertungsverfahren (D9, D10, R1, R4) geeignet, die relevanten Stoffe/Stoffgruppen zu zerstören oder unumkehrbar umzuwandeln?

2. Führen die entsprechenden Prozesse möglicherweise zur Neubildung von POPs?
3. Verursachen Beseitigung oder Verwertung möglicherweise eine Umwelt- oder Gesundheitsgefährdung? Eine Emission von signifikanten POP Mengen in die Umwelt wird grundsätzlich als Risiko betrachtet.

Im Bericht werden mögliche Risiken identifiziert sowie mögliche Maßnahmen zur Risikominimierung diskutiert und als Entscheidungsgrundlage für die Empfehlungen für Grenzwerte und Entsorgungswege herangezogen.

Szenarien und Prognosen

Als wesentliche Entscheidungsgrundlage für die Ableitung von Grenzwerten und Entsorgungswegen, wurden Szenarien anhand typischer Konzentrationen der Stoffe/Stoffgruppen in relevanten Abfallfraktionen und Produktkategorien sowie den innerhalb der einzelnen Anwendungen angefallenen Abfallmengen zur Betroffenheit von Abfällen bei möglichen unteren POP Grenzwerten erstellt.

Zudem wurden Prognosen auf Grundlage aktuell und historisch eingesetzter Mengen der relevanten Stoffe/Stoffgruppen und typischer Konzentrationen in relevanten Produkten und Abfällen gemacht. Die Prognosen stellen insbesondere eine Abschätzung des zukünftigen jährlichen Anfalls der Stoffe/Stoffgruppen in den relevanten Anwendungsgebieten dar. Die Länge des Prognosezeitraums hängt von der vorhersehbaren Einsatzdauer der Stoffe und der Gebrauchsdauer der relevanten Produkte ab.

Die Szenarien und Prognosen sind im Bericht ausführlich dargestellt.

Evaluierung der unteren und oberen Begrenzungskriterien

Tabelle 3 zeigt die Ergebnisse aus der Evaluierung der unteren und oberen Begrenzungskriterien für die ausgewählten Stoffe und Stoffgruppen. Die Tabelle stellt insbesondere in Verbindung mit den Stoffflüssen und der Risikoabschätzung eine wesentliche Diskussionsgrundlage für die Empfehlung von UPGW und geeignete Entsorgungswege dar.

Tabelle 3: Ergebnisse aus der Evaluierung der unteren und oberen Begrenzungskriterien für die ausgewählten Stoffe und Stoffgruppen

	HBCD	HCBD	PCN	PCP	SCCP
Untere Begrenzungskriterien (mg/kg)					
(A) Analyseverfahren	1,0	0,1	0,1	0,1	1,0
(H) Hintergrundkontamination	0,1	0,1	1,0	1,0	1,0
(BV) Beseitigungs- und Verwertungskapazitäten	10	0,1	0,1	0,1	1,0
(W) Wirtschaftliche Auswirkungen	1.000/ 100 (1)	0,1	0,1	0,1	1.000/ 100 (2)
Obere Begrenzungskriterien (mg/kg)					
(GW) Grenzwerte	1.000	100	10	100	10.000
(UG) Mögliche Umwelt- und Gesundheitsauswirkungen	1.000	200	100	100	18.000

(1) Möglich falls die Schredderleichtfraktion aus der Altautoverwertung üblicherweise unter 100 mg HBCD pro kg liegt

(2) 100 mg/kg möglich falls der SCCP haltige Gummiabfall abgetrennt und separat behandelt werden kann

Empfehlungen für Grenzwerte und Entsorgungswege

Auf der Grundlage der Ergebnisse des Forschungsvorhabens lassen sich Empfehlungen für Grenzwerte und Entsorgungswege ableiten. Diese sollen einerseits eine möglichst weitgehende Ausschleusung von Schadstoffen gewährleisten und andererseits umweltgerechte Recyclingprozesse ermöglichen.

Die Empfehlungen betreffen den in Deutschland relevanten unteren POP-Grenzwert („UPGW“). Es handelt sich dabei um die Konzentrationsgrenze gemäß Artikel 7(4)a der EU POP-Verordnung.

Im Bericht sind die Empfehlungen ausführlich diskutiert. In Tabelle 4 sind Grenzwertvorschläge für UPGW sowie Empfehlungen für Verwertungs- und Beseitigungswege für die fünf ausgewählten Stoffe/Stoffgruppen zusammengefasst.

Tabelle 4: Empfehlungen für Grenzwerte und Entsorgungswege im Überblick

HBCD – Vorschlag möglicher UPGW: 100 – 1.000 mg/kg	
Bereich	**Empfehlung**
Werkstoffliche Verwertung HBCD-freie EPS/XPS Produkte	Grundsätzlich sollte bei werkstofflicher Verwertung die Vermischung HBCD-haltigen Materials mit HBCD-freiem Material (z.B. EPS Verpackungsmaterial) zur stofflichen Verwertung für nicht HBCD-haltige Produkte vermieden werden. Möglichst weitgehend getrennte Sammlung und Behandlung von EPS Dämmstoffen und EPS Verpackungsabfällen.
Energetische Verwertung EPS/XPS Dämmmaterialien	Verbrennung in nach dem Stand der Technik ausgerüsteten Müllverbrennungsanlagen (MVAn) unter fachmännischer Mischung im Bunker der MVAn. Vermeidung von Staubbildung beim Umgang mit den Dämmmaterialien. Unter Umständen kann es sinnvoll sein, persönliche Schutzmaßnahmen (Atemmasken) zu ergreifen, um die mögliche Inhalation von HBCD-haltigem Staub zu vermeiden.
Deponierung EPS/XPS	Minimierung der Deponierung durch eine möglichst weitgehende Abtrennung bei Abbruch und Sanierung. Minimierung der Deponierung durch die möglichst weitgehende Abtrennung von Störstoffen vom mineralischen Anteil von Bauschutt und geeignete Entsorgung (energetische Verwertung).
Export von Elektroaltgeräten (HBCD in HIPS und andere POPs)	Export von Elektroaltgeräten nur in Länder, in denen eine geeignete Verwertung und Beseitigung von Elektroaltgeräten sichergestellt ist.
Werkstoffliche Verwertung von HIPS aus dem Elektrobereich	Minimierung des Eintrags in Recyclate durch Umsetzung der möglichst weitgehenden Abtrennung von bromhaltigen Kunststoffen aus Elektroschrott nach Maßgabe der Richtlinie 2012/19/EU und deren geeignete Entsorgung (energetische Verwertung).
Energetische Verwertung HIPS aus dem Elektrobereich	Verbrennung nach dem Stand der Technik.
Deponierung HIPS aus dem Elektrobereich	Minimierung der Deponierung durch Umsetzung der möglichst weitgehenden Abtrennung von bromhaltigen Kunststoffen aus Elektroschrott nach Maßgabe der Richtlinie 2012/19/EU und deren geeignete Entsorgung (energetische Verwertung).
Flammgeschützte Textilien aus dem institutionellen Bereich	Empfehlung, flammgeschützte Textilien aus dem institutionellen Bereich, welche aus der Zeit vor 2007 stammen, energetisch zu verwerten.
Flammgeschützte Textilien aus dem Automobilbereich	Prüfen, ob vorübergehend eine energetische Verwertung der Schredderleichtfraktion aufgrund möglicherweise erheblicher HBCD Gehalte durchgeführt werden sollte.
HCBD – Vorschlag möglicher UPGW: 0,1 – 100 mg/kg	
Bereich	**Empfehlung**
keine relevanten Abfälle	Grundsätzlich: Verbrennung nach dem Stand der Technik.
PCN – Vorschlag möglicher UPGW: 1 – 10 mg/kg	

Bereich	Empfehlung
keine relevanten Abfälle	Grundsätzlich: Verbrennung nach dem Stand der Technik.

PCP – Vorschlag möglicher UPGW: 1 – 100 mg/kg

Bereich	Empfehlung
Stoffliche Verwertung imprägnierter Althölzer (Holzhackschnitzel und Holzspäne für die Herstellung von Holzwerkstoffen)	Die Verwertung von Altholz der Altholzkategorie AIV zu Holzhackschnitzeln und Holzspänen für die Herstellung von Holzwerkstoffen (z.B. Holzspanplatten) ist laut AltholzV nicht zugelassen. In der Praxis können aber u.U. auch Anteile imprägnierter Althölzer in andere Altholzkategorien gelangen und der stofflichen Verwertung zugeführt werden. Anhang II zu §3, Abs. 1 der AltholzV setzt einen Grenzwert von 3 mg PCP/kg Trockenmasse für Holzhackschnitzel und Holzspäne zur Herstellung von Holzwerkstoffen fest. Die Anlagenbetreiber sind verpflichtet, diesen Grenzwert einzuhalten.
Energetische Verwertung/ Verbrennung imprägnierter Althölzer (Altholzkategorie AIV)	Mit Holzschutzmittel behandeltes Altholz (Altholzkategorie IV) ist nach den Vorgaben der AltholzV energetisch zu verwerten/thermisch zu beseitigen. Um eine hohe Zerstörungsrate zu gewährleisten, sollte die Verbrennungstemperatur dabei mindestens 800°C betragen (Zerstörungsrate › 99,9%). Unter kontrollierten Verbrennungsbedingungen kann eine POP Neubildung weitestgehend ausgeschlossen werden. Vermeidung von Staubbildung bei der mechanischen Zerkleinerung von belastetem Altholz. Unter Umständen kann es sinnvoll sein, persönliche Schutzmaßnahmen (Atemmasken) zu ergreifen, um die mögliche Inhalation von PCP-haltigem Staub zu vermeiden.
Verwertung imprägnierter Althölzer (ohne energetische Verwertung) (Altholzkategorie AIV)	Die in Deutschland zugelassenen Verwertungsverfahren für Altholz der Altholzkategorie IV sind die Gewinnung von Synthesegas zur weiteren chemischen Nutzung und Herstellung von Aktivkohle/ Industrieholzkohle. Da diese Verfahren ähnlich hohe Prozesstemperaturen aufweisen wie die energetische Verwertung/Verbrennung ist anzunehmen, dass der PCP Gehalt im Altholz weitestgehend zerstört wird. Die genauen Zerstörungsraten dieser Verfahren sind jedoch nicht bekannt. Vermeidung von Staubbildung bei der mechanischen Zerkleinerung von belastetem Altholz. Unter Umständen kann es sinnvoll sein, persönliche Schutzmaßnahmen (Atemmasken) zu ergreifen, um die mögliche Inhalation von PCP-haltigem Staub zu vermeiden.
Deponierung imprägnierter Althölzer	Die Deponierung von Altholz ist in Deutschland nicht zugelassen. In der AltholzV ist die Beseitigung von Altholz auf die thermische Beseitigung beschränkt.

SCCP – Möglicher UPGW: 100 – 10.000 mg/kg

Bereich	Empfehlung
Stoffliche Verwertung (Gummi aus Gummiförderbändern für den Einsatz im Untertagebergbau)	Minimierung des Eintrags in Recyclate durch weitgehende Abtrennung von SCCP-haltigen Gummiförderbändern aus dem Untertagebergbau und deren geeignete Entsorgung (energ. Verwertung/Verbrennung). Vor der stofflichen Verwertung muss der Metallanteil des Förderbandes, soweit wie möglich, vom Gummi abgetrennt werden. Dies kann zur Staubbildung führen und stellt ein mögliches Umwelt- und Gesundheitsrisiko dar. Um das Risiko zu minimieren, sollte Staubbildung soweit wie möglich vermieden werden. Inhalation von belastetem Staub kann durch die Verwendung von Atemmasken vermieden werden.
Energetische Verwertung/ Verbrennung (Gummi aus Gummiförderbändern für den Einsatz im Untertagebergbau)	Aufgrund hoher Verbrennungstemperaturen bei der energetischen Verwertung/Verbrennung (›800°C) ist anzunehmen, dass der Gehalt an SCCP in gebrauchten Gummiförderbändern weitestgehend zerstört wird. Die Zerstörungsraten für SCCP sind jedoch nicht bekannt. Ein Umwelt- und Gesundheitsrisiko ist zu erwarten, falls SCCP-haltiger Abfall vor der energetischen Verwertung/Verbrennung mechanisch zerkleinert werden muss (Staubbildung). Um Umwelt- und insbesondere Gesundheitsrisiken zu minimie-

	ren, sollte Staubbildung soweit wie möglich vermieden werden. Inhalation von belastetem Staub kann durch die Verwendung von Atemmasken vermieden werden.
Deponierung (Gummi aus Gummiförderbändern für den Einsatz im Untertagebergbau)	Nicht relevant
Stoffliche Verwertung (Dichtungsmassen aus Bau- und Abbruchabfällen)	Minimierung des Eintrags in Recyclate durch weitgehende Abtrennung von SCCP-haltigen Dichtungsmassen aus Bau- und Abbruchabfällen und deren geeignete Entsorgung (energ. Verwertung/Verbrennung, Sonderabfallverbrennung). Eine vollständige Abtrennung ist, aufgrund ihrer Beschaffenheit, in der Praxis nicht möglich. Bei der Entfernung von Dichtungsmassen aus Gebäuden sollten keine schnell laufenden Maschinen verwendet werden, um Hitzeentwicklung zu vermeiden. Um das Risiko zu minimieren, sollte Staubbildung soweit wie möglich vermieden werden. Inhalation von belastetem Staub kann durch die Verwendung von Atemmasken vermieden werden.
Energetische Verwertung/ Verbrennung (Dichtungsmassen aus Bau- und Abbruchabfällen)	Aufgrund hoher Verbrennungstemperaturen bei der energetischen Verwertung/Verbrennung (>800°C) ist anzunehmen, dass der Gehalt an SCCP in Dichtungsmassen weitestgehend zerstört wird. Die Zerstörungsraten für SCCP sind jedoch nicht bekannt. Ein Umwelt- und Gesundheitsrisiko ist zu erwarten, falls SCCP-haltiger Abfall vor der energetischen Verwertung/Verbrennung mechanisch zerkleinert werden muss (Staubbildung). Um Umwelt- und insbesondere Gesundheitsrisiken zu minimieren, sollte Staubbildung soweit wie möglich vermieden werden. Inhalation von belastetem Staub kann durch die Verwendung von Atemmasken vermieden werden.
Sonderabfallverbrennung (Dichtungsmassen aus Bau- und Abbruchabfällen)	In der Praxis ist nicht zu erwarten, dass SCCP-haltige Dichtungsmassen vollständig abgetrennt und separat behandelt werden können (durch die Anhaftung an der Oberfläche der Baumaterialien). Der erfolgreich separierte Abfallstrom sollte in Sonderabfallverbrennungsanlagen entsorgt werden. Aufgrund hoher Verbrennungstemperaturen (>1.000°C) ist anzunehmen, dass der SCCP Gehalt im Abfall weitestgehend zerstört wird. Die genauen SCCP Zerstörungsraten sind jedoch nicht bekannt.
Deponierung (Dichtungsmassen aus Bau- und Abbruchabfällen)	Bei der Deponierung besteht grundsätzlich das Risiko, dass SCCP langfristig aus der Deponie in die Umwelt gelangen. Unter der Annahme, dass der SCCP-haltige Abfallstrom zusammen mit Beton, Fliesen, Ziegel und Keramik Abfällen behandelt wird, wäre die Menge des Mischabfallstroms sehr hoch, die theoretische SCCP Konzentrationen aber vernachlässigbar gering. Aufgrund der geringen SCCP Konzentration sind keine konkreten Umwelt- oder Gesundheitsrisiken zu erwarten. Durch die möglichst weitgehende Abtrennung kann der Effekt der Verschleppung und globalen Verteilung minimiert werden.

Summary

This report has been translated into English from its original version in German which is available under the title “Ermittlung von potentiell POP-haltigen Abfällen und Recyclingstoffen - Ableitung von Grenzwerten”.

Background and objectives

Persistent organic pollutants (POPs) are chemical substances which are persistent in the environment and strongly bioaccumulate in the food chain, especially in fatty tissue, thus reaching concentrations which have adverse effects on human health and the environment. Moreover, POPs have the potential for long-range transport and can be globally distributed via air and ocean currents.

The Stockholm Convention on POPs and the Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) are dynamic instruments, whose substance lists are amended continuously. At present, five substances or substance groups are proposed to be added – the so-called “candidate POPs” – or were added (HBCD) to the Stockholm Convention in May 2013:

- Hexabromocyclododecane (HBCD),
- Hexachlorobutadiene (HCBD),
- Polychlorinated naphthalenes (PCN),
- Pentachlorophenol (PCP) and
- Short chain chlorinated paraffins (SCCP).

The declared political objective of European and national waste policy is on the one hand to promote a circular economy in order to save natural resources. On the other hand waste policy also aims to guarantee the protection of human health and the environment. The provisions concerning the permissibility of waste treatment operations according to the waste hierarchy demonstrate the generally intended balance between the two goals: In those cases where recycling leads to a cycle of pollutants, which is undesirable from an environmental and health perspective, the hierarchical priority of recycling is no longer valid. In these cases waste or the contained pollutants can and should be removed from the economic cycle in the sense of the protection of environment and health.

The balance between the two fundamental goals of waste policy has to be found especially concerning the POPs content inwaste and mixtures and products as an output of recycling processes (recyclates), in particular through the determination of pollutant-specific limit values.

Those limit values have to reflect both, the principal of proportionality as well as the environmental precautionary principle. For an appropriate determination of limit values, a solid basis of facts and data is required for each pollutant. The Annexes to the EU POP Regulation are the relevant legal instruments in this context.

Against this background the objective of the present study is to

- collect data on the occurrence of the five POP substances/substance groups in relevant waste and recyclates;
- carry out an assessment of the quantities of POP-containing recyclates remaining in the economic cycle; and
- based on these data, derive proposals for limit values in accordance with Annex IV of the POP Regulation as well as for specific waste treatment operations , which ensure pollutant removal to the largest extent possible on the one hand and environmentally sound recycling processes on the other hand.

Approach/Methodology

Approach

After research on the possible occurrence of the substances in products and waste, targeted laboratory analyses aiming to improve the existing data basis were carried out. Subsequently, occurrence and fate of the relevant substances and substance groups in Germany were estimated on the basis of the improved information and risks arising from the products, waste and recyclates were outlined. Proposals for limit values in accordance with Annex IV of the POP Regulation were derived for the different substances/substance groups and recommendations on adequate disposal options and treatment technologies were made.

Extensive research was performed in order to establish a data basis on the occurrence of the relevant substances in products and waste. Substance and mass flows were developed on the basis of the available information. For this purpose, the following information was analysed for each substance/substance group as far as available:

- Chemical characteristics
- Legal background
- Production and trends
- Use and trends
- Selection of relevant application fields (in which the substance/substance group is used/generated in considerable amounts)
- Detailed information on selected application fields

The research was focused on applications/products/waste where the relevant substances/substance groups are expected to occur according to information from literature and/or from which a significant input into the environment is expected.

Based on the outcome of the research, specific products/waste/recyclates were chosen for the five substances/substance groups in close coordination with the UBA[1] and a corresponding sampling and analysis plan was elaborated. The analytical measurements and laboratory analyses were targeted to specific products, waste and recyclates in order to fill specific knowledge gaps. In total 45 analytical measurements were carried out in order to analyse and quantify the presence of the relevant substances/substance groups in products, waste and recyclates.

In the project report the applied and available analytical methods and parameters are described in detail. The outcomes of the laboratory analyses are discussed against the project background.

The results of the analysis as well as further research served to extend and specify the data gathered during the preliminary research. Based on more specific substance and mass flows and additional information on the occurrence of the POP substances in products and waste as well as on their treatment, an overview was generated which shows in which sectors the substances/substance flows typically occur and which risks arise from the corresponding waste and recyclates. The product life cycle times of the relevant products and currently applied waste treatment operations were taken into account.

Derivation of proposals for limit values in accordance with Article 7(4)a of the POP Regulation, disposal and recovery operations

Type and quantity of POP-containing material streams, which are currently circulating in the economic cycle and will be remaining in the future, were estimated. For the different substances/substance groups proposals for limit values in accordance with Annex IV of the POP Regula-

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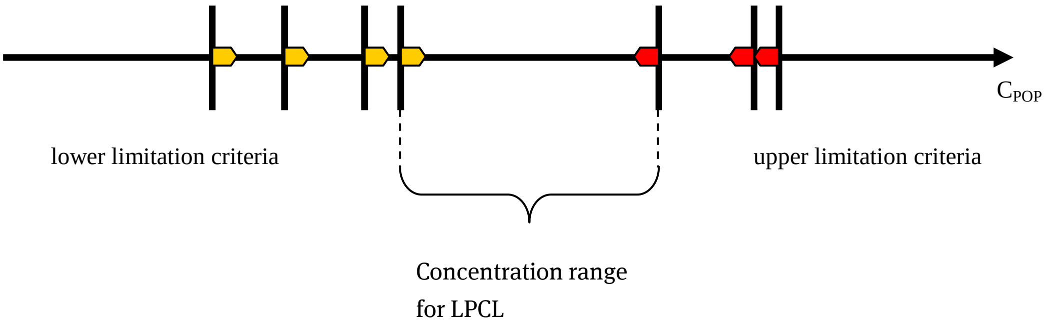
[1] The UBA (Umweltbundesamt) is the German Federal Environment Agency.

tion were derived which ensure pollutant removal to the largest extent possible on the one hand and environmentally sound recycling processes on the other hand.

Waste with a POP content exceeding the low POP concentration limit (LPCL) is subject to the regulations of the Stockholm Convention on destruction or irreversible transformation as stipulated in Article 6. 1. (d) (ii). Waste ranging below the LCPL is subject to other relevant legal regulations on the disposal or treatment of waste. Environment, health and other aspects are to be considered there.

The methodological approach to derive limit values restricts the range of possible concentration limits for each of the relevant substances on the basis of a set of lower and upper limitation criteria. Certain of these criteria indicate concentrations below which limit values should not be set (e.g. the detection limits of analytical methods), others indicate concentrations above which limit values should not be set (e.g. potential effects on human health and the environment). Figure 1 graphically illustrates the delimitation of a concentration range for a possible LPCL through lower and upper limitation criteria:

Figure 3: Delimitation of the concentration range for a limit value through lower and upper limitation criteria



For each substance a limit value within the determined concentration range is possible. This approach intends to ensure on the one hand that the limit value can be implemented realistically in the light of the available data, and on the other hand, that human health and the environment are protected from persistent organic pollutants to the largest extent possible.

In order to narrow the range of possible limit values for every substance, four lower and two upper limitation criteria are applied. Options for the LPCL can be derived from the aggregation of the results for the individual criteria.

Lower limitation criteria:

- (A) Analytical potential: It must be possible to control limit values analytically (H) Background contamination: Limit values should be above existing environmental background contaminations
- (BV) Disposal and recovery capacities: Limit values should be established in a way that the (new) required capacities for recovery and disposal are realistically available
- (W) Economic feasibility: Limit values should be established in a way that required additional disposal costs are economically reasonable.

Upper limitation criteria:

- (GW) Limit values: Limit values should not contradict existing limit values
- (UG) Possible adverse effects on human health and the environment: Limit values should be established in a way that adverse effects on human health and the environment are avoided

In the report a detailed evaluation of the lower and upper limitation criteria is included, which enables to specifically narrow the range of options for the low POP concentration limit for the relevant substances/substance groups.

Material flows and substance flows

Hexabromocyclododecane (HBCD)

At present, HBCD is only produced at one site in the EU, located in the Netherlands, with an annual production of about 6,000 t. Besides, HBCD is imported to and also exported from the EU and Germany as a chemical itself, in formulations and in flame retarded articles. HBCD is not produced in Germany.

Globally HBCD has been used since the 1960ies. It has been used in considerable amounts in four principal product types.

The only remaining use in Germany, in which HBCD is used in very significant quantities is application in EPS and XPS in the construction sector. It is estimated that the used quantities amounted to about 2,700 t in 2012. Since 2013 HBCD is substituted in this use as well and is expected to be completely replaced by August 2015. Currently HBCD is no longer used in HIPS (High Impact Polystyrene) in electrical and electronic appliances. In the textile industry, its use was stopped in 2007.

On the basis of historic, current and expected amounts of use and emissions it can be estimated which quantities of HBCD did already become waste or will become waste in the future. Calculations and estimations for Germany demonstrate that the bulk of HBCD-containing waste will have to be disposed of in the future. Most relevant is the use in the construction sector mainly due to the long lifetime of the corresponding products and the considerable quantities used in this sector. For other EPS and XPS relevant applications, dominated by the packaging sector, HBCD is no longer used in Germany. Due to the short product lifetimes in this sector, HBCD could possibly be imported to Germany and enter the corresponding waste flows. The situation for the use of HBCD in HIPS for electrical and electronic devices is similar. There is no specific information indicating that HBCD is still used in this sector.

It seems that HBCD has no longer been used in the textile industry in Germany since 2007. Already in the preceding years, the consumption quantities of HBCD had fallen substantially. It can therefore be expected that corresponding products will be of very limited relevance in the medium term.

Assessments concerning the quantity of HBCD in waste demonstrate that the major share of HBCD is still incorporated in products in use and will enter the waste stream in the future (see Table 1). This applies especially for EPS and XPS foams used in building and construction: on the one hand due to their long lifetime (50+/-25 years) and on the other hand due to the considerable quantities of HBCD used in this sector (in total more than 60,000 t until 2015).

Based on the average concentration of HBCD in relevant products, the corresponding waste amounts can be derived:

Table 5: Cumulated HBCD-containing waste amounts derived from estimated consumption quantities (in tons) for the relevant applications

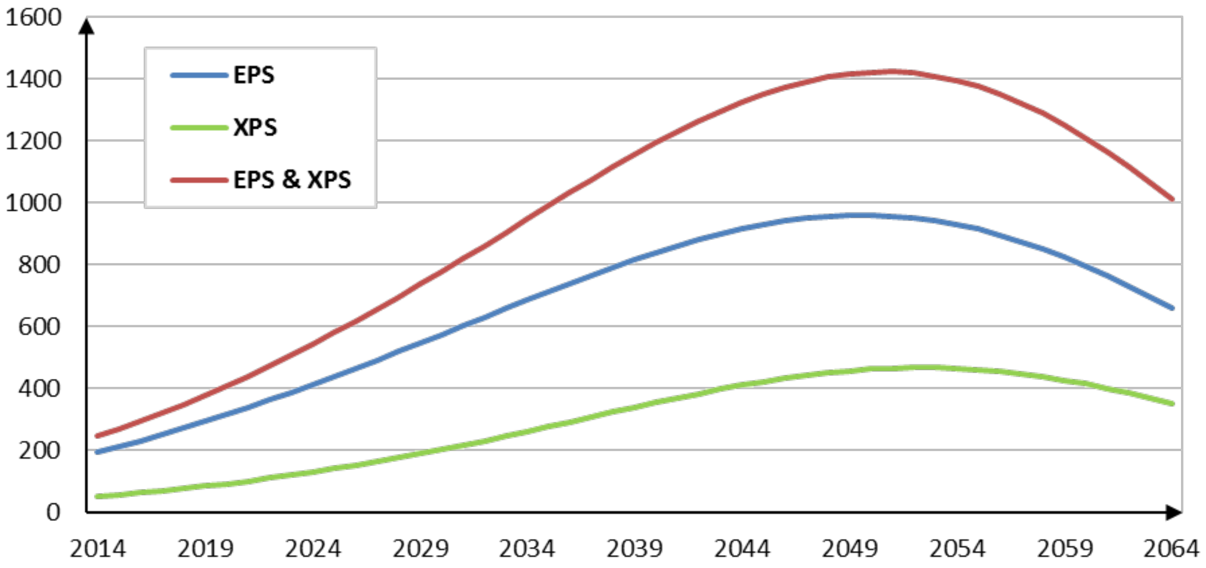
Waste	Amount of HBCD in waste (in t)	HBCD concentration (in %)	Waste amount (in t)	Arisings after 2012 (in t)	Arisings until 2012 (in t)
EPS products construction	42,829	0.70	6,118,429	5,921,665	196,764
XPS products construction	19,102	1.5	1,273,470	1,252,026	21,444

EPS/XPS other	3,719	0.70*	531,286	0	531,286
HIPS products	1,306	4.00*	32,650	16,200	16,450
Textiles	4,114	8.00*	51,425	11,563	39,863
Total	71,070		8,007,259	7,201,453	805,806

* no longer in use at present

The bulk of HBCD-containing waste will have to be disposed of from the construction sector (see Figure 2). Depending on the lifetime of HBCD treated products and the time when the products were placed on the market, it can be estimated how the annual arisings of HBCD will change over time and to which amounts HBCD will arise in corresponding waste in the future. The following figure illustrates the estimated annual quantities of HBCD in EPS and XPS waste from the construction sector.

Figure 4: Estimated annual quantities (in t) of HBCD in EPS und XPS waste in construction from 2014 until 2064



Even if HBCD is no longer in use, the occurrence of corresponding products in the waste flows can still be relevant in the far future, depending on their specific lifetimes. The EPS/XPS applications apart from construction, HIPS in electronic devices and polymer dispersion in textiles, are irrelevant or of comparatively minor importance, in comparison to the EPS/XPS applications in the construction sector.

It can be concluded that HBCD is of particular relevance in EPS and XPS materials from the construction sector (see Table 2).

Hexachlorobutadiene (HCBD)

Anthropogenic emission sources of HCBD are intentional production, unintentional production and waste from historical application. There are no natural sources of HCBD. Since the end of the 1970s, HCBD is neither produced nor used in Europe.

In the past, HCBD was used for various purposes. HCBD can also be formed as an unintentional by-product during the synthesis of organo-chlorine compounds, incineration processes and the production of magnesium.

In Germany HCBD has never been produced intentionally. However, at the end of the 1970s, about 4,500 t/a HCBD were formed as a by-product during low-pressure chlorolysis for the production of tetrachloroethene (PER) and tetrachloromethane (TETRA).

Disregarding historical use and emission of HCBD, the unintentional production of HCBD represents the main emission source nowadays.

Possibly relevant occurrence of HCBD was investigated. The project results indicate that HCBD is not relevant in products, waste and recyclates in Germany (see Table 2).

Polychlorinated naphthalenes (PCN)

Until the 1970s, PCN were produced as high volume chemicals. They have no longer been produced in Germany since 1989. PCN have historically been used for various purposes but they can also be formed unintentionally during different thermal processes. Incineration processes, especially waste incineration, are regarded as the most important current sources. It is assumed that PCN are formed under similar conditions as dioxins and furans.

Possibly relevant occurrence of PCN was investigated. The project results indicate that PCN are not relevant in products, waste and recyclates in Germany (see Table 2).

Pentachlorophenol (PCP)

Regarding the current global production of PCP, no detailed information can be given. In 1981, the worldwide production of PCP amounted to about 90,000 t. According to recent sources, in the whole UNECE region PCP is only produced in the USA. In 2011 the worldwide production of PCP was indicated as about 10,000 t. In Germany the production ceased in 1985/86.

PCP was used in its phenolic form (PCP), as salt (NaPCP) and as ester (PCPL). Due to its outstanding bactericidal and fungicidal properties, PCP and its derivatives are suitable for a range of different applications. It was mainly used for the preservation of wood and buildings and for timber treatment, but also for textile and leather impregnation as well as in pulp, paper and board industry. Moreover, PCP was applied in sealants, fillers and casting compounds, glues, lacquers and paints.

Industrial wood impregnation is considered as the only remaining application in the whole UNECE region. In Germany PCP was mainly used for wood impregnation (about 61% in 1983) and for the treatment of special textiles (about 13% in 1983). Nevertheless the application of PCP in Germany was stopped already in 1989.

In 1979 about 500 t PCP was used in Germany. In contrast to the EU, the PCP consumption declined significantly already at the beginning of the 1980s. In 1983 for instance, only half of the total consumption of 1979 was used, and two years later only about 80 t PCP. The major part of the total amount of PCP was used for wood impregnation.

Due to partly very long lifetimes of impregnated wood products, especially in the construction sector, it can be assumed that PCP treated wood will continue to become waste and will have to be disposed of over the next years. PCP still occurs as a hazardous substance, for instance in the context of construction waste recycling processes.

Potentially relevant occurrence of PCP was investigated. The project results indicate that PCP is relevant in waste (and possibly also in recyclates) in Germany (see Table 2).

Short chain chlorinated paraffins (SCCP)

SCCP production and use quantities have decreased significantly in Germany, similar as in the whole EU during the last couple of years. The decrease was particularly related to the EU Directive 2002/45/EC which restricted the two most important application fields of SCCP in Germany (about 74% of the German total consumption were used in metal working and leather fat liquoring).

There is only limited information about the current production of SCCP and available production capacities in the EU. It can be assumed that only one enterprise continues producing bigger amounts of SCCP (> 1,000 t per year). Owing to slack demand, especially over the last years, it is uncertain whether further producers will place SCCP on the European market. SCCP have no longer been produced in Germany since the middle of the 1990s. Imports of SCCP and other chlorinated paraffins cannot generally be excluded.

In Germany as in the whole EU, SCCP are in use for various purposes. According to literature SCCP uses include applications as softeners, binding agents, flame retardants and in polymeric materials, lacquers and paints, rubber products, paper, textiles, sealants and adhesives. The current use of SCCP in Germany is roughly estimated to amount to about 85 t/y.

At present the most important application fields for SCCP are the use as flame retardants in rubber conveyor belts for the mining industry (about 26 t) and the use as softener and flame retardant in sealants for the construction sector (about 38 t). However, the European Commission proposes to adjust Annex I to the POP Regulation to technological progress and to delete the above mentioned applications from the Annex to the Regulation. Whether and when this will be realised is not certain yet. Generally the use of SCCP is likely to cease and the annual waste amounts to be disposed of will continue to decrease. Appropriate alternatives for both applications are on the market. Some companies have already managed to substitute SCCP successfully.

Potentially relevant occurrence of SCCP was investigated. The project results indicate that SCCP are relevant in waste (and possibly also in recyclates) in Germany (see Table 2).

Relevant products, waste, recyclates

Overview of relevant sectors

Based on substance and mass flows as well as additional information concerning the occurrence in products and waste, Table 2 demonstrates in which sectors the substances/substance groups typically occur and may cause relevant risks.

Table 6: Overview of POPs, relevant sectors and corresponding amounts of substances/substance groups in products, waste and emissions (in Germany in 2012); highlighted sectors are considered in the risk assessment.

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
Expanded Polystyrene (EPS) for construction	HBCD	Until 2015 high relevance in products and in the future for many decades in waste due to long lifetimes (ca. 161 t HBCD/y in 2012; ca. 960 t HBCD/y around 2050)	n.r.	1,708	161
Extruded Polystyrene (XPS) for construction	HBCD	Until 2015 high relevance in products and in the future for many decades in waste due to long lifetimes	n.r.	979	41
EPS/XPS other than construction	HBCD	At present no longer relevant in products; also in waste no longer relevant due to limited lifetime of products	n.r.	0	0.4
High Impact Polystyrene (HIPS) for electrical and	HBCD	At present no longer relevant in products; former use in elec-	n.r.	0	70

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
electronic devices		tronic devices. Imports might play a certain role for waste.			
Polymer dispersions for textiles	HBCD	Since 2007 no longer relevant in products	n.r.	0	290
Sewage sludge	HBCD	Not relevant	n.r.	n.r.	0.1
Incineration residues waste incineration	HBCD	Not relevant	n.r.	n.r.	0.01
Products from historical applications	HCBD	Not relevant	n.r.	n.r.	n.r.
Unintentional production – Production of chlorinated solvents	HCBD	Not relevant	n.r.	n.r.	n.r.
Unintentional production – Incineration processes waste	HCBD	Not relevant	n.r.	n.r.	n.r.
Unintentional production – Production of plastics	HCBD	Not relevant	n.r.	n.r.	n.r.
Sewage sludge	HCBD	Not relevant	n.r.	n.r.	n.r.
Former use in various sectors	PCN	Not relevant	n.r.	n.r.	n.r.
Electronics industry	PCN	Not relevant	n.r.	n.r.	n.r.
Waste incineration	PCN	Not relevant	n.r.	n.r.	n.r.
Secondary copper production	PCN	Possibly relevant			
Secondary aluminium production	PCN	Not relevant	n.r.	n.r.	n.r.
Chlor-alkali electrolysis	PCN	Not relevant	n.r.	n.r.	n.r.
Wood impregnation	PCP	Relevant in waste and possibly also in recyclates	n.r.	n.r.	140
Textile industry	PCP	In comparison to wood impregnation of minor relevance	n.r.	n.r.	‹‹
Substances from metal and leather treatment	SCCP	Not relevant	n.r.	n.r.	n.r.
Rubber industry	SCCP	Relevant in products, waste and possibly also in recyclates	n.r.	26	176
Sealants and adhesives	SCCP	Relevant in products and waste	n.r.	38	66
Paints and lacquers	SCCP	Not relevant	n.r.	n.r.	n.r.
Textile industry	SCCP	Durable textile products for military purposes might still play a role	n.r.	n.r.	‹‹
Leather industry	SCCP	Not relevant	n.r.	n.r.	n.r.
PVC and other polymeric materials	SCCP	Not relevant	n.r.	n.r.	n.r.
Special papers	SCCP	Not relevant	n.r.	n.r.	n.r.

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
Secondary source (sewage sludge)	SCCP	Not relevant	n.r.	n.r.	n.r.

Risk assessment

The sectors which were identified as relevant were subject to a risk assessment. In the risk assessment especially the following questions were considered:

- Are disposal and recovery operations (D9, D10, R1, R4), permitted according to Annex V, part 1 of the EU POP Regulation, appropriate to destroy or irreversibly transform the relevant substances/substance groups?
- Can the corresponding processes lead to an unintended generation of new POPs?
- Can disposal or recovery cause a risk to human health or the environment? The emission of significant amounts of POPs into the environment is generally considered a risk.

In the report potential risks are identified and possible risk mitigation measures are discussed and are used as a decision basis for the proposal of limit values and disposal operations.

Scenarios and prognoses

As an essential decision basis for the derivation of limit values and waste treatment operations, scenarios of concerned waste amounts for potential low POP concentration limits were established. These reflect typical concentrations of substances/ substance groups in relevant waste fractions and product categories as well as in waste amounts arising from the different applications.

Moreover, prognoses were elaborated on the basis of current and historic use quantities of the relevant substances/substance groups and their typical concentrations in relevant products and waste. In particular, these prognoses represent an estimation of the future annual occurrences of the substances/ substance groups in relevant application fields. The length of the prognosis period depends on the foreseeable duration of use of the substances and of the lifetime of the relevant products.

The scenarios and prognoses are elaborated in detail in the report.

Evaluation of the lower and upper limitation criteria

Table 3 shows the results of the evaluation of the lower and upper limitation criteria for the selected substances and substance groups. Taking the substance flows and risk assessment into consideration, this table represents an important discussion basis for proposing LPCLs and appropriate treatment options.

Table 7: Results from the evaluation of lower and upper limitation criteria

	HBCD	HCBD	PCN	PCP	SCCP
Lower limitation criteria (mg/kg)					
(A) Analytical potential	1.0	0.1	0.1	0.1	1.0
(H) Background contamination	0.1	0.1	1.0	1.0	1.0
(BV) Disposal and recovery capacities	10	0.1	0.1	0.1	1.0
(W) Economic feasibility	1,000/ 100 (1)	0.1	0.1	0.1	1,000/ 100 (2)
Upper limitation criteria (mg/kg)					
(GW) Limit values	1,000	100	10	100	10,000

(UG) Possible adverse effects	1,000	200	100	100	18,000

(1) Possible if shredder light fraction from recycling of end-of-life vehicles is usually below 100 mg HBCD per kg

(2) Possible if SCCP-containing rubber waste can be separated and treated separately

Proposals for limit values and waste treatment operations

On the basis of the results of this research project, proposals for limit values and waste treatment operations can be derived. They are intended on the one hand to ensure pollutant removal to a maximum extent possible and on the other hand to enable environmentally sound recycling processes.

The proposals for limit values concern the low POP concentration limit (LPCL) which is relevant in Germany. Specifically it refers to the concentration limit in accordance with Article 7(4)a of the EU POP Regulation.

The recommendations are discussed in detail in the report. A conclusion of proposed low POP concentration limits as well as recommended disposal and recovery operations for the five selected substances/ substance groups are illustrated in Table 4.

Table 8: Overview of proposals for limit values and recommendations for waste treatment operations

HBCD – Proposal for potential LPCL: 100 – 1,000 mg/kg	
Sector	**Recommendation**
Material recovery HBCD free EPS/XPS products	Generally the mixture of HBCD-containing and HBCD-free material (e.g. EPS packaging) should be avoided in material recovery of HBCD free products. Separate collection and treatment of EPS insulation material and EPS packaging waste as far as reasonably possible.
Energy recovery EPS/XPS insulation materials	Incineration in incineration plants equipped with the best available technologies and in professional mixture in the bunker of the plant. Avoidance of dust generation during handling of insulation materials. It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of HBCD-containing dust.
Landfill EPS/XPS	Minimisation of landfilling through separation in demolition and reconstruction as far as reasonably possible. Minimisation of land filling through separation of impurities from the mineral fraction of construction waste as far as possible and appropriate treatment (energy recovery).
Export of old electronic devices (HBCD in HIPS and other POPs)	Export of old electronic devices only to countries, where adequate recovery and disposal of old electronic devices is ensured.
Material recovery HIPS from electronics industry	Minimisation of the release into recyclates through separation of brominated plastics from WEEE as far as possible in accordance with Directive 2012/19/EU and appropriate treatment (energy recovery).
Energy recovery HIPS from electronics industry	State-of-the-art incineration
Landfill HIPS from electronics industry	Minimisation of landfilling through separation of plastics containing bromine from WEEE as far as possible in accordance with Regulation 2012/19/EU and appropriate treatment (energy recovery).
Flame retarded textiles from the institutional sector	Recommendation for energy recovery for flame retarded textiles from the institutional sector produced before 2007.
Flame retarded textiles from automobile sector	Examination whether temporarily energy recovery of the shredder light fraction should be carried out due to possibly significant HBCD concentration.
HCBD – Proposal for potential LPCL: 0.1 – 100 mg/kg	
Sector	**Recommendation**

No relevant waste	As a basic principle: state-of-the-art incineration.
PCN – Proposal for potential LPCL: 1 – 10 mg/kg	
Sector	**Recommendation**
No relevant waste	As a basic principle: state-of-the-art incineration.
PCP – Proposal for potential LPCL: 1 – 100 mg/kg	
Sector	**Recommendation**
Material recovery of impregnated waste wood (wood chips for the production of wood based materials)	According to the German Altholzverordnung/AltholzV, the recovery of waste wood classified as waste wood of category AIV for the production of wood based materials (e.g. chipboard) is not permitted. However in practice parts of impregnated wood can be disseminated into other waste wood categories and be submitted to material recovery. Annex II to §3, Abs. 1 of AltholzV determines a limit value of 3 mg PCP/kg dry matter for wood chips for the production of wood based materials. Plant operators are obliged to comply with this limit value.
Energy recovery/incineration of impregnated waste wood (waste wood category AIV)	Waste wood treated with wood preservatives (waste wood category IV) is to be recovered/ disposed of thermally in accordance with the AltholzV. In order to guarantee high destruction rates, the incineration temperature should reach at least 800°C (destruction rate › 99.9%). Under controlled incineration conditions the formation of new POPs is can be excluded to the largest extent possible. Avoidance of dust generation in mechanical breakdown of contaminated waste wood. Personal precautionary measures (breathing masks) It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of PCP-containing dust.
Recovery of impregnated waste wood (without energy recovery) (waste wood category AIV)	Recovery operations permitted in Germany for waste wood of waste wood category IV are the production of synthesis gas for further chemical purposes as well as the production of activated carbon/industrial charcoal. As in the corresponding processes similar process temperatures as in energy recovery/incineration are used, it can be considered that the PCP content in waste wood is almost completely destroyed. However specific destruction rates in these processes are not known. Avoidance of dust generation in mechanical breakdown of contaminated waste wood. It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of PCP-containing dust.
Landfill of impregnated waste wood	Landfilling of waste wood is not permitted in Germany. The AltholzV restricts waste wood disposal to thermal disposal.
SCCP – Proposal for potential LPCL: 100 – 10,000 mg/kg	
Sector	**Recommendation**
Material recovery (rubber from rubber conveyor belts for the use in underground mining)	Minimisation of the release into recyclates through separation of SCCP-containing rubber conveyor belts from underground mining as far as possible and appropriate treatment (energy recovery/incineration). Prior to the material recovery the metal fraction of the conveyor belt has to be separated from the rubber fraction as far as possible. This can result in dust generation and presents a potential environmental and health risk. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Energy recovery/incineration (rubber from rubber conveyor belts for the use in underground mining)	Due to high incineration temperatures in energy recovery/incineration (›800°C) it can be assumed that the SCCP content in used rubber conveyor belts is almost completely destroyed. However, exact destruction rates for SCCP have not been identified. Environmental and health risks are expected if SCCP-containing waste has to be comminuted mechanically prior to energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Landfill (rubber from rubber con-	Not relevant

veyor belts for the use in underground mining)	
Material recovery (sealants from construction and demolition waste)	Minimisation of the release into recyclates through separation of SCCP-containing sealants from construction and demolition waste and appropriate treatment (energy recovery/incineration, hazardous waste incineration). Complete separation is not feasible in practice. When removing sealants from buildings, fast running machines should not be used in order to avoid heat generation. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Energy recovery/incineration (sealants from construction and demolition waste)	Due to high incineration temperatures in energy recovery/incineration (>800°C) it can be considered that the SCCP content in sealants is almost completely destroyed. However, specific destruction rates for SCCP are not available. Environmental and health risks can be expected if SCCP-containing waste has to be comminuted mechanically prior to energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Hazardous waste incineration (sealants from construction and demolition waste)	It is not expected in practice that SCCP-containing sealants can be completely separated and treated separately (as they adhere to the surface of the construction materials). Successfully separated waste streams should be treated in hazardous waste incineration plants. Due to high incineration temperatures (>1,000°C) it can be considered that the SCCP content is almost completely destroyed. However, exact destruction rates for SCCP are not available.
Landfill (sealants from construction and demolition waste)	Landfilling generally involves the risk that SCCP may be released into the environment in the long term. Presuming that the SCCP-containing waste stream is treated together with concrete, tiles, bricks and ceramic waste, the amount of the mixed waste stream would be very high, while the theoretical SCCP concentration would be insignificant. Due to the insignificant SCCP concentration no specific environmental or health risks are expected. Global distribution can be restricted through separation to the largest extent possible.

1 Background and objectives

POPs and POP-candidates

Persistent organic pollutants (POPs) are chemical substances which are persistent in the environment and strongly bioaccumulate in the food chain, especially in fatty tissue, thus reaching concentrations which have adverse effects on human health and the environment. Moreover, POPs have the potential for long-range transport and can be globally distributed via air and ocean currents.

Individual POPs are subject of

- the Stockholm Convention on Persistent Organic Pollutants[2], and/or
- the POPs Protocol[3] to the regional UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)[4] .

Both conventions under international law recognise the particular problems related to POPs and the need to take international action on POPs with the aim to reduce and/or eliminate production, use and emissions of POPs. In this sense they contain provisions for their parties on intentionally and unintentionally released POPs and POP-containing wastes. The Stockholm Convention on POPs and the Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) are dynamic instruments, whose substance lists are amended continuously.

At present, five substances or substance groups are proposed to be added – the so-called “candidate POPs” – or were added (HBCD[5]) to the Stockholm Convention in May 2013:

- Hexabromocyclododecane (HBCD),
- Hexachlorobutadiene (HCBD),
- Polychlorinated naphthalenes (PCN),
- Pentachlorophenol (PCP) and
- Short Chain Chlorinated Paraffins (SCCP).

Recycling: Resource efficiency versus preventing the cycling of pollutants

The declared political objective of European and national waste policy is on the one hand to promote a circular economy in order to save natural resources or – according to the EU Waste Framework Directive 2008/98/EC[6] to move closer to a “recycling society” by “seeking to avoid waste generation and to use waste as a resource” (recital 28). The intention to close material cycles is also expressed in the five step waste hierarchy of the WFD which defines the basic priorities for the treatment of waste for policy. Material recycling has a higher priority than other types of recovery such as e.g. thermal recovery, which in turn is preferred to disposal.

On the other hand waste policy also aims to guarantee the protection of human health and the environment. The provisions concerning the permissibility of waste treatment operations according to the waste hierarchy demonstrate the generally intended balance between the two goals: In those cases

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[2] The Stockholm Convention text and further information is available at http://chm.POP.int/

[3] The 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs) from 24.06.1998, available at http://www.unece.org/env/lrtap/POP_h1.htm

[4] UNECE Convention on Long-range Transboundary Air Pollution from 13.11.1979, available at http://www.unece.org/env/lrtap/

[5] Decision SC-6/13, available at http://chm.pops.int/TheConvention/ConferenceoftheParties/ReportsandDecisions/tabid/208/Default.aspx

[6] DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives

where recycling leads to a cycle of pollutants, which is undesirable from an environmental and health perspective, the hierarchical priority of recycling is no longer valid. In these cases waste or the contained pollutants can and should be removed from the economic cycle in the sense of the protection of environment and health.

POPs and recycling

The balance between the two fundamental goals of waste policy has to be found especially concerning the POPs content in waste and mixtures and products as an output of recycling processes (recyclates) in particular through the determination of pollutant-specific limit values.

Those limit values have to reflect both, the principal of proportionality as well as the environmental precautionary principle. For an appropriate determination of limit values, a solid basis of facts and data is required for each pollutant. The Annexes to the EU POP Regulation are the relevant legal instruments in this context.

EU POP Regulation

The EU is party to both the Stockholm Convention on POPs and the POPs Protocol under the UNECE CLRTAP Convention. At the Community level, the relevant legal act for implementation of these documents is the POP Regulation EC (No) 850/2004[7] (amended accordingly) which, at the same time, sets out further obligations for Member States. Additionally to international implementation obligations, the Regulation specifies further requirements. Specifically relevant for recycling are, as explained above, all waste related policies including regulations on maximum POP contents concerning mixtures and products as an output of recycling processes (recyclates).

With regard to the treatment and disposal of POP-containing wastes, apart from Annexes IV and V, Article 7 of the EU POP Regulation is of major relevance. Following Article 7, wastes consisting of POPs, containing or contaminated with them, must be treated in such way as to ensure that the POP content is destroyed or irreversibly transformed. Whereas pre-treatment is allowed, disposal and recovery options with the goal of recovery, recycling, reclamation or reuse of POPs are banned.

Exemptions of this principle are possible

- if the POP content is below the concentration limit as of Annex IV (“low POP concentration limit (LPCL)”), Article 7(4) lit. a;
- in exceptional cases for specific waste streams for which destruction or irreversible transformation does not represent the environmentally preferable option, Article 7(4) lit. b; those wastes are listed in Annex V with their maximum POP concentration limits (MPCL).

In relation to recycling it should be mentioned, that Article 3 and Annexes I and II of the POP Regulation open the opportunity for product-related regulations. Accordingly, manufacturing, marketing and use of specific POPs are banned (Annex I) or limited (Annex II). In accordance with Article 4(1) lit b.) this does not apply for “substances occurring as an unintentional trace contaminant in substances, preparations[8] and articles”; Annex I sets concentration limit for specific POPs which can no longer be assumed as “unintentional contaminant”.

As prescribed in Annex V, Part 1 of the POP Regulation, for each waste that exceeds the concentration limit (low limit value) set in Article 7(4)a, only the following waste disposal and recovery opera-

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[7] Regulation EC (No) 850/2004 of the European Parliament and the Council of 29 April 2004 on persistent organic pollutants amending Directive 79/117/EEC (OJ L 158 of 30 April 2004, p. 7); as last amended by Regulation (EU) No 519/2012 of the European Commission of 19 June 2012 amending Regulation (EC) No 850/2004 of the European Parliament and the Council on persistent organic pollutant as regards Annex I (OJ L 159 of 20 June 2012, p. 1)

[8] Note: POP Regulation terminology is somewhat different from the one in REACH / GHS

tions are allowed, for the cases in which the content of POPs is eliminated of irreversibly transformed:

- D9 (physico-chemical treatment)
- D10 (incineration on land)
- R1 (reuse as fuel)
- R4 (Recycling / reclamation of metals and metal compounds).

Permanent storage in appropriately safe and deep underground disposal sites, in rock formations or in salt mines, and designated landfills for hazardous waste may, in exceptional cases, for wastes listed in Part 2 of Annex V be allowed if the respective maximum POP concentration limit is not exceeded. However, the maximum POP contents refer only to landfills for hazardous waste and are not applicable to permanent underground disposal sites for hazardous waste including salt mines.

The POP Regulation Annexes shall be adapted at EU level in the comitology procedure to include developments in the framework of international agreements as well as technical improvements. In February 2013 draft amendments to Annexes IV and V of the POP Regulation were sent to the Member States for comments by mid-March 2013. Table 5 lists the substances studied within this project and included in the draft amendment:

Table 9: The draft amendment to Annexes IV and V of the POP Regulation (as of March 2014) encompasses lower and upper limit values for the following POPs-containing wastes relevant for this project (HBCD, HCBD, PCN, PCP and SCCP)

Substance	CAS-No	„lower value“* in mg/kg	„upper value“** in mg/kg
HBCD	–	–	–
HCBD	87-68-3	100	1,000
PCN	–	10	1,000
PCP	–	–	–
SCCP	85535-84-8	10,000	10,000

* Concentration limit according to Article 7 Paragraph 4 Point a

** Maximum values for the concentration of substances listed in Annex IV (the limits are exclusively for hazardous waste and do not apply for permanent underground disposal sites for hazardous wastes including salt mines)

Data Gaps

There are partly significant knowledge gaps regarding the occurrence of POPs in wastes and products (and particularly recyclates) of the candidate substances in question.

Objective

A condition for the setting of limit values is the detailed knowledge of the presence of pollutants in waste and products. The project aims to collect data on the presence of Hexabromocyclododecane (HBCD), Hexachlorobutadien (HCBD), Polychlorinated naphthalenes (PCN), Pentachlorophenol (PCP) and short chain chlorinated paraffins (SCCP) in relevant waste and recyclates in Germany. In addition, an estimation of the quantities of POP-containing waste and recyclates remaining in the economic cycle is carried out. On the basis of these data proposals for limit values to be defined in Annex IV of the POP Regulation as well as for certain disposal pathways are to be derived, which enable a maximised removal of pollutants on the one hand and environmentally sound recycling processes on the other hand.

2 Approach/methodology

The project concept and schedule, which were agreed end 2012 in a kick off meeting with the responsible UBA personnel, can be shortly summarised as follows:

After a preliminary research on the possible occurrence of the POPs candidates in products and waste, targeted laboratory analyses aiming to improve the existing data basis were carried out. Subsequently, occurrence and fate of the relevant substances and substance groups in Germany were estimated on the basis of the improved information and risks arising from the products, waste and recyclates were outlined. Proposals for limit values in accordance with Annex IV of the POP Regulation were derived for the different substances/substance groups and recommendations on adequate disposal options and treatment technologies were made.

2.1 Material flows and substance flows

Extensive research was performed in order to establish a data basis on the occurrence of the relevant substances in products and waste. As far as possible, this includes amounts of substances and products produced and imported as well as waste amounts treated domestically or sent abroad. Furthermore, detailed information on relevant application fields was taken into account.

Within the context of this research it was especially examined whether the following sectors are relevant for the respective substances/substance groups in Germany, due to current or historical applications (e.g. the historical use of PCP in wood impregnation):

HBCD (see section 0)

- Expanded Polystyrene foams (EPS) in the construction sector
- Extruded Polystyrene (XPS) for the construction industry
- EPS/XPS apart from the construction sector
- High Impact Polystyrene (HIPS) for electrical and electronic devices
- Polymer dispersions for textiles
- Sewage sludge
- Waste incineration

HCBD (see section 3.3)

- Historical applications
- Unintentional production – Production of chlorinated solvents
- Unintentional production – Incineration processes
- Unintentional production – Production of plastics
- Unintentional production – Non-ferrous metal industry – Production of magnesium
- Sewage sludge

PCN (see section 3.4)

- Historical applications
- Unintentional production – Incineration of municipal waste/hazardous waste/hospital waste
- Production of magnesium
- Production of secondary copper
- Production of secondary aluminium
- Chlor-alkali electrolysis

PCP (see section 3.5)

- Wood impregnation
- Textile industry

SCCP (see section 3.6)

- Sealants and adhesives
- Rubber industry
- Paints and lacquers
- Textile industry
- Leather industry
- Metal treatment
- PVC and other polymeric materials
- Sewage sludge

Within the scope of the research, substance and mass flows were developed on the basis of the available information. For this purpose, the following information was analysed for each substance/substance group as far as available:

- Chemical characteristics
- Legal background
- Production and trends
- Use and trends
- Selection of relevant application fields (in which the substance/substance group is used/generated in considerable amounts)
- Detailed information on selected application fields

The research was focused on applications/products/waste where the relevant substances/substance groups are expected to occur according to information from literature and/or from which a significant input into the environment is expected.

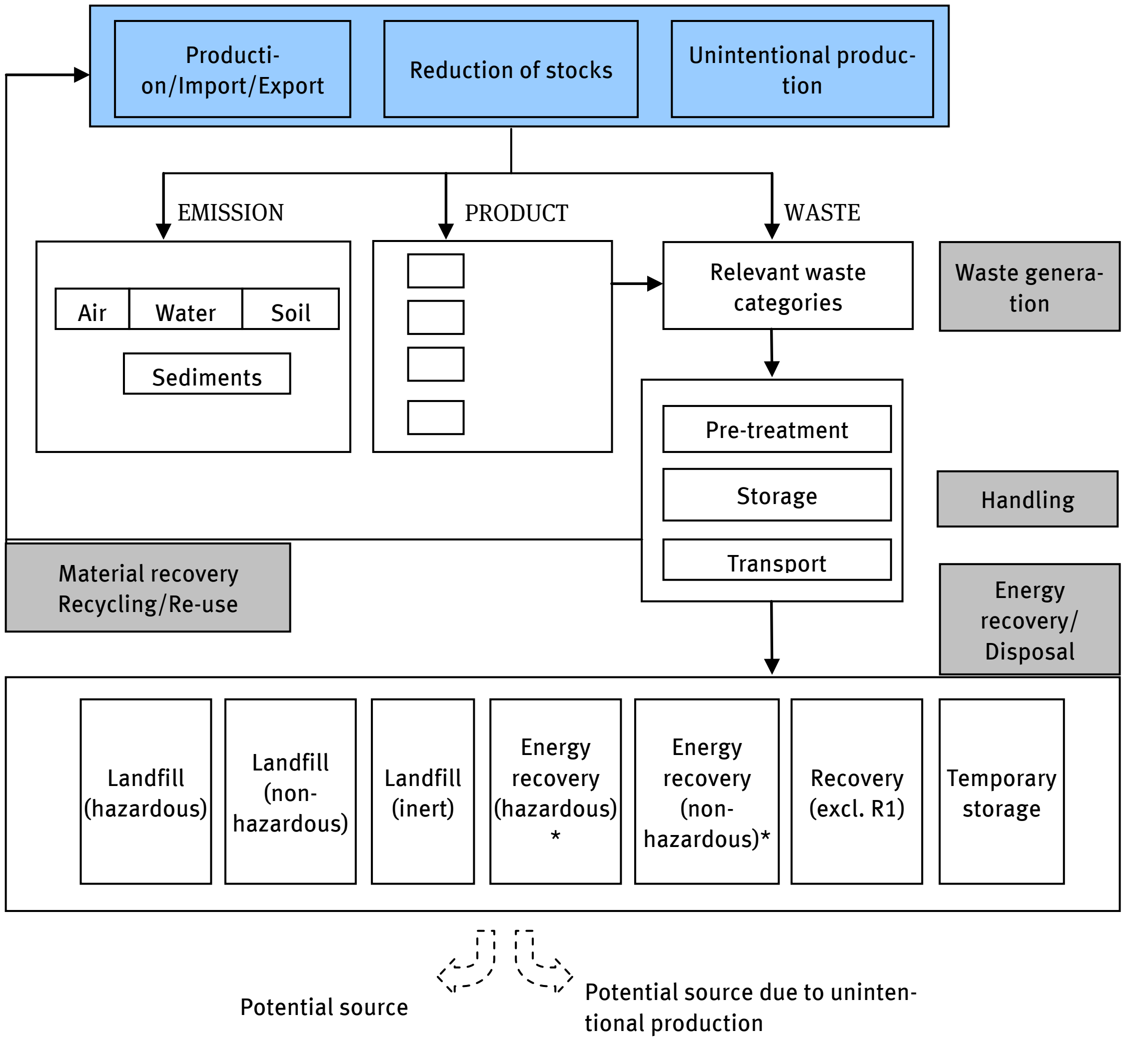
In addition to the literature review important actors were interviewed on new relevant literature and other relevant information (e.g. measurement data on the concentration of the substances/substance groups in products, waste and recyclates), in order to gather the corresponding literature/information.

A recommendation letter in German and English was provided by the UBA in order to support the research and the sampling. Selected experts from industry and authorities were contacted and asked for project-related information. Moreover, individual experts who were identified in the course of the research and who are able to deepen the existing information and fill data gaps were selectively contacted.

On the basis of these data substance flows (for the relevant substances/substance groups in products, waste and recyclates from relevant application fields) and material flows (for the products, waste and recyclates containing the relevant substances/substance groups) were developed, as far as sufficient data are available. The product life time of the relevant products and currently applied waste treatment operations were taken into account. The substance and material flows for relevant application fields are aggregated in substance and material flows for the relevant substances/substance groups in Germany.

Figure 3 graphically illustrates the general structure of those substance and material flows.

Figure 5: General structure of substance flows and material flows



* including R1 (principally used as fuel or as other means of energy generation, with the exception of PCB-containing waste)

On the basis of the available data conclusions were made for the further proceeding (especially for the chemical analyses). The information on the occurrence of the relevant substances/ substance groups and the corresponding substance and mass flows enable conclusions on substantial points:

- Relevance of certain substances/substance groups for the path waste, product and recyclate of the substance flows and material flows
- Comparison of the relevance of different substances/substance groups
- Comparison of the relevance of different industrial activities
- Comparison of the relevance of waste treatment and recovery options for the different substances/substance groups
- Basis for scenarios for different limit values according to Annex IV of the POP Regulation and for the concern of recyclates (these scenarios basically respond to the question “Which waste and recyclates in which amounts would be concerned and therefore would have to be treated as POP waste and would not be available as recyclates anymore if a certain limit value was established?”)

- Comparison of the relevance of possible input of the relevant substances/substance groups into the environment (due to the handling of waste: energy recovery or disposal, respectively material recovery)
- Availability of information and identification of knowledge gaps especially regarding the presence of the relevant substances/substance groups in products, waste and recyclates

2.2 Sampling and chemical analyses

Based on the outcomes of the research, specific products/waste/recyclates were chosen for the five substances/substance groups in close coordination with the UBA and a corresponding sampling and analysis plan was elaborated. The analytical measurements and laboratory analyses were targeted to specific products, waste and recyclates in order to fill specific knowledge gaps. Between October 2013 and March 2014, 45 analytical measurements were performed in total in order to quantify the presence of the relevant substances/substance groups in products, waste and recyclates in selected cases (sampling period from July to October 2013).

2.3 Extension and specification of the data basis

The results of the analyses as well as further research served to extend and specify the data gathered during the preliminary research. Based on more specific substance and mass flows and additional relevant information on the occurrence of the POP substances in products and waste as well as on their treatment, an overview was generated which shows the sectors in which the substances/substance flows typically occur and which risks arise from the corresponding waste and recyclates. The product life cycle time of the relevant products and currently applied waste treatment operations were taken into account.

2.4 Derivation of proposals for limit values in accordance with Article 7(4)a of the POP Regulation, disposal and recovery operations

On the basis of preceding research, types and quantities of POP-containing material streams were estimated, which are currently circulating and will in the future remain in the economic cycle. For the different substances/substance groups proposals for limit values in accordance with Annex IV of the POP Regulation were derived. Moreover, depending on the type of waste, different disposal and recovery operations leading to the destruction of the POP content of the waste are presented and justified as well as the types of waste for which permanent storage in accordance with Annex V, part 2 of the POP Regulation should be the preferred option. In this context also the potential generation of new POPs is taken into account.

2.4.1 Overview and objectives of the method for the derivation of limit values in accordance with Article 7(4)a of the POP Regulation

On the basis of the available data, proposals for limit values in accordance with Annex IV of the POP Regulation as well as for specific waste treatment operations shall be derived, which ensure pollutant removal to the largest extent possible on the one hand and environmentally sound recycling processes on the other hand.

A distinction is made between “low POP concentration limits” (LPCL) in accordance with Art. 7(4)a of the POP Regulation and “maximum POP concentration limits” (MPCL) in accordance with Art. 7(4)b of the POP Regulation. LPCL and MPCL are to be defined in Annex IV or in Annex V part 2 of the POP Regulation. The method enables to derive proposals for LPCL for certain POPs.

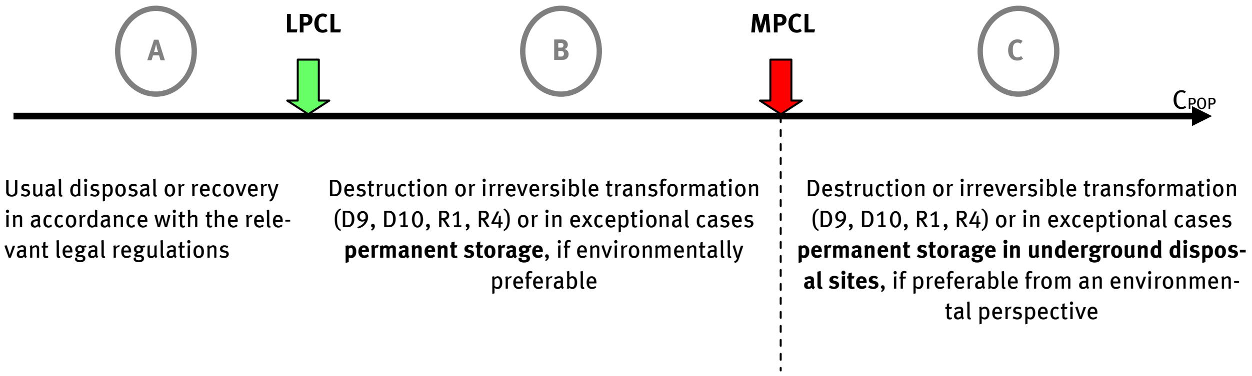
Waste with a POP content exceeding the LPCL is subject to the regulations of the Stockholm Convention on destruction or irreversible transformation as stipulated in Article 6. 1. (d) (ii). Waste with a POP content ranging below the LCPL is subject to other relevant legal regulations on the disposal or recovery of waste[9]. Environment, health and other aspects are to be considered there.

For waste containing POPs in concentrations equal to or exceeding the LPCL, only certain disposal or recovery operations (D9, D10, R1, R4) are permissible in accordance with Annexes I and II of the Regulation 2008/98/EC.

Three concentration ranges (A, B and C in Figure 4), which are relevant under the POP Regulation, are generally possible for POP-containing waste. Those result in certain consequences – depending on the selected limit values:

The consequences regarding different POP concentrations in waste depending on LPCL and MPCL are graphically illustrated in the following figure.

Figure 6: Consequences regarding different POP concentrations in waste depending on LPCL and MPCL



Usual disposal or recovery in accordance with the relevant legal regulations

Destruction or irreversible transformation (D9, D10, R1, R4) or in exceptional cases **permanent storage**, if environmentally preferable

Destruction or irreversible transformation (D9, D10, R1, R4) or in exceptional cases **permanent storage in underground disposal sites**, if preferable from an environmental perspective

According to Footnote (1) in Annex V, part 2, the established MPCLs solely apply to landfill sites for hazardous substances and are not applicable to permanent underground disposal sites for hazardous substances, including salt mines. Therefore the MPCL only applies to the disposal in above ground landfill sites. The disposal in above ground landfill sites is precluded in Germany by the German Landfill Regulation (see Deponieverordnung/DepV, § 7(1) 7). Hence the MPCL has no practical relevance in Germany.

2.4.2 Basic principles of the method for the derivation of LPCLs

The method allows deriving proposals for LPCLs for specific POPs.

The principle of the method is based on the delimitation of the concentration range of a possible limit value for each of the relevant substances by means of a set of different lower and upper limitation criteria. Certain of these criteria indicate concentrations below which limit values should not be set, others indicate concentrations above which limit values should not be set. The following figure illus-

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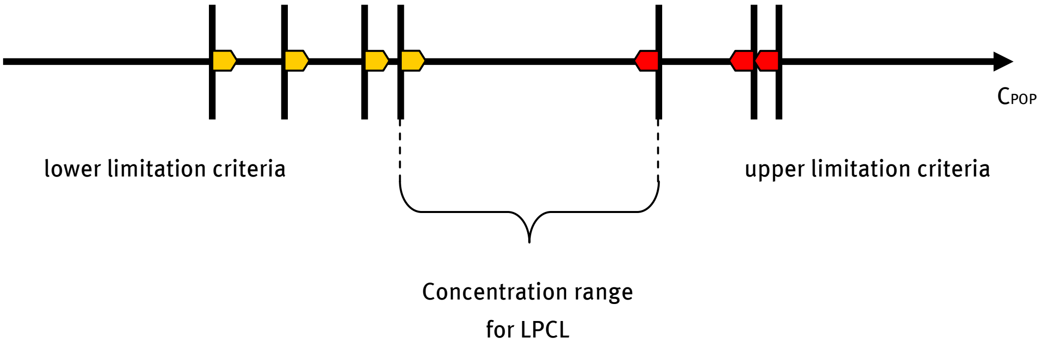
[9] EU POP Regulation Article 7(4) a: *„waste containing or contaminated by any substance listed in Annex IV may be otherwise disposed of or recovered in accordance with the relevant Community legislation, provided that the content of the listed substances in the waste is below the concentration limits to be specified in Annex IV"*

trates the delimitation of a concentration range for a possible LPCL through lower and upper limitation criteria:

Figure 7: Delimitation of the concentration range for a limit value through lower and upper limitation criteria



For each substance a limit value within the determined concentration range is possible. This approach intends to ensure on the one hand that the limit value can be implemented realistically in the light of the available data, and on the other hand, that human health and the environment are protected from persistent organic pollutants to the largest extent possible.

The methodology does not exclude the possibility that upper limitation criteria might range below lower limitation criteria. For instance, limit values which already exist at national and international level (upper limitation criterion) can possibly range below lower limitation criteria. In such cases it is not possible to choose a potential limit value within a derived concentration range. In such cases a proposal can be made and justified on the basis of the available information as well as on expert knowledge and discussion.

Moreover the method allows proposing differentiated limit values for specific waste streams, in case they are linked with specific risk potentials. A POP substance can be contained in residues resulting from waste incineration, for instance, and can therefore be landfilled underground as hazardous waste (→ minor risk potential). It can also be contained in sewage sludge and can possibly be applied directly on agricultural soil (→high risk potential). In such cases, a (higher) limit value for the waste stream “incineration residues” and a (lower) limit value for the waste stream “sewage sludge” could be proposed.

2.4.3 Lower and upper limitation criteria

In order to determine the range of possible limit values for every substance, four lower and two upper limitation criteria are applied. Options for LPCLs can be derived from the aggregation of the results for the individual criteria.

Lower limitation criteria:

- **(A) Analytical potential**: It must be possible to control limit values analytically
- **(H) Background contamination**: Limit values should be above existing environmental background contaminations
- **(BV) Disposal and recovery capacities**: Limit values should be established in a way that the (new) required capacities for recovery and disposal are realistically available
- **(W) Economic feasibility**: Limit values should be established in a way that required additional disposal costs are economically reasonable

Upper limitation criteria:

- **(GW) Limit values**: Limit values should not contradict existing limit values
- **(UG) Possible adverse effects on human health and the environment**: Limit values should be established in a way that adverse effects on human health and the environment are avoided

2.4.3.1 (A) Analytical potential

It must be possible to control limit values analytically, i.e. corresponding analytical methods with sufficient detection limits should be available at reasonable economic conditions. Therefore information on the availability of analytical methods, their detection limits and the costs of analyses for the relevant substances and substance groups form a decisive information basis for the derivation of limit values. The LPCLs should lie above the detection limits of economically available analytical methods.

Analysis costs and detection limits depend on the individual matrix which is examined, as well as on the expenditures invested in the analysis. For the evaluation, not the minimum detection limit of an analytical method is used, but, as far as available, the detection limit in the usual waste matrices under usual effort. Analysis costs include costs for a typical sample preparation. Costs up to €500 per individual measurement are regarded as economically available.

In the context of this research project, analyses were performed by a recognised laboratory with many years of experience in the analysis of POPs, using appropriate analytical methods on typical waste/recyclates/products of the relevant substances/substance groups. Matrices, costs and detection limits underlying these analyses are applied in addition to the information from literature as reference values for the assessment of the detection limits and the economic availability.

2.4.3.2 (H) Background contamination

Limit values should be above existing environmental background contaminations. An LPCL below the existing background contamination would cause considerable economical consequences. As a result, excavated soil could possibly be subject to the POP waste regime and would have to be disposed of and recovered as POP waste.

Therefore the existing background contamination with the relevant substances/substance groups is an important basis of information for the derivation of limit values.

Information on the existing environmental background contamination is summarised in section 7.3.1.2. The monitoring results are divided in typical background contamination and increased contamination, e.g. in the vicinity of point sources. In order to take into account the generally limited availability of data, an uncertainty factor of 10 is applied and a corresponding value is derived, below which the LPCL should not be established. The derivation is performed pursuing the following concept: highest background contamination x uncertainty factor (10) = result for the limitation criterion “background contamination”.

[BiPRO 2011] serves as literature source for the presentation of existing background contaminations. In the course of the research the information gathered in the above mentioned study was determined to be extensive and up to date. Further relevant sources, especially regarding data on Germany, could not be identified.

2.4.3.3 (BV) Disposal and recovery capacities

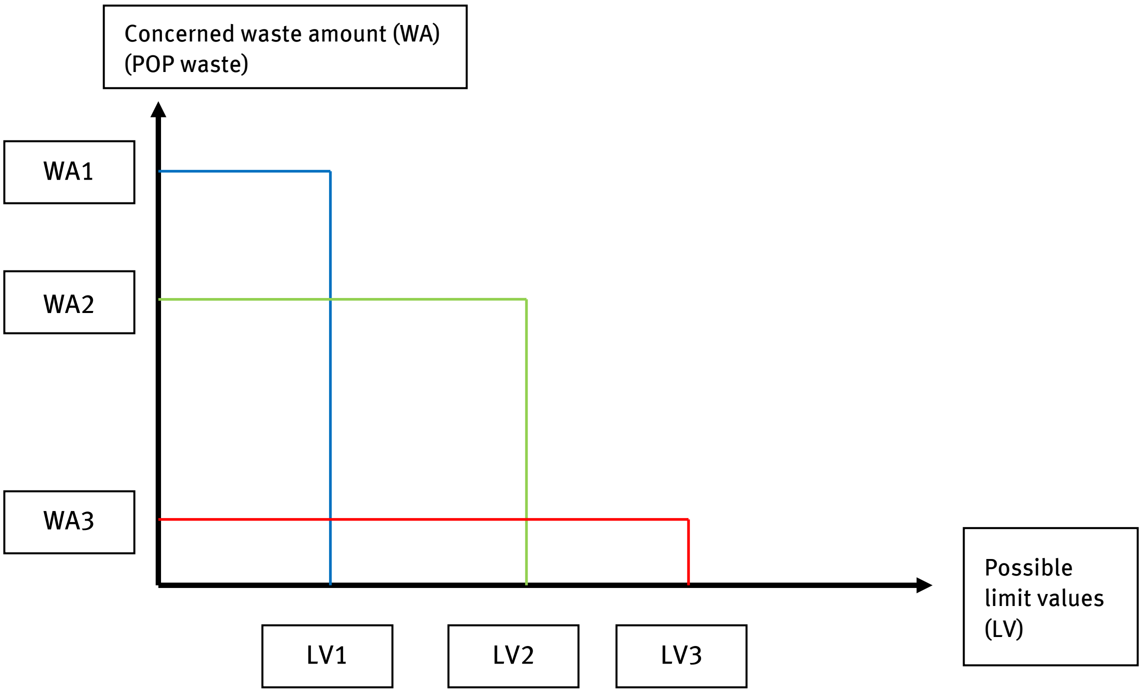
Limit values should be established in a way that the (new) required capacities for recovery and disposal are realistically available.

Possible LPCL might implicate considerable changes in waste treatment, as some wastes will not be permissible for recycling or landfilling anymore, but will inevitably have to be submitted to energy recovery/thermal disposal. This proceeding guarantees that the POP content is destroyed or irreversibly transformed without undue delay. Therefore the availability of appropriate capacities for proper disposal and recovery should be assessed for different LPCL.

In order to derive limit values, which will not result in capacity constraints, at first scenarios for realistic LPCL are elaborated and their respective consequences on the waste management operations are analysed. The influence of the low POP concentration limits depends on the limit value, the existing concentrations in the relevant waste streams (range and average concentration) and the amount of concerned waste streams. On the basis of the concentration values of relevant waste streams, different scenarios for realistic LPCL are elaborated and graphically illustrated. Thus the waste amounts concerned at selected limit values can be shown.

An exemplary result of different scenarios is illustrated in Figure 6:

Figure 8: Scenarios for concerned waste amounts for different limit values



The amounts and types of concerned waste (WA1, WA2 and WA3 in Figure 6) and their current disposal operations can be presented on the basis of material flow analyses. The concerned waste for different realistic limit values would have to be disposed of or recovered (D9, D10, R1 or R4) in accordance with Annex V, part 1 of the POP Regulation. It can be concluded, which amounts and types of waste would have to be treated differently than at present for specific limit values (LV1, LV2 and LV3 in Figure 6). The modified treatment options can be predicted and it can be verified whether the required capacities will be available.

An additional increase of up to 5% of the currently required capacity of the relevant thermal waste treatment sites is considered justifiable (justification see section 7.3.1.3). The required capacities in relation to every substance/substance group are calculated via a comparison of the changes in the required thermal treatment capacities resulting from different possible low POP concentration limits with the total treatment capacities available in Germany (change in % = quantity change of the current state for possible LPCL/total capacity).

2.4.3.4 (W) Economic feasibility

Limit values should be established in a way that required additional disposal costs are economically reasonable.

The analysis of possible disposal operations can indicate how costs for the future disposal and recovery operations will change (e.g. changed costs when a distinct type of waste can no longer be landfilled but has to be incinerated in the future).

In case the POP content of waste exceeds the LPCL, specific disposal and recovery operations are permitted (D9, D10, R1, R4, permanent underground disposal).

Waste with a POP content exceeding the proposed limit value causes the following possible changes in disposal and recovery operations:

- at present: deposition — in future: incineration (D10 or R1)
- at present: recycling/re-use — in future: incineration (D10 or R1)
- at present: deposition — in future: underground disposal
- at present: recycling/re-use — in future: underground disposal

In theory POP-containing waste can also be deposited after stabilisation[10]. However, stabilisation is not relevant for the waste streams analysed in this research project and will not be taken into account in the economic impact assessment.

The resulting changes in costs for possible modifications of disposal and recovery operations have to be taken into account as well. An assessment of those economic consequences is carried out calculating the average costs for modified disposal and recovery operations.

The costs for waste incineration in Germany range between € 80 and € 250 per tonne of waste [Bio 2012]. For the economic impact assessment, an average of € 170 is calculated. At this point a differentiation between the incineration in hazardous waste incineration plants and municipal waste incineration plants or between hazardous and non-hazardous waste is not necessary in the scope of this project. According to the Directive 2000/76/EC on the incineration of waste or the Industrial Emissions Directive (IED) 2010/75/EU on industrial emissions, there is no legal obligation to incinerate hazardous waste exclusively in hazardous waste incineration plants. The plants rather have to hold specific permits for the waste categories incinerated and comply with certain provisions for hazardous waste.

[BiPRO 2011] states that the option recycling/re-use costs an average € 40 per tonne of waste. The costs for the deposit of waste in Germany range between € 60 and € 220 per tonne. For the economic assessment average costs of € 140 are used for the calculations [Bio 2012].

According to information from German operators of underground disposal sites, costs for underground disposal lie between € 260 and € 900 per tonne, irrespective of the deposited waste category [EC 2010]. The upper end of the price refers to waste which for example requires specific storage (e.g. separate storage or storage in an isolated area; see [EC 2010]). For the economic assessment average costs of € 260 per tonne are used for the calculations.

Table 6 shows both the calculated costs for the different disposal and recovery operations as well as the cost changes resulting in case the possible LPCL was exceeded.

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[10] Stabilisation is a chemical/physical treatment (D9) and is therefore permissible for POP-containing waste in accordance with Annex V, Part 1 of the POP Regulation. Decision 2000/532/EC states: „Stabilisation processes change the dangerousness of the constituents in the waste and thus transform hazardous waste into non-hazardous waste."

Table 10: Changes in costs for relevant disposal and recovery operations

Current treatment	Future treatment in case LPCL is exceeded	Cost changes per tonne of waste
Deposit (€ 140)	Incineration: D10 or R1 (€ 170)	€ 30
Recycling/Re-use (€ 40)	Incineration: D10 or R1 (€ 170)	€ 130
Deposit (€ 140)	Underground disposal (€ 260)	€ 120
Recycling/Re-use (€ 40)	Underground disposal (€ 260)	€ 220

The cost changes per tonne of waste shown in Table 6 serve as a basis for the assessment of the economic impacts of possible LPCL (cf. section 7.3.1.4).

2.4.3.5 (GW) Limit values

Limit values should not contradict to existing limit values. To this end, existing limit values are summarised at national and international scale.

On the basis of existing limit values, the potential of possible conflicts between existing limit values and proposed limit values is discussed, in particular whether and how existing limit values delimit possible LPCLs.

2.4.3.6 (UG) Possible adverse effects on human health and the environment

Limit values should be established in a way that adverse effects on human health and the environment are avoided and human health and the environment are protected from POPs as far as reasonably possible.

Risks for human health and the environment can basically arise throughout the whole waste "lifecycle" (generation, transport, pre-treatment and treatment for disposal/recovery). In the scope of the present research project proposals for low POP concentration limits in the sense of the POP Regulation shall be derived. Hence, the phase of disposal and recovery is the only relevant lifecycle step. As a consequence, it is necessary to estimate above which POP contents the disposal and recovery of POP-containing waste could possibly have adverse effects on human health and the environment.

Owing to their toxicity, POPs can generally cause adverse effects on health and the environment when humans or other organisms are exposed to them or when environmental compartments are contaminated.

A tangible effect will only occur when a human or environmental exposure to POPs exceeds certain concentration limits. The (predicted) environmental concentration which causes no effect is called (P)NEC ((predicted) no effect concentration)[11]. In case this concentration is not exceeded, no environmental hazards are expected. The occupational exposure limit is the concentration of a substance in workplace air (in mg/m^3), for which the health of employees is not expected to be affected. In case this concentration is not exceeded, no health risks are expected. The biological limit value is the maximum permissible concentration of a substance detected in the blood of an employee, at which adverse health effects are not expected. In case this concentration is not exceeded, no health risks are expected.

In certain cases the disposal/recovery of the POP content of waste can directly cause exposure of humans and the environment (e.g. via the application of POP-containing sewage sludge on agricultural soil). If the POP content exceeds the (P)NEC, direct adverse effects are possible.

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[11] (P)NEC = (**p**redicted) **n**o **e**ffect **c**oncentration

In certain cases the disposal/recovery of the POP content of waste can indirectly cause exposure of humans and the environment (e.g. when POPs leach from a landfill site, when the POPs fraction isn't destroyed completely during incineration or when new POPs are generated in the incineration process). If the resulting POP content exceeds the (P)NEC, adverse effects are possible.

In other cases the POP content of a waste can cause an exposure of humans or the environment already during pre-treatment or during disposal and recovery treatments (e.g. via POP emissions generated in the shredding process of POPs-containing waste). If the resulting POP content in the workplace exceeds the permissible occupational exposure limit or if the POP content in the blood of an employee or a third persons exceeds the biological limit value, adverse health effects are possible.

In these cases the risk depends on specific frame conditions. In order to analyse those conditions, pre-treatment, treatment and disposal/recovery of the waste are discussed. In the course of the analysis (see section 6) especially the following questions are taken into account:

- Are the disposal and recovery operations (D9, D10, R1, R4) permitted according to Annex V, part 1, appropriate to destroy or irreversibly transform the relevant substances/substance groups?
- Can the corresponding processes lead to an unintended generation of new POPs?
- Can disposal or recovery cause a risk to human health or the environment (i.e. a relevant exposure of humans or the environment)? The emission of significant amounts of POPs into the environment is generally considered a risk.

To this end, relevant information on the essential exposure pathways has to be taken into account and possible health and environmental risks resulting from different procedures in waste recovery and disposal have to be discussed. Information on tolerable daily intake (TDI) levels and minimal risk levels (MRL) suggest, which amounts of the relevant substances/substance groups can be ingested by humans without any expected health risks.

3 Material flows and substance flows

3.1 Overall material flows

Selected material flows are described in the following and form the basis for the development of substance and material flows for the individual substances/substance groups:

- Construction materials and construction waste
- Plastic waste
- Domestic waste
- Hospital waste
- Hazardous waste
- Sewage sludge
- Ashes and slag from waste incineration

3.1.1 Construction materials and construction waste

HBCD, PCP and SCCP are or were applied in products which are or were used in the construction sector. Table 7 gives an overview of the most relevant products and their typical use in the construction sector.

Table 11: Typical use of HBCD, PCN and SCCP in the construction sector

Product	Relevant candidate POP	Typical use in the construction sector
EPS insulation panels XPS insulation panels	HBCD	Insulation panels, floor slabs, foundations Outer insulation of walls in contact with soil Outer insulation walls/facades Insulation in humid and refrigerated rooms Insulation of floors and ceilings Roof insulation
HIPS Distribution boxes	HBCD	Distribution boxes for electrical lines
Impregnated wood	PCP	Interior and exterior wooden constructions Window frames
Paints and varnishes	SCCP	Coatings
Sealants	SCCP	Joint sealants
Adhesives	SCCP	Adhesives
Rubber and plastic products	SCCP	PVC cables, other flame retarded rubber and plastic products

Table 8 gives an overview of the waste identifications of C&D waste and the partial waste streams in which the relevant substances/substance groups are very likely to occur.

Table 12: Waste designation of C&D waste and possibly POP-relevant fractions

Waste code	Waste designation	Possibly POP-relevant waste fraction
17	Construction and demolition wastes (including excavated soil from contaminated sites)	
17 01	Concrete, bricks, tiles and ceramics	Adhesions possible
17 01 01	Concrete	Adhesions possible
17 01 02	Bricks	Adhesions possible
17 01 03	Tiles and ceramics	Adhesions possible
17 01 06*	Mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances	HBCD, SCCP in correspondingly mixed C&D waste containing e.g. coatings, adhesives, etc.
17 01 07	Mixtures of, or separate fractions of concrete, bricks, tiles other than those mentioned in 17 01 06	HBCD, SCCP in correspondingly mixed C&D waste containing e.g. coatings, adhesives, etc.
17 02	Wood, glass and plastic	
17 02 01	Wood	PCP-containing wood
17 02 02	Glass	
17 02 03	Plastic	HIPS distribution boxes, SCCP-containing paints, lacquers, sealants, adhesives, plastics etc.
17 02 04*	Glass, plastic and wood containing or contaminated with dangerous substances	PCP-containing wood
17 03	Bituminous mixtures, coal tar and tarred products	
17 03 01*	Bituminous mixtures containing coal tar	
17 03 02	Bituminous mixtures other than those mentioned in 17 03 01	
17 03 03*	Coal tar and tarred products	
17 04	Metals (including their alloys)	
17 04 01	Copper, bronze, brass	
17 04 02	Aluminium	
17 04 03	Lead	
17 04 04	Zinc	
17 04 05	Iron and steel	
17 04 06	Tin	
17 04 07	Mixed metals	
17 04 09*	Metal waste contaminated with dangerous substances	
17 04 10*	Cables containing oil, coal tar and other dangerous substances	SCCP-containing PVC cables
17 04 11	Cables other than those mentioned in 17 04 10	SCCP-containing PVC cables
17 05	Soil (including excavated soil from contaminated sites), stones and dredging spoil	Fractions of XPS from insulation of foundations, roadbeds etc. possible

Waste code	Waste designation	Possibly POP-relevant waste fraction
17 05 03*	Soil and stones containing dangerous substances	Fractions of XPS from insulation of foundations, roadbeds etc. possible
17 05 04	Soil and stones other than those mentioned in 17 05 03	Fractions of XPS from insulation of foundations, roadbeds etc. possible
17 05 05*	Dredging spoil containing dangerous substances	
17 05 06	Dredging spoil other than those mentioned in 17 05 05	
17 05 07*	Track ballast containing dangerous substances	
17 05 08	Track ballast other than those mentioned in 17 05 07	
17 06	Insulation materials and asbestos-containing construction materials	
17 06 01*	Insulation materials containing asbestos	
17 06 03*	Other insulation materials consisting of or containing dangerous substances	EPS/XPS insulation material
17 06 04	Insulation materials other than those mentioned in 17 06 01 and 17 06 03	EPS/XPS insulation material Note: Insulation materials include glass wool, rock wool and polystyrene. Insulation materials are regarded harmless if they were produced after 01/06/2000
17 06 05*	Construction materials containing asbestos	
17 08	Gypsum-based construction materials	
17 08 01*	Gypsum-based construction materials contaminated with dangerous substances	Adhesions of SCCP-containing paints, adhesives, EPS/XPS insulation material, etc. possible
17 08 02	Gypsum-based construction materials other than those mentioned in 17 08 01	
17 09	Other construction and demolition wastes	
17 09 01*	Construction and demolition wastes containing mercury	
17 09 02*	Construction and demolition wastes containing PCB (for example PCB-containing sealants, PCB-containing resin-based floorings, PCB-containing sealed glazing units, PCB-containing capacitors)	SCCP-containing sealants
17 09 03*	Other construction and demolition wastes (including mixed wastes) containing dangerous substances	Adhesions/fractions of HBCD, SCCP and PCP in correspondingly mixed C&D waste
17 09 04	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	Adhesions/fractions of HBCD, SCCP and PCP in correspondingly mixed C&D waste

A substantial part of the candidate POPs HBCD, SCCP and PCP applied in Germany were or are used in the construction sector. Thus, the treatment and disposal operations of construction and demolition waste in Germany have a significant influence on the fate or the destruction of those substances/substance groups.

Due to the above-mentioned assumption, the following waste codes are particularly relevant: 17 01 06*, 17 01 07, 17 02 01, 17 02 04*, 17 04 10*, 17 04 11, 17 05 03*, 17 05 04, 17 06 03*, 17 06 04, 17 08 01*, 17 09 02*, 17 09 03*, 17 09 04.

An inquiry to the German Demolition Association (original title in German: Deutscher Abbruchverband e.V.) revealed that no statistical data on planned demolition activities (total generation of demolition waste, arising of the relevant fractions by waste codes) are gathered or known there, but that statistical data is available at the German Federal Statistical Office. The association does not possess information concerning arising amounts or recovery and disposal of the relevant types of waste (e.g. EPS and XPS insulation materials, adhesives, sealants, etc.).

The total amount of construction waste arising in Germany is estimated at 50 million t/a [UBA 2013].

According to Consultic, a total of 372 kt of post consumer plastic wastes (i.e. plastic waste generated by private or commercial end users) arose in the construction sector in 2011, as well as 83 kt of PS-E post consumer plastic wastes [Consultic 2012]. It is unclear which proportion of the PS-E post consumer waste originates from the construction sector.

Apart from EPS/XPS, waste code 17 06 04 also includes other insulation materials[12]. The proportion of the EPS/XPS insulation materials is unclear. It seems that in practice, EPS/XPS insulation materials are recovered and disposed of as secondary fractions of other waste streams. Especially the high quantity waste streams (codes 17 01 07 and 17 05 04) but also all other construction waste streams come into consideration here (see Table 9).

The waste profile for waste code 17 06 04, which includes EPS/XPS insulation materials, available on the German Information Portal on Waste Assessment (IPA; original designation in German: Informationsportal zur Abfallbewertung) does not mention polymeric materials in the characteristics of the composition [IPA 2012a]. In addition to the statements from operators of construction waste processing sites, this can be seen as a further indication that the waste from EPS and XPS insulation materials in the construction sector is still of limited importance.

C&D waste – besides mining waste – accounts for the biggest share of the total waste arising in Germany. According to the statistical coverage of the German working-group for closed-loop construction (ARGE KWTB; original designation in German: Arbeitsgemeinschaft Kreislaufwirtschaftsträger Bau), the bulk of the 200.7 million t of C&D waste arising in 2004 was excavated soil with 128.3 million t (63.9%). Building and road works rubble amounted to 50.5 million t (25.2%) and 19.7 million t (9.8%) respectively, together representing the second largest mass flow within C&D waste. Construction site waste (1.9 million t or 0.9%) and gypsum-based construction waste (0.3 million t or 0.2%) accounted for a significantly smaller proportion. Building rubble is defined as mineral substances from construction works, possibly with minor impurities (non-mineral). In addition to concrete it can also contain rests of other mineral construction materials, such as bricks, glass, plaster, etc [UBA 2013].

It can be assumed that considerable shares of the EPS and XPS waste from construction and demolition arise from building rubble which amounts to an estimated 50 million tonnes.

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[12] Insulation materials include glass wool, rock wool and polystyrene. (Mineral fiber) insulation materials are regarded harmless if they were produced after 01/06/2000. Polystyrene is regarded as harmless. Harmless insulation materials are assigned to waste code 170604. For their disposal containers of 2 to 20 m^3 are used.

Due to the potential of the contained recyclable materials the primary focus in the treatment of construction waste lies on the recovery of construction and road works rubble, concentrating especially on the recovery of the mineral fraction. The objective is to achieve very pure fractions of identical mineral materials in order to permit high quality recycling [UBA 2013]. ARGE KWTB state on their homepage that the building industry increased the recovery quota of mineral waste from about 50 to nearly 90 percent between 1995 and 2005[13]. According to [UBA 2013], recovery and recycling quotas of more than 70% have been reached over the last years.

The substance streams relevant for this project are not the primary target of mechanical recycling (see Table 9). Insulation materials from PS-E, other flame retarded polymeric materials and rubber, adhesives, sealants and coatings as well as waste wood are usually regarded as impurities and are separated as far as possible from the mineral fraction and recovered or disposed of separately. However, a neat separation of impurities is often not really possible, e.g. because they adhere to the mineral fractions (concrete, bricks, plaster etc.). Among other things, this can impair the environmental impact of recycled aggregates [UBA 2013]. This can principally also be due to the occurrence of the candidate POPs HBCD, PCP and SCCP. According to the German Landfill Regulation, the loss on ignition in landfills may be up to 3.5 or 10%, depending on the landfill category. For the landfill category 0 for inert waste the loss on ignition may amount to 3%. As a result, it is possible to dispose of construction rubble with organic impurities of up to 3% in landfill sites for construction waste.

Accordingly, it is important to promote closing the loops for mineral materials in the dismantling of buildings and in the processing of the generated materials through appropriate techniques and processes. With the optimised application of dismantling processes and appropriate processing techniques, substance flows can be kept separate and the production of high-quality recycled construction materials can be achieved. High quality standards are required in order to guarantee the marketability of the recycled construction materials (see [UBA 2013]). At the same time, the application of appropriate techniques and processes allows that POP-containing material streams are separated as far as possible from mineral and metal fractions in the construction rubble and that an appropriate disposal of those material streams can be attained.

Table 13: Appraisal on the recovery and disposal of relevant products in the construction sector

Product	Relevant candidate POP	Assessment on recovery and disposal of relevant products in the construction sector
EPS insulation panels XPS insulation panels	HBCD	Assignment to ASN code 17 06 04, where at present only secondary partial stream apart from mineral fibre insulation materials. Increasing proportion in the future. Not in the focus of recovery of construction waste. Remainders are recovered with or separated from the mineral fraction as impurities and are usually recovered or landfilled. No quantitative data available.
HIPS distribution boxes	HBCD	Assignment to code 170203 or 170204*, where at present only secondary partial stream apart from other polymeric materials. Not in the focus of recovery of construction waste. Remainders are recovered with or separated from the mineral fraction as impurities and the separated fraction is (usually thermally) recov-

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[13] Source: http://www.euwid-recycling.de/news/wirtschaft/einzelansicht/Artikel/arge-kreislaufwirtschaftstraeger-bau.html (Note: The working-group for closed-loop construction ARGE KWTB dissolved. The union of associations and organisations of the construction industry, which was founded in 1995, had committed itself voluntarily to the target to distinctively reduce the deposit of reusable construction waste.)

		ered or landfilled. No quantitative data available.
Impregnated wood	PCP	Assignment to waste wood category AIV. Separate disposal and usually energy recovery. Quantitative data available.
Paints and lacquers, sealants, adhesives, rubber and plastic products	SCCP	Secondary partial flow in concrete, bricks, tiles and ceramic mixtures or fractions (17 01 06* and possibly others). Not in the focus of recovery of construction waste. Remainders are recovered with or separated from the mineral fraction as impurities and the separated fraction is (usually thermally) recovered or landfilled. Often in the form of hardly separable remaining traces (especially paints, lacquers, adhesives, sealants) in the mineral fraction and corresponding recovery and disposal. Quantitative data partly available.

3.1.2 Plastic waste

HBCD and SCCP are or were used in polymeric materials. Table 10 gives an overview of the most relevant products and their typical use:

Table 14: Typical use of HBCD and SCCP in plastics

Relevant candidate POP	Typical plastic products
HBCD	EPS insulation panels XPS insulation panels Packaging Distribution boxes for electrical lines Stereo and video equipment
SCCP	Paints and lacquers Sealants Adhesives PVC cables and other flame retarded plastic and rubber products

Disregarding non-material applications, the processed amount of plastics in Germany amounted to 11.86 million t in 2011. If imports and exports are taken into account, a domestic plastics consumption of 9.65 million t can be derived for Germany in 2011. The amount of plastic waste generated in Germany amounted to 5.45 million t in the same year, 1.01 million t of which being production and processing waste[14] and 4.44 million t being post consumer waste[15]. Processed amount, consumption and waste generation are increasing (by about 5%/a each from 2009 to 2011) [Consultic 2012].

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[14] Wastes which arise during production or processing of plastics (usually one pure substance)

[15] Wastes which arise after the use of the plastic products (often impure substances). Including wastes which arise in installation, fitting or laying etc. (e.g. pipes, cables, floorings, insulation panels, etc.)

Table 11 shows an overview of the sources of generation of the observed plastic wastes.

Table 15: Plastic wastes for recovery and disposal by point of generation (types of origin are marked in colours: white=commercial end users; light blue=private households; dark blue = producers; yellow=processors; table adapted from [Consultic 2012])

Points of generation 2011	Recorded quantities of plastic waste		
	Amount in kt	Recovery in kt	Disposal in kt
Commercial wastes via private waste management enterprises	994	974	20
Commercial wastes similar to domestic wastes via public-sector waste management enterprises	162	158	4
Shredder facilities (end-of-life vehicles only) incl. car dismantlers & car workshops	189	174	15
Collection and recovery schemes for commercial packaging (also transport packaging and overpacks)	345	345	0
Other collection and recovery schemes (AGPR, German Plastic Pipe Association, roof sheetings, Rewindo, etc.)	95	95	0
Sales packaging	1400	1400	0
Residual waste households	849	829	20
Bulky waste households*	188	186	2
Collection of recyclable materials (public-sector waste management enterprises)**	45	45	0
WEEE from households, commerce and industry (collection via public-sector waste management enterprises, recycling centres, commerce & private waste management enterprises)	171	170	1
Producers	74	72	2
Processors	936	934	2
Total	**5448**	**5382**	**66**

*e.g. furniture, carpets, „white goods", „brown goods"

**various plastic products, e.g. pipes, containers, foils from households and commerce from bring systems (e.g. Bavaria and Baden-Wurttemberg)

The proportions of disposal, energy recovery and material recovery differ considerably depending on the type of origin. For waste generators and processors material recovery amounts to about 70% and 90% respectively, as the wastes are pure and clean, whereas for private households and commercial end users it amounts to 35% and 30% (see Table 12).

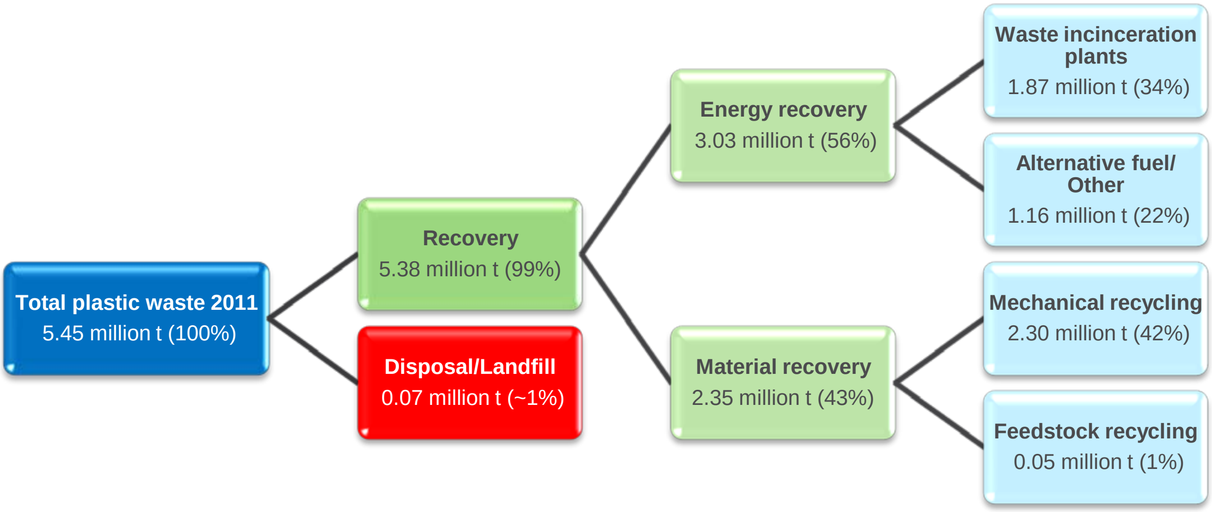
Table 16: Plastic wastes for recovery and disposal by types of origin in 2011 [Consultic 2012]

Type of origin	Amount in kt	Disposal in %	Energy recovery in %	Material recovery in %
Private households	2,653	0.9	64.6	34.6
Commercial end users	1,785	2.2	67.8	30.0
Plastics processing	936	0.2	9.8	90.0
Plastics production	74	2.7	26.6	71.1

About 56% of the 5.45 million t of recorded plastic waste were submitted to energy recovery, 42% to mechanical recycling and approximately 1% each to feedstock recovery and disposal (landfilling) (see Figure 7). As far as the post consumer waste (4.44 million t) is concerned, about 66% went into energy recovery, 32% into mechanical recycling and approximately 1% each into feedstock recycling and disposal (landfilling), [Consultic 2012].

The following figure illustrates the substance flow for the total amount of recorded plastic waste in Germany.

Figure 9: Plastic waste and recovery - recovery operations incl. production and processing wastes (figure adopted from [Consultic 2012])



The following differentiations are possible for the relevant sectors [Consultic 2012]:

- 70.2% of the post consumer plastic waste generated in the construction sector (372 kt in 2011) is submitted to energy recovery, 25.8% to mechanical recycling (0% to feedstock recycling) and 4% is landfilled (see Table 13).
- 57.8% of the post consumer plastic waste generated in the packaging sector (2,692 kt in 2011) is submitted to energy recovery, 39.8% to mechanical recycling, 2.0% to feedstock recycling and 0.4% is landfilled. Within plastic packaging waste from households (1,839 kt in 2011), 54.6% undergoes energy recovery, 42.1% mechanical recycling and 2.9% feedstock recycling, while 0.4% is landfilled. Within industrial/commercial plastic packaging waste (853 kt in 2011), 64.7% is directed to energy recovery, 34.7% to mechanical recycling, 0% to feedstock recycling and 0.6% is landfilled (see Table 13) [Consultic 2012].
- 90.0% of the post consumer plastic waste generated in the electronics industry (241 kt in 2011) is directed to energy recovery, 7.5% to mechanical recycling (0% to feedstock recycling) and 2.5% is landfilled (see Table 13) [Consultic 2012].
- Within the total amount of plastic waste arising in the post consumer sector (2,692 kt in 2011), 65.9% are submitted to energy recovery, 31.5% to mechanical recycling, 1.2% to feedstock recycling and 1.4% is landfilled (see Table 13) [Consultic 2012].

Table 13 gives an overview of the arising waste amounts and the treatment operations in those sectors.

Table 17: Plastic waste for recovery and disposal by type of origin in 2011 [Consultic 2012]

Sector	Arisings (kt)	Mechanical recycling (%)	Feedstock recycling (%)	Energy recovery (%)	Disposal (Landfill) (%)
Packaging	2,692	39.8	2.0	57.8	0.4
Packaging from households	1,839	42.1	2.9	54.6	0.4
Industrial/commercial packaging	853	34.7	0.0	64.7	0.6
Electrical/electronic industry	241	7.5	0.0	90.0	2.5
Construction	372	25.8	0.0	70.2	4.0
Total post consumer plastic waste	4,438	31.5	1.2	65.9	1.4

3.1.3 Household waste

The amount of household waste generated in Germany in 2011 totalled about 44 million tonnes. A large proportion of the waste was directed to material (~64%) and energy recovery (~16%). The remaining share was incinerated (~16%) or treated for disposal (~4%) [DESTATIS 2013a]. This distribution will form the basis for the assessments performed in section 2.1.

3.1.4 Hospital waste

HCBD and PCN can be formed unintentionally in incineration processes. In this context, the incineration of hospital waste, hazardous waste and municipal waste are of particular relevance. The waste generation (medical and biological waste) in Germany amounted to approximately 280,000 t in 2010 [EUROSTAT 2013c]. This waste was treated/disposed of in Germany as follows:

Table 18: Recovery/disposal of medical and biological waste [EUROSTAT 2013c]

Treatment of medical and biological waste in Germany in 2010 (total)	Total	Incineration (energy recovery R1)	Recovery other than R1	D10 (Incineration)	Disposal (Landfill)
in [t]	269,394	118,867	4,362	144,761	1,404
in [%]	100.0	44.1	1.6	53.7	0.5

Table 19: Recovery/disposal of non-hazardous medical and biological waste [EUROSTAT 2013c]

Treatment of medical and biological waste in Germany in 2010 (non-hazardous)	Total (non-hazardous)	Incineration (energy recovery R1)	Recovery other than R1	D10 (Incineration)	Disposal (Landfill)
in [t]	258,893	113,467	4,362	139,660	1,404
in [%]	100.0	43.8	1.7	53.9	0.5

Table 20: Recovery/disposal of hazardous medical and biological waste [EUROSTAT 2013c]

Treatment of medical and biological waste in Germany in 2010 (hazardous)	Total (hazardous)	Incineration (energy recovery R1)	Recovery other than R1	D10 (Incineration)	Disposal (Landfill)
in [t]	10,501	5,400	0	5,101	0
in [%]	100.0	51.4	0	48.6	0

3.1.5 Hazardous waste

There are about 30 hazardous waste incineration plants in Germany. Most of the plants are located in the vicinity of chemical industry sites and mainly dispose of the wastes generated by the neighbouring industrial plants. Nowadays they are often disembodied from the chemical companies and carry out their own waste acquisition.

The available annual incineration capacity of the hazardous waste incineration plants amounts to approximately 1.5 million tonnes. But in fact, far less hazardous waste is incinerated, with the capacity utilisation of the different plants varying widely [UBA 2014].

POP-containing wastes can generally be incinerated in hazardous waste incineration plants as well as in municipal waste incineration plants (see also section 2.4.3.4).

3.1.6 Sewage sludge

Sewage sludge is a potential secondary source of different POPs. In 1998, about 2.2 million t of dry matter (DM) of sewage sludge had to be disposed of. Since then the annual amount of sewage sludge to be disposed of has decreased continuously. The amount fell to just below 2 million t of DM in 2009. Merely the years 2004 to 2006 saw a slight increase by a few 10,000 t of DM. One major reason for this development is the increase in anaerobic sludge digestion, as it reduces the amount of sewage sludge which has to be disposed of. The thermal disposal increased from 9% in 1991 to 52.5% in 2009. Landfilling of sewage sludge dropped from 42% to almost zero percent. This is due to the landfill ban for untreated waste in force since 1 June 2005. Also the recovery in landscape architecture decreased. Agricultural recovery rates remained fairly static over the years [UBA 2012].

Table 17 summarizes the treated amounts of sewage sludge and the treatment operations applied in Germany in the year 2010.

Table 21: Treated amounts of sewage sludge and treatment operations in Germany (data for 2010 from [UBA 2012])

	Total sewage sludge treatment	Agricultural recovery	Landscaping measures	Other material recovery	Thermal disposal	Landfilling
Amount in [t]	1,887,408	566,295	259,312	58,052	1,003,749	-
Share in [%]	100.00	30.00	13.74	3.08	53.18	-

In 2010, about 2 million tonnes of sewage sludge were disposed of in Germany. Approximately half of this amount was disposed of thermally. Agricultural recovery, landscaping measures and other material recovery operations (such as composting or recultivation measures) accounted for 883,659 t DM of sewage sludge. Some German Federal States such as Baden-Wurttemberg or North Rhine-Westphalia are incinerating more than 60% of the sewage sludge generated in their territory. The agricultural use of sewage sludge predominates especially in Mecklenburg-West Pomerania, Lower Saxony, Rhineland-Palatinate and Schleswig-Holstein [UBA 2012].

3.1.7 Ashes and slag from waste incineration

HCBD and PCN can be formed unintentionally during incineration processes and can be contained in residues from waste incineration. The following tables show the amounts of treated sludge and liquid wastes as well as the incineration residues from waste treatment in Germany [EUROSTAT 2013d].

Sludge and liquid waste from waste treatment

Table 18 shows statistical data concerning the treatment of sludge and liquid waste from waste treatment.

Table 22: Treatment of sludge and liquid waste from waste treatment

Treatment of sludge and liquid waste from waste treatment in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	189,140	33,152	69,975	10,981	75,032
Share in [%]	100.00	17.53	37.00	5.81	39.67

Table 19 shows statistical data concerning the treatment of hazardous sludge and liquid waste from waste treatment.

Table 23: Treatment of hazardous sludge and liquid waste from waste treatment

Treatment of sludge and liquid waste from waste treatment in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	144,552	30,908	44,254	10,663*	58,727
Share in [%]	100.00	21.38	30.61	7.38	40.63

*Own calculation (was not indicated in ESTAT for confidentiality reasons)

Table 20 shows statistical data concerning the treatment of non-hazardous sludge and liquid waste from waste treatment.

Table 24: Treatment of non-hazardous sludge and liquid waste from waste treatment

Treatment of sludge and liquid waste from waste treatment in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	44,588	2,244	25,721	318*	16,305
Share in [%]	100.00	5.03	57.69	0.71	36.57

*Own calculation (was not indicated in ESTAT for confidentiality reasons)

Incineration residues

Table 21 shows statistical data concerning the treatment of incineration residues.

Table 25: Treatment of incineration residues

Treatment of incineration residues in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	19,619,921	420,322	13,141,307	1,079	6,057,213
Share in [%]	100	2.14	66.98	0.01	30.87

Table 22 shows statistical data concerning the treatment of hazardous incineration residues.

Table 26: Treatment of hazardous incineration residues

Treatment of incineration residues in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	863,074	423	681,264	641	180,746
Share in [%]	100.00	0.05	78.93	0.07	20.94

Table 23 shows statistical data concerning the treatment of non-hazardous incinceration residues.

Table 27: Treatment of non-hazardous incineration residues

Treatment of incineration residues in Germany (data for 2010)					
Treatment operations	Total waste treatment	Energy recovery (R1)	Recovery other than energy recovery	Incineration/ disposal (D10)	Disposal
Treated in 2010 [t]	18,756,847	419,899	12,460,043	438	5,876,467
Share in [%]	100.00	2.24	66.43	0.002	31.33

3.2 Hexabromocyclododecane (HBCD)

3.2.1 Manufacture and use

Production

Currently within the EU, HBCD is exclusively produced in the Netherlands with the annual production of about 6,000 t (year 2005, pure HBCD in the form of powder or granulates). HBCD is also imported and exported to/from the EU and Germany as a chemical in preparations and in fame retarded products. Major producing countries outside the EU are the USA, Japan and China ([ECB 2008], [UNEP/POPS/POPRC.6/10]). The production was relatively constant at about 6,000 t/a in the EU between 2003 and 2007 (see [IOM 2008]). According to information from industry sources, the production in the Netherlands was at the same level in 2011 i.e. approximately 6,000 t/a [PS foam 2011]. HBCD is not manufactured in Germany. It was stopped in 1997 [ECB 2008]. HBCD is imported to Germany and possibly also exported. Eurostat and the Federal Statistical Office have no specific data on the production and trade of HBCD.

Use

Globally, HBCD has been used since the 1960s. The main application, as flame retardant in foam insulation panels, began in the 1980s [UNEP/POPS/POPRC.6/10]. The first recorded use dates from 1957 in a family house in Berlin (see [Dämmstoffindustrie 2013a]). HBCD is used exclusively as an additive flame retardant [IOM 2008], which is not bound to the plastic matrix. Currently, the main application is in the plastics and textile industries. HBCD can be used as a single substance or in combination with other flame retardants, such as antimony trioxide and decabromodiphenyl ether. HBCD is used in four relevant product types:

- as coarse-pored foam or EPS, e.g. as rigid insulation panels,
- as fine pore foam or XPS which mainly serve as rigid insulation panels in construction,
- as HIPS for audio and visual equipment, distribution boxes for electrical lines in the construction sector and refrigerator lining, and
- as polymer dispersion for textiles [ECB 2008].

In polystyrene foams HBCD is usually used as a single flame retardant without additives [PS foam 2011].

According to the plastics industry, HBCD was mainly (i.e. 90 %) used in polystyrene (PS). The main application is in EPS and XPS foam panels for the construction sector. Around 2 % of the total amount of HBCD is used in HIPS. Examples of HBCD-containing EPS and XPS products are EPS and XPS insulation panels used in the construction sector (for inside and outside applications) to avoid frost damage on the roads and rails, for transport vehicles and to a lesser extent for packaging materials (excluding food packaging). HBCD-containing HIPS products are audiovisual equipment (video and stereo equipment), distribution boxes for electrical wiring in the building sector and refrigerator lining. In the textile sector, HBCD is used as a coating agent in polymer dispersions for cotton and synthetic fabrics, for example, for furniture, mattresses, curtains, home textiles, etc. There are also reports on the use of HBCD in polypropylene (PP), in styrene-acrylonitrile copolymer resins (SAN resins), polyvinyl chloride (PVC), as well as unsaturated polyesters, adhesives and coatings. Whether these applications are relevant in Europe is not entirely clear [ECB 2008].

EPS waste may be introduced as granules also to improve soil properties (see [UNEP/POPS/POPRC.6/10] and [Vogdt 2009]. According to the industry association Industrieverband Hartschaumstoff e.V. (IVH), this area of application goes far back into the past. For years, the production and processing technology has been designed in order to feed EPS residues automatically in the production processes during the production cycle. Therefore, no waste is generated during the EPS-production, which would need to be recycled externally. The members of the IVH association usually do not market EPS residues for soil improvement. For this purpose ecologically and economically viable alternatives are available.

HBCD-containing EPS, XPS, HIPS products and polymer dispersions for the textile coating are listed in [IOM 2008]:

EPS:

- panels/insulation panels in the construction industry
- car seats
- rigid packaging for sensitive equipment (marginal use)
- packaging material such as “chips” and moulded EPS parts (marginal use)
- props for theatre, film and exhibitions (marginal use)

Car seats, rigid packaging for sensitive equipment and packaging material from moulded EPS parts are considered to have little relevance by the EU PS foam industry. Improper disposal could result in relevant releases of HBCD [PS foam 2011]

XPS:

- cold bridge insulation
- sandwich panels and laminates
- cavity insulation
- floors
- basement walls and foundations
- flat roof insulation
- ceiling insulation

HIPS:

- audio and visual equipment
- distribution boxes for electrical lines in the construction sector
- refrigerator lining

HBCD is used in polymer dispersion on an acrylic or latex basis with different viscosity. HBCD particles for textile coating must be very small. HBCD-containing formulations are available as water-based dispersions with binder and up to 20 other substances. The dispersions are used in the textile processing industry for the following products:

- upholstered furniture
- seating in transportation
- curtains and drapes
- mattresses ticking
- home textiles (e.g. blinds)
- automotive textiles and car upholstery

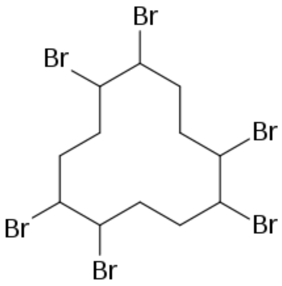
In conclusion, the main applications are in the plastics and textile industries. HBCD is used in four major product types: XPS, EPS, HIPS and polymer dispersions for textiles. The main use of HBCD (90 %) at EU level is in EPS and XPS in the construction industry. About 2 % of the total consumption of HBCD is used in HIPS for electronic products and articles. The remaining quantity of about 6 % is used in EPS and XPS for packaging and insulation panels for transportation vehicles. About 2% is currently used in the textile coating for upholstery fabrics, mattresses, curtains, wall coverings and home textiles (see [ECB 2008] and [CPAN 2010]. In Germany, the use of HBCD in upholstery fabrics, mattresses, curtains, wall coverings, etc. is limited to specific institutions e.g. theatres, concert halls, cinemas, other public places, etc.

The use of EPS and XPS in the construction sector is the only current application in Germany where significant amounts of HBCD are used. According to estimates, the amounts used in 2012 are likely to amount to approximately 2,700 t (see Table 31). Since 2013, HBCD is being substituted in this application and will be completely replaced by August 2015.

3.2.2 Chemical characteristics

Molecular formula:	HBCD	$C_{12}H_{18}Br_6$
CAS number:	HBCD	25637-99-4[16]
Molar mass	HBCD	641.73 g/mol

Figure 10: Structural formula of HBCD



There are 16 isomers of HBCD which differ in the spatial arrangement of six covalent bonds of bromine substituents (see Figure 8). In technical products α-, β- and γ-isomers occur. A distinction is made between high and low melting HBCD. The distribution of α-, β- and γ-isomers in technical HBCD varies between 70-95 % of γ-HBCD and 5-30 % of α- and β-HBCD [Swerea 2010]. Low melting HBCD contains 70-80% of γ-HBCD and 20-30 % of α- and β-HBCD. High melting HBCD contains 90 % or more of γ-HBCD. Commercial HBCD is present as a white solid.

Detailed information on the chemical characterisation of HBCD is available in the Stockholm Convention Risk Profiles (see [UNEP/POPS/POPRC.6/13/Add.2], section 1.1).

3.2.3 Legal background

Waste treatment

According to Annex VII of the Directive 2012/19/EU of the European Union and the Council on waste electrical and electronic equipment on the selective treatment of materials and components of electrical and electronic equipment, referred to in Article 8 (2), plastics containing brominated flame retardants have to be removed from any separately collected waste electrical and electronic equipment.

Restrictions on placing on the market and use

HBCD is listed as a PBT substance in Annex XIV (List of substances subject to authorisation) of the REACH Regulation (EC) No 197/2006 coming into force on 21 February 2006 and expiring on 21 August 2015 without any exemptions. After the expiration date, placing on the market and use of the substance shall be banned, unless it has been authorised for a particular use. It should be noted that under Article 56(6) (a) the authorisation is not required for PBT substances such as HBCD in case it is present in preparations with a concentration limit of below 0.1 % by weight.

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[16] There is another CAS number for the same substance: 3194-55-6

HBCD and all relevant isomers (CAS No 25637-99-4, 3194-55-6, 134237-50-6, 134237-51-7, 134237-52-8) are identified as “substances of very high concern” (SVHC) due to their PBT properties and accordingly are added to the Candidate List from 28 October 2008 (Decision number ED/67/2008). Further this leads to certain obligations in the REACH Regulation laid down in Article 7.2 (inform ECHA), Article 7.3 (appropriate instructions to the recipient), Article 31.1 (provide a safety data sheet) and Article 33 (duty to communicate information on substances in articles).

In May 2013, a global ban on HBCD was decided at the Conference of the Parties to the Stockholm Convention ([UNEP/POPS/COP.6/33], Decision SC-6/13). In October 2013, the decision entered into force and all parties (including the EU and all Member States) had an obligation to implement it by October 2014, unless a party relies on Article 22(3) (b) and chooses to temporarily withdraw (“opt out”) from the decision (Decision SC 6/13). In the case of HBCD, the Commission and Member States considered to temporarily cancel the decision until 21 August 2015 to avoid a legal conflict between REACH and the international obligations under the Stockholm Convention. After 21 August 2015 production, placing on the market and use of HBCD in the EU is banned under REACH, unless an authorisation is granted for a specific use (see above). The responsibility to decide for an “opt out” lies in the hands of the EU since HBCD is regulated under EU legislation (REACH). The EU Commission has the obligation to inform the Secretariat about the temporary cancellation of the decision (Decision SC-6/13). The Commission makes it clear that temporary cancellation is binding for both the European Union and Member States. Once the conflict between REACH and the Stockholm Convention no longer exists, the EU will adopt the decision (“opt in”). Currently, the Commission expects this to be possible in August 2015 [POP CA HBCD 2013]

According to information from the industry, an alternative for HBCD in EPS and XPS is available. The switch to the alternative has been in process since January 2013. It is assumed that HBCD will be no longer in use in EPS and XPS in Germany by August 2015 [VCI 2013].

The latest authorisation approvals can be found on the ECHA website[17]. The HBCD authorisation was recently published. [ECHA 2015]

Classification in accordance with the CLP Regulation

Reproductive toxicity, Category 2; H361[18]. Additional category for effects on or via lactation; H362[19]. Furthermore, HBCD is classified in the registration dossier that was submitted to the ECHA with the environmental hazard statement H410[20].

The classification of mixtures containing these substances results from Annex 1 of Regulation (EC) 1272/2008.

3.2.4 Occurrence (production, import/export, consumption, relevance of occurrence in Germany)

Trade

The EU consumption of HBCD was just under 10,500 t, with a slightly descending trend in 2010 (see Figure 9). The current HBCD consumption in the EU is therefore likely to be around 10,000 t/year. According to the European Flame Retardant Association (EFRA) 10,000 - 12,500 tonnes of HBCD were sold in 2011 (see [EFRA / VECAP 2012]). According to Albemarle the current demand in Europe

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[17] See http://www.echa.europa.eu/de/web/guest/addressing-chemicals-of-concern/authorisation/applications-for-authorisation

[18] „Suspected of damaging fertility or the unborn child“

[19] „May cause harm to breast-fed children“

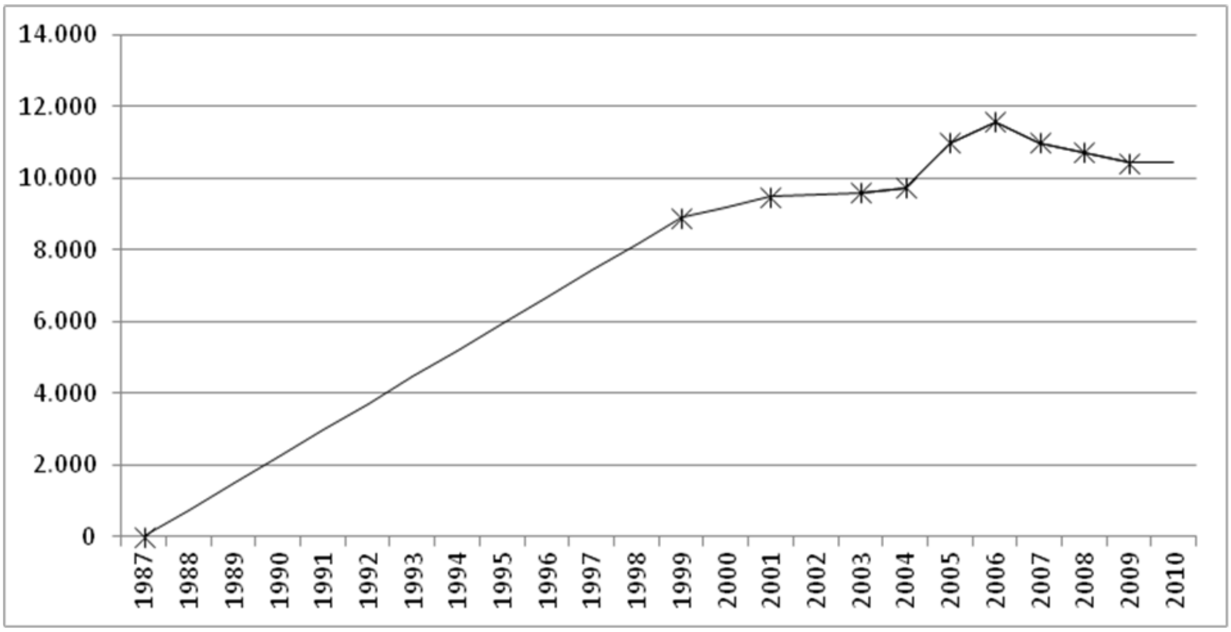
[20] „ Very toxic to aquatic life with long lasting effects“

(Europe consisting of Western and Eastern Europe) and the Middle East is about 12,400 t (40 % of the world total of 31,000 t). Specific data on the import and export of HBCD is not available. Assuming that the production volume of HBCD in the Netherlands continues to be stable at 6,000 t/year, the import (as a technical HBCD or as a concentrated premix) into the EU is likely to be at least 4,000 t/year. HBCD is not manufactured in Germany and is solely imported.

Use

Figure 9 illustrates the assessed consumption of HBCD in Europe, starting from late 1980s until 2009.

Figure 11: Assessment of HBCD consumption in tonnes in Europe from late 1980s to 2009 [BiPRO 2011]



The listing of HBCD under the Stockholm Convention was adopted at the Conference of the Parties to the Stockholm Convention in May 2013. As a result, the use will be prohibited in the future.

During a side event on HBCD, held at 9th Persistent Organic Pollutant Review Committee (POPRC) Meeting in October 2013, possible alternatives were presented[21], comments from users shared[22] and the implementation status in Canada, the EU and the USA were discussed.

Chemtura, Albemarle and ICL-IP produce under Dow's license a brominated polymer as an alternative flame retardant to HBCD. The licensees are currently expanding their production capacities assuming that the globally annually required quantity of HBCD amounting to about 31,000 tonnes can be substituted betimes. Chemtura already sells the alternative for EPS and XPS applications among others in the EU and believes that the alternative is suitable and economically available. Green Chemicals presented the current status with regard to another alternative to HBCD.

Users, such as INEOS Styrenics, are concerned whether suitable alternatives will be timely and economically available. INEOS Styrenics assumes that the sufficient quantity, produced by the licensees, will only be available from 2018 (see Figure 10, taken from the presentation of Stephen Long, INEOS Styrenics, at the HBCD side event at 9th POPRC).

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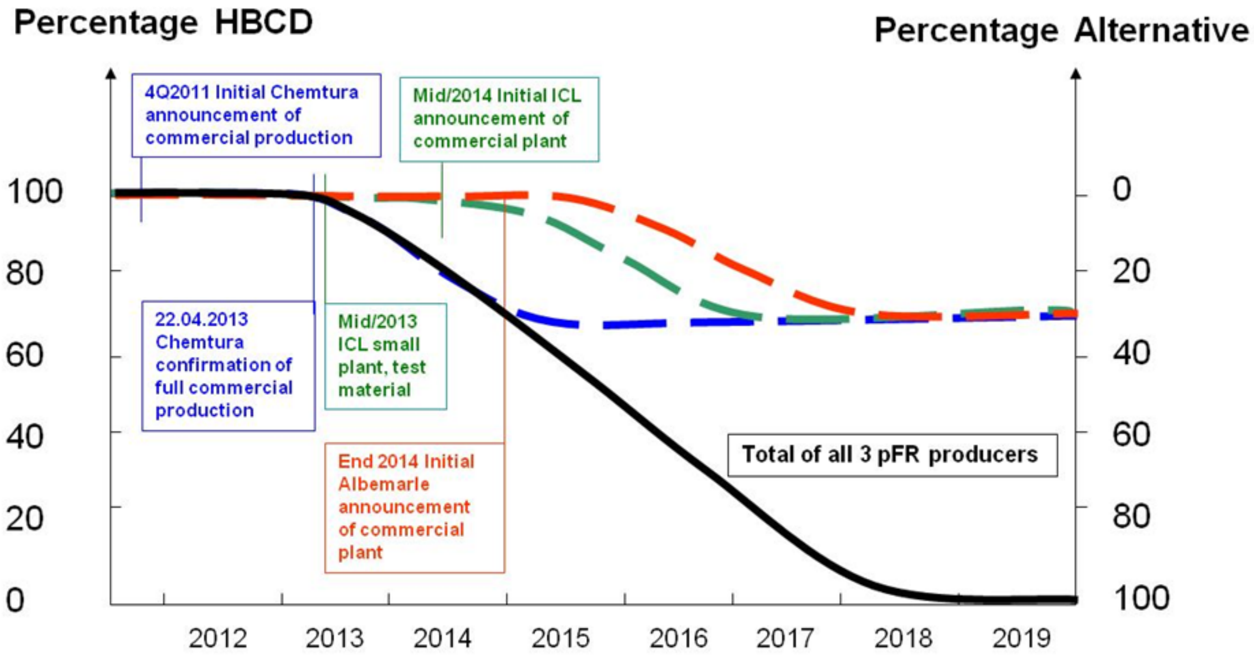
[21] From the following producer: Chemtura, Albemarle, ICL-IP, GreenChemicals

[22] From the following user: INEOS Styrenics, BASF, Dow Building Solution, Synthos SA, Isochemical, Sirap Insulation, Kaneka Corporation, Knauf insulation, Flint Hills Resources

Figure 12: Assessment of the availability of the brominated flame retardant polymer as an alternative to HBCD (Figure taken from presentation of Stephen Long, INEOS Styrenics, October 2013)



INEOS Styrenics concludes that the substitution of HBCD is possible, however, the use of HBCD in Europe over a period of 5 years (after August 2015) should be permitted to enable the substitution, while ensuring the availability of the final products.

Synthos assumes that HBCD may be substituted by 2019 with the brominated polymer and announced the authorisation for the further use of HBCD.

In general, the users consider the brominated polymer as a suitable alterative (partly with restriction):

- Dow Building Solutions will use it exclusively in its products before August 2015;
- Flint Hills switched completely to the brominated polymer;
- Apyros believes that the Chemtura´s brominated polymer is suitable for the production of flame-retardant granules for XPS;
- Kaneka (Japan) has substituted HBCD in EPS. In XPS, the substitution will take place in 2014 (limitation: the price of the alternative is acceptable but slightly higher; the resistance to light of the alternative is lower)
- Knauf Insulation indicated that the substitution is technically possible, however there are cost increases (higher demand and higher price)

In Germany, HBCD is used in particular as a flame retardant in polystyrene in construction. The amounts used in the past and currently relevant applications are shown in Table 31 for the period 1988 to 2016.

Table 24 shows the quantities of PS and PS-E waste generated in Germany in 2011:

Table 28: PS and PS-E waste generated in Germany in 2011 [Consultic 2012]

Plastics	Generated waste total (kt)	Post-Consumer share (kt)	Producer share (kt)	Processor share (kt)
PS	285	252	~2	30
PS-E	111	83	~3	25

In total plastic waste from electrical and electronic sector amounted to 241 kt in 2011 (amongst others PS including HBCD-containing HIPS), [Consultic 2012]. The proportion of HBCD-containing HIPS is not known.

The total plastics waste in the construction sector in 2011 was 372 kt [Consultic 2012]. The amount of generated PS-E waste from the building sector is unclear. Data for the amounts of EPS insulating materials from the demolition or restoration are not available. Currently, the German insulation industry assumes that the removal rate of the insulation in thermal insulation composite systems is less than 1 ‰ of the annually used quantity of such systems (see [Dämmstoffindustrie 2013a]). Based on the project results (see below), it is estimated that around 23 kt/year (EPS) and 3 kt/year (XPS) of waste is generated from demolition and restoration.

Typical levels of HBCD used in German products are 0.7 % for EPS and 1.5 % for XPS. The substitution of HBCD started since January 2013. HBCD should no longer be used by August 2015.

Across the EU, HBCD is used for the production of EPS and XPS in approximately equal proportions (48 % EPS and 52 % XPS). In Germany, the share of EPS is around 64 % and XPS around 36 % (reference year 2012).

The production takes place at 5 production sites (see [UBA 2009]). According to [PlasticsEurope 2012] the production of PS foams takes place at 4 sites (Leuna/Schkopau, Ludwigshafen, Marl and Wismar). Additionally, PS foam is produced at one more site (Schwarzheide; see [BASF 2012a]).

Table 25 contains the calculated domestic consumption of EPS in Germany for the years 2006 to 2011.

Table 29: Domestic consumption of expandable polystyrene in primary forms in tons calculated from the production in Germany (Source: EUROSTAT, Production category 20.16.20.35), import to and export from Germany (Source: Federal Statistical Office, CN Category 39)

Year	Import (I) (in t)	Production (P) (in t)	Export (E) (in t)	Domestic consumption (I+P-E) (in t)
2006	98,620.6	485,728.0	0.0	584,348.6
2007	116,528.7	475,606.0	0.0	592,134.7
2008	112,487.4	494,589.0	0.0	607,076.4
2009	135,953.1	451,308.0	0.0	587,261.1
2010	148,277.8	535,395.0	0.0	683,672.8
2011	150,397.9	545,033.0	0.0	695,430.9

Expandable polystyrene is used in primary moulds for the production of EPS and XPS. Due to fire regulations in Germany, insulation panels for the construction industry in general must be flame retardant. Typically, the flame retardance is achieved by using HBCD in concentrations of 0.7 % (EPS) and 1.5 % (XPS). Partly the flame retardance for packaging is also ensured by using the same concentrations in EPS/XPS. The use of XPS for packaging is insignificant. It is possible that flame retarded HBCD-containing EPS/XPS packaging is imported (usually together with the contained products) and enters the waste streams in Germany. No specific information is available.

The Federal Statistical Office has export and import data for „boards, platters, among other things made from polymers of styrene“ available. It can be assumed that this category is mainly constituted of EPS and XPS panels. A differentiation in EPS and XPS panels is not possible. The German trade balance indicates around 23,516 tonnes of export surplus in 2012. Table 26 illustrates this export surplus for the years 2006 to 2012.

Table 30: German export surplus including boards, platters, of styrene polymers (WA39211100; Source: Statistics Office, query 392111 PS platters A-export DESTATIS 51000-0016)

Year	Export surplus (in t)	EU export surplus (in t)	Extra EU export surplus (in t)
2006	36,862.9	24,698.5	12,164.4
2007	39,375.2	24,556.5	14,818.7
2008	44,141.9	28,443.9	15,698.0
2009	39,382.4	26,458.5	12,923.9
2010	37,166.3	24,847.1	12,319.2
2011	29,133.9	16,614.2	12,519.7
2012	23,516.1	11,424.2	12,091.9

Imports from EU Member States where non-flame-retarded EPS and XPS panels are used occur only to a very limited extent.

3.2.5 Selection of relevant products, wastes and recyclates in Germany

3.2.5.1 Development and situation in Europe

In conclusion, the main applications are or were in the plastics and textile industries. HBCD is or was used in four major product types: PS foams (XPS, EPS), HIPS and polymer dispersions for textiles. Only a certain percentage of the corresponding products contain HBCD. For example, about 77% of EPS and XPS insulation panels used by the construction industry in the EU contain HBCD as flame retardant. In Germany, this value is close to 100%. Table 27 presents the different product types and products with their relevance regarding use of HBCD in the EU.

Table 31: Product types, products and relevant use of HBCD in the EU according to different sources

Product type	EPS	XPS	EPS	XPS	HIPS	Polymer-dispersion
Product	Insulation panels for the construction industry		Other products (e.g. packaging)		Electronic products and articles	Textiles
ECB 2008	< 90%		n.a.		2%	~ 10% in 2003
IOM 2008	Main use				2% in EU 15 2000 - 2004	2% in 2007
	48% in 2006	52% in 2006				
POPRC.6/10	Main use				2%	2%

SWEREA 2010[23]	96.4%	1.8%	1.8%

The main use of HBCD in the EU (90 %) is in EPS and XPS for the building sector followed by 6 % of EPS and XPS insulation panels used for transportation vehicles, packaging and other applications. HBCD is used for XPS in slightly higher amounts than for EPS (approximate ratio 52:48[24]). About 2 % of the total consumption of HBCD is in HIPS for electronic products and articles. Around 2 % is used in textile coating for upholstery fabrics, mattresses, curtains, wall coverings and home textiles (see [ECB 2008] and [CPAN 2010]).

The relative importance of HBCD consumption in the EU for textiles has changed over time. Since 2007, the consumption is around 2 % of the total consumption (see [IOM 2008], [POPRC.6/10], [Swerea 2010]). In 2003, the share was about 10 % (see [ECB 2008]). According to [IOM 2008], it is assumed that the consumption for textiles has significantly dropped and that according to industry information in 2007 around 2 % or a little more than 200 tonnes was consumed for textiles.

Table 28 shows the estimated HBCD consumption in tonnes in the EU in the relevant uses for the period from 1988 to 2010.

Table 32: Estimated HBCD consumption in tonnes in the EU for the period 1988 to 2010 ([BiPRO 2011] based on [ECB 2008], [Nordic COM 2007], [IOM 2008], [PS foam 2011])

Year	Total consumption (in t)	EPS in construction sector	XPS in construction sector	EPS/XPS for other applications	HIPS for electronic products	Polymer-dispersions for textiles
1988	742	291	321	41	15	74
1989	1,483	583	641	82	30	148
1990	2,225	874	962	122	45	223
1991	2,967	1,165	1,282	163	59	297
1992	3,708	1,456	1,603	204	74	371
1993	4,450	1,748	1,924	245	89	445
1994	5,192	2,039	2,244	286	104	519
1995	5,933	2,330	2,565	326	119	593
1996	6,675	2,621	2,886	367	134	668
1997	7,417	2,913	3,206	408	148	742
1998	8,158	3,204	3,527	449	163	816
1999	8,900	3,495	3,847	490	178	890
2000	9,200	3,613	3,977	506	184	920
2001	9,500	3,731	4,107	523	190	950
2002	9,550	3,750	4,128	525	191	955
2003	9,600	3,770	4,150	528	192	960
2004	9,750	3,916	4,311	548	195	780
2005	11,000	4,516	4,971	633	220	660
2006	11,580	4,858	5,347	680	232	463

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[23] Calculated based on Table 7 in [SWEREA 2010]

[24] Calculated based on consumption data for XPS and EPS in [IOM 2008] for the period 2002 to 2006 (52.36% use of XPS and 47.64% use of EPS)

Year	Total consumption (in t)	EPS in construction sector	XPS in construction sector	EPS/XPS for other applications	HIPS for electronic products	Polymer-dispersions for textiles
2007	11,000	4,712	5,188	660	220	220
2008	10,733	4,598	5,062	644	215	215
2009	10,439	4,472	4,923	626	209	209
2010	10,439	4,472	4,923	626	209	209

The product lifetime is of crucial importance when estimating the presence of HBCD in products, waste streams and recyclates. Various sources ([Morf et al. 2007], [EBC 2008], [PS foam 2011]) were considered in [BiPRO 2011] to estimate the average product lifetimes and ranges for the most relevant applications of HBCD. Only after the product´s lifetime, the products are disposed of as waste and cause contamination of waste streams and possibly recyclates. Table 29 gives an overview of the relevant average product lifetimes and ranges.

Table 33: Average product lifetimes and ranges in years for the most relevant applications of HBCD [BiPRO 2011]

Application	EPS/XPS in construction sector	EPS/XPS in other applications	HIPS for electrical equipment	Polymer dispersions for textiles
Product lifetimes (in years; range in brackets)	50 (+/-25)	0 - 20	9 (+/-5)	10 (+/-3)

In a UFOPLAN project, the following lifetimes for buildings are considered: 2% - 30 years; 40% - 50 years, 30% - 70 years, 20% - 90 years, 8% > 90 years (see [UBA 2013]). Taking into account that in that project lifetimes of buildings are considered, and that PS foams also incur prior to the demolition of buildings in renovation, the maximum of 50 years for the service lifetime, 50 +/- 25 years for the generation of PS foams from demolition and renovation are considered as an appropriate basis for a long-term prognosis.

The wide range of lifetimes for other applications of EPS/XPS relates to a broad range of relevant products (e.g. packaging, car seats, theatre props). These other applications are heavily dominated by packaging, which is usually disposed of immediately after use and therefore contributes by far most to the generation of waste within one year after use.

For the estimation of HBCD levels, finally entering waste streams, the amounts must be corrected by the emissions that occur during manufacture and use. Emissions are usually low. Emission factors for the relevant applications of HBCD were calculated in [BiPRO 2011]. The emissions for the different product categories can be estimated on the basis of specific emission factors.

The amount of HBCD present in the waste and recycled materials depends on HBCD concentrations used in the various products. Table 30 gives an overview of typical HBCD concentrations for the relevant product categories on the basis of different information sources.

Table 34: HBCD concentration in different product categories

Product category	HBCD content (in%)	A (a) Max (b) R (c)	Reference	Remark
EPS products	0.7	a	[CeficEfra 2006]	
EPS products	0.7	b	[IOM 2008] [ECB 2008]	

Product category	HBCD content (in%)	A (a) Max (b) R (c)	Reference	Remark
EPS products	0.7		[CPAN 2010]	
EPS products	0.7 - 1.0		[Morf et al. 2007]	
EPS products	0.51	a		Average concentration calculated based on [PS foam 2011]
XPS products	2.5	a	[CeficEfra 2006]	
XPS products	2.0		[CPAN 2010]	
XPS products	1.5		[Morf et al. 2007]	
XPS products	1.0 – 3.0	c	[ECB 2008]	
HIPS products	1.0 – 3.0	c	[ECB 2008] [IOM 2008]	
HIPS products	5.0 – 7.0	c	[ECB 2008] [IOM 2008]	7% were used in the EU Risk Assessment Report as a „worst case“ (see [ECB 2008])
Textile products	5 – 48		[ECB 2008] [IOM 2008]	Content in the polymer dispersion (the content of the ready-dilution is about 15%)
Textile products	~ 25		[ECB 2008] [IOM 2008] [Morf et al. 2007] [Swerea 2010]	Content in coating
Textile products	7 – 9	c	[Morf et al. 2007]	Contamination of treated textiles
Textile products	2.2 – 4.3	c	[UNEP/POPS/POPRC .6/10]	Contamination of treated textiles in upholstered furniture from Japan
Treated textiles	6 – 15	c	[CeficEfra 2006]	

(a)= Average, (b) = Maximum, (c) = Range

For the calculation of the substance and mass flows in Germany, the following average HBCD concentrations are used (see Table 30):

- EPS products: 0.7 %
- XPS products: 1.5 %
- EPS and XPS products without differentiation: 0.7 %[25]
- HIPS products: 4 %
- Textiles: 25 % in coatings; 8 % in treated textiles

Figure 11 illustrates the importance of HBCD consumption for the relevant product categories in Europe. The consumption in the EU is estimated to about 10,500 t/year (reference year 2009), [BiPRO 2011].

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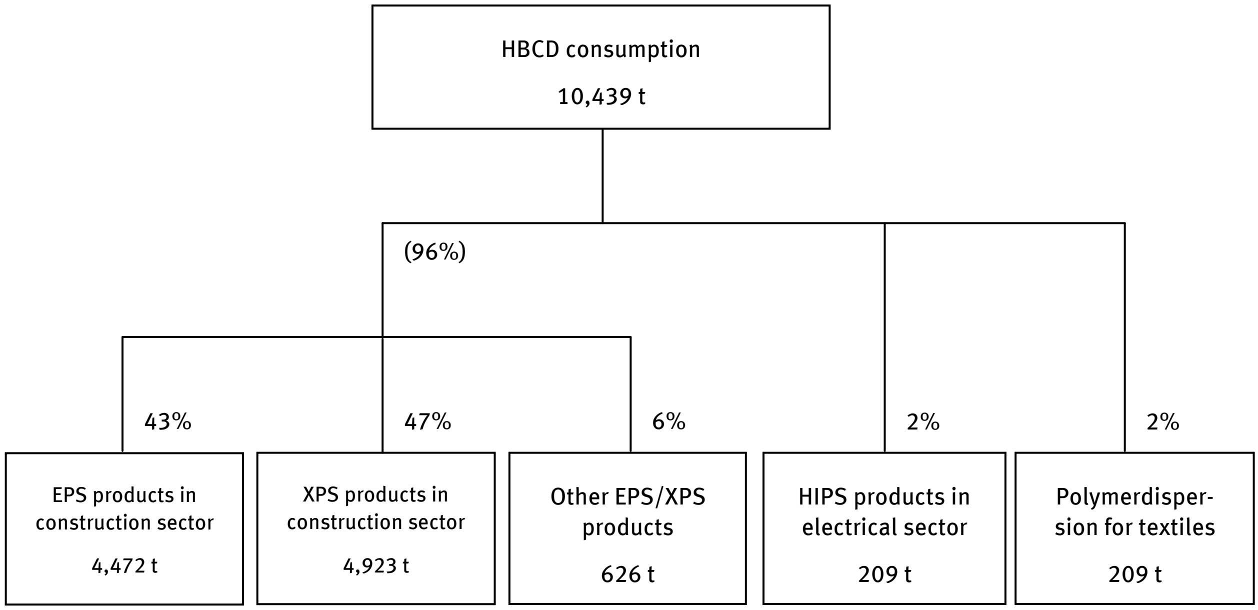
[25] In this category EPS products with 0.7% HBCD content dominate

Figure 13: Importance of the relevant product categories with respect to the HBCD consumption in the EU (reference year 2009; see BiPRO 2011)



At EU level in 2009, the consumption of EPS and XPS was around 96 % of the total consumption. 2 % were used for each, the HIPS applications and polymer dispersion (PD) for textiles.

The use of HBCD in HIPS and polymer dispersions for textiles has declined in recent years and therefore the use in EPS and XPS remains the only relevant application (see [ECHA 2013a]).

3.2.5.2 Development and situation in Germany

Based on historic, current and forecasted use levels and emissions it can be estimated which quantities of HBCD have already incurred as waste and will in future arise as waste. Corresponding calculations for EU 27 are available in [BiPRO 2011]. Calculations and estimates for Germany show that the situation is not significantly different from the European and that by far the biggest share of HBCD-containing waste will occur in the future. In particular, the application in the construction sector with relatively high use levels and very long product lifetimes is crucial.

In the context of this project and in consultation with the German Federal Environment Agency, it was decided that due to high relevance of PS foams in the construction sector, EPS and XPS waste and recyclates from the construction sector, will be chemically analysed for their HBCD content. To this end, samples of insulating materials were procured from construction and/or recycling sector companies and were analysed during the project period (No. 1 HBCD: XPS insulation material samples from the building sector; No. 2 HBCD: EPS ground material from insulation material from the building sector; No. 5 HBCD: recyclate from PS-E insulating material). The results of the chemical analyses and a discussion of the results are included in section 5.3.

In other EPS and XPS relevant applications that are dominated by the packaging, HBCD is already no longer used in Germany. Due to the short product lifetime, HBCD could possibly enter the waste streams in Germany through import. To determine possible HBCD levels from the packaging sector, it was decided in consultation with the Environmental Protection Agency to carry out chemical analyses of samples from this sector (No. 8 HBCD: EPS-mixed packaging waste; No. 9 HBCD: PS-E ground material from packaging; No. 10 HBCD: recyclate from PS-E packaging; Nr. 12 HBCD: recyclate from PS-E packaging; Nr. 12b HBCD: recyclate from PS-E packaging). The results of the chemical analysis and a discussion of the results are given in section 5.3.

The same applies for the use of HBCD in HIPS in the electrical sector. There is no specific information that HBCD is still used in this area (however, the current use cannot be excluded). In the waste sector HBCD-containing HIPS from electrical equipment can occur due to previous use and imports. To determine possible HBCD levels, it was decided in consultation with UBA to carry out chemical analyses of samples obtained from recycling companies (No. 13 HBCD: bromine-containing waste from electrical and electronic equipment; No. 13b HBCD: PS recyclate from waste electrical and electronic equipment (WEEE). The results of the chemical analyses and a discussion of the results are given in section 5.3.

It is also believed that HBCD is no longer used in the textile sector in Germany since 2007. Already in the years before the use levels have declined. Correspondingly there is limited possibility that the relevant products occur in waste. Again, imports could play a role. Chemical analyses were not carried out during the project due to the low relevance.

In Germany, according to recent information, HBCD is currently neither used in packaging (at EU level around 6 %[26]) nor in the textile sector[27] (at EU level around 2 %). There is also no specific evidence that HBCD is still used in HIPS in the electrical equipment sector[28] (at EU level around 2 %). However, the use cannot be ruled out.

The insulation industry has provided specific consumption data of HBCD in EPS and XPS within the construction sector in Germany (see Table 31). No specific figures are available for the period from 1960 to 1980 (the first use for the exterior insulation system in a family house in Berlin was documented in 1957; see [Dämmstoffindustrie 2013a, Dämmstoffindustrie 2013b]). The following table shows the estimated quantities for the use from 1988 to 2016, assuming that HBCD was used in similar ratios as in the EU. It is assumed that in Germany HBCD is no longer used in the textile sector since 2007 and in electrical equipment and other EPS/XPS applications since 2012 (see Table 31).

Table 35: Estimated HBCD consumption in tonnes in Germany for the period from 1988 to 2016 for the relevant applications*

Year	Total consumption (in t)	EPS in construction	XPS in construction	EPS/XPS for other applications	HIPS for electrical products	Polymer dispersions for textiles
1988	947	673	228	15	5	27
1989	1,030	689	248	29	11	53
1990	1,112	705	267	44	16	80
1991	1,283	805	292	59	21	106
1992	1,478	904	342	73	27	133
1993	1,669	1,004	386	88	32	160
1994	1,959	1,198	436	102	37	186
1995	2,081	1,238	470	117	43	213
1996	2,146	1,242	485	132	48	239
1997	2,337	1,312	559	146	53	266

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[26] The use of HBCD in packaging accounts for the major part of expandable PS in non-construction sector.

[27] In the textile sector HBCD is no longer according to the German association of producers of textile, paper, leather and fur auxiliaries and colourants, surfactants, complexing agents, antimicrobial agents, polymeric flocculants, cosmetic raw materials, pharmaceutical excipients and allied products (TEGEWA) since 2007.

[28] According to the ZVEI, the member survey did not reveal any detailed information to answer the questions. There is no concrete evidence that HBCD is still used. However the use cannot be ruled out.

Year	Total consumption (in t)	EPS in construction	XPS in construction	EPS/XPS for other applications	HIPS for electrical products	Polymer dispersions for textiles
1998	2,433	1,297	624	161	59	293
1999	2,489	1,297	634	176	64	319
2000	2,608	1,348	683	181	66	330
2001	2,543	1,274	673	187	68	341
2002	2,476	1,216	661	188	68	342
2003	2,469	1,203	663	189	69	344
2004	2,438	1,174	718	197	70	280
2005	2,383	1,135	706	227	79	237
2006	2,702	1,456	753	244	83	166
2007	2,415	1,276	817	241	80	0
2008	2,583	1,452	817	236	79	0
2009	2,665	1,543	817	229	76	0
2010	2,865	1,668	891	229	76	0
2011	3,025	1,738	981	229	76	0
2012	2,687	1,708	979	0	0	0
2013	2,015	1,281	734	0	0	0
2014	1,344	854	490	0	0	0
2015	672	427	245	0	0	0
2016	0	0	0	0	0	0

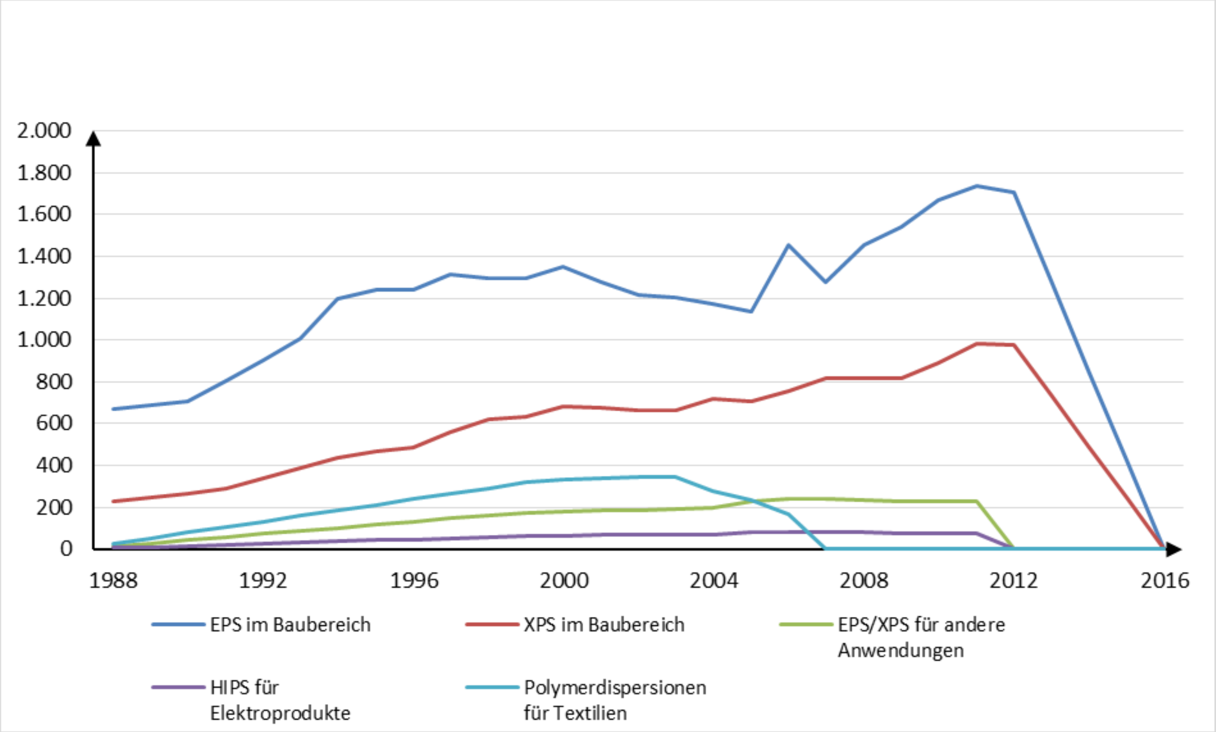
*(EPS in construction/XPS in construction calculated based on [Dämmstoffindustrie 2013a] and [Dämmstoffindustrie 2013b], further applications calculated based on Table 28 considering current information; explanations in the text)

From 1988 to 2012 in Germany the total amount of HBCD consumed was 54,823 t. Due to the substitution in the construction sector, which started at the beginning of 2013 and the legislative framework, the consumption has already declined and should be stopped by autumn 2015. At a linear reduction of the consumption quantities of EPS and XPS in the construction sector from 2012, the use in the period from 2013 including 2015 could be still 4,031 t. Thus, for the period from 1988 to 2016 the total amount of HBCD consumed is 58,854 t. The individual applications contribute to this total tonnage as follows:

▸ EPS in construction:	33,117 t
▸ XPS in construction:	16,597 t
▸ EPS/XPS for other applications:	3,719 t
▸ HIPS for electrical products:	1,306 t
▸ Polymer dispersions for textiles:	4,114 t

Figure 12 illustrates the development of consumption in the relevant applications since 1988:

Figure 14: Estimate of HBCD consumption in the relevant applications in Germany from 1988 to 2016 (in tonnes)



Key to colours: EPS for construction displayed in dark blue, XPS for construction in red, EPS/XPS for other sectors in green, HIPS for electronics sector in purple, PD for textiles in light blue

Figure 12 illustrates that the EPS and XPS applications in the building sector, compared to the other three applications, have a higher relevance. For the latter, there is no further information on quantities consumed in Germany for the period before 1988.

Estimates for the EPS and XPS applications in the construction sector for the period from the 1960s going beyond Table 31 are available. According to information from the German insulation industry [Dämmstoffindustrie 2013a] the HBCD consumption in Germany for EPS was around 35,000 tonnes from 1981 to 2012 (HBCD content: 0.7 %). For the period from 1960 to 1980, the association does not have reliable data. However, the linear extension of the curve can be used to calculate the additional HBCD consumption for that period which was 5,000 tonnes. This can be used to calculate the amount of HBCD used in EPS between 1966 and 2016 which is around 42,830 tonnes. The calculated amount of XPS used in Germany from 1965 to 2012 according to [Dämmstoffindustrie 2013b] is over 35 million cubic meters. Because of the unclear import quantities and estimated numerical values for the period from 1966 to 1990, the estimated volume is 40 million cubic meters. This gives an average density of 33 kg/m^3 and the average HBCD content of 1.5 % of weight of HBCD used in XPS in around 19,100 tonnes (rounded to 20,000 tonnes) in the period between 1966 to 2016.

Table 32 shows how much HBCD in Germany (until 2012) was already incurred as waste and how much HBCD will incur as waste in the future (including 2013-2015). The figures have been calculated taking into account the product lifetimes in Table 29. Cut-offs and releases are not considered due to the low relevance in the following figure.

The non-construction related use of EPS/XPS is mainly influenced by use for packaging. Therefore, the expected products lifetimes in this sector (0-20 years; see Table 29) appears to be too long. Packaging is generally disposed of immediately after the use or within one year. Accordingly, the estimate of the future revenue from waste is also too high. It can be assumed, that currently estimated ranges for HBCD occurring in waste streams are not relevant and will not be relevant in the waste streams in the future. Packaging waste and construction waste must be kept separate to avoid cross-contamination from the building sector.

Table 36: Cumulated amounts of HBCD wastes from the estimated use quantities by 2015 (in tonnes)

Use	Total HBCD in waste (t)	Application after 2012 (t)	Application before 2012 (t)
EPS[1]	42,829	41,452	1,377
XPS[1]	19,102	18,780	322
EPS/XPS other	3,719	0	3,719
HIPS[2]	1,306	648	658
PD[2]	4,114	925	3,189
Total	71,070	61,805	9,265

[1] considering HBCD amounts from 1966

[2] considering HBCD amounts from 1988

The assessment demonstrates that the vast amount of HBCD is still present in products in circulation and will occur in the waste streams in the future. In particular, this is the case for EPS and XPS foams that have been used in the construction sector: firstly due to their long life time (50 +/- 25 years) and secondly due to the high use quantities of HBCD in this sector (in total about 60,000 t by 2015). In the textile sector, the situation is opposite: the majority of HBCD has already incurred as waste and only relatively small quantities are henceforth to enter the waste stream.

Based on the above shown average concentrations of HBCD in relevant products, the corresponding amounts of HBCD-containing waste can be estimated as listed in Table 33:

Table 37: Cumulated HBCD-containing waste quantities from the estimated use quantities for relevant applications (in tonnes)

Waste	HBCD amount in waste (in t)	HBCD concentration (in %)	Amount of waste (in t)	Application after 2012 (in t)	Application before 2012 (in t)
EPS products in construction	42,829	0.70	6,118,429	5,921,665	196,764
XPS products in construction	19,102	1.5	1,273,470	1,252,026	21,444
EPS/XPS other	3,719	0.70*	531,286	0	531,286
HIPS products	1,306	4.00*	32,650	16,200	16,450
Textiles	4,114	8.00*	51,425	11,563	39,863
Total	71,070		8,007,259	7,201,453	805,806

*currently no use

By far the largest HBCD and waste quantities are expected in the future and are expected to come from the construction industry. Depending on the lifetime of HBCD-containing products and the time of use, estimations can be made on how the annual quantities of HBCD in waste change over time and in what quantities HBCD is expected to occur in the waste streams in the future. Corresponding estimates for the annual amounts of HBCD from the relevant waste streams for the relevant applications are graphically shown below:

Figure 15: Estimation of the future annual occurrence of HBCD in EPS and XPS wastes from the building sector in the period 2014-2016 (in tonnes)

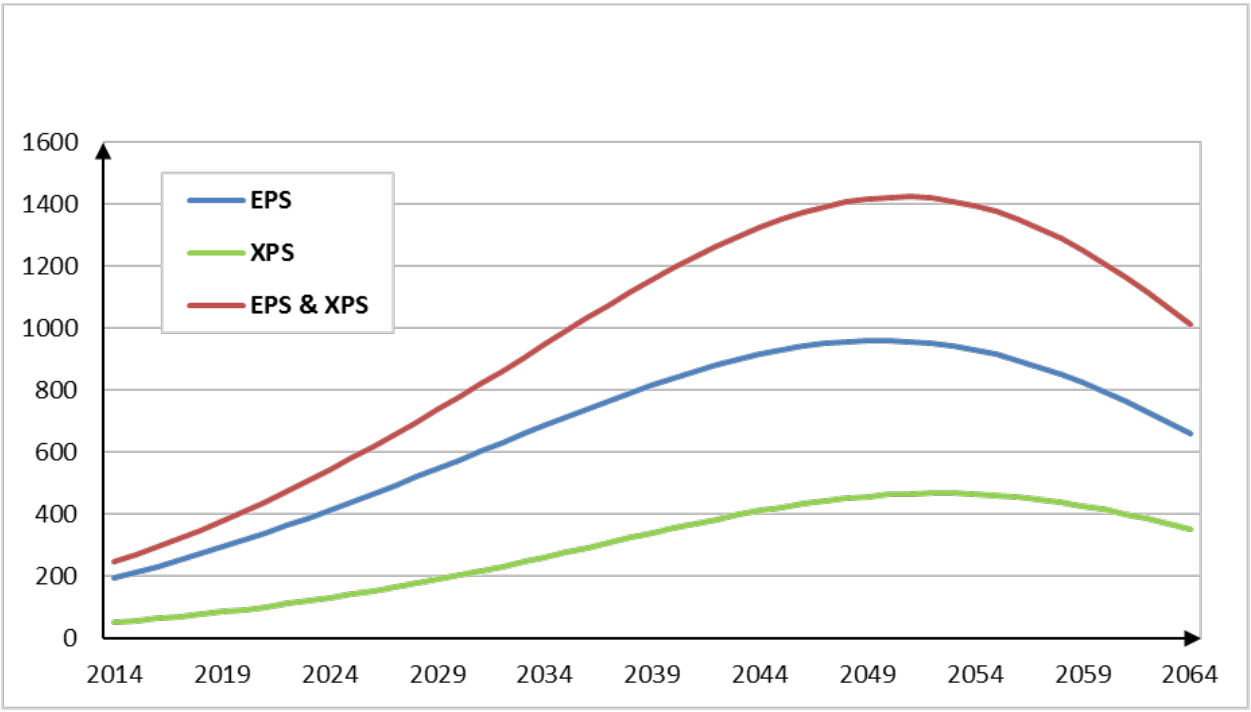


Figure 16: Estimation of the annual occurrence of HBCD in HIPS waste from the electronic equipment by 2027 (in tonnes)

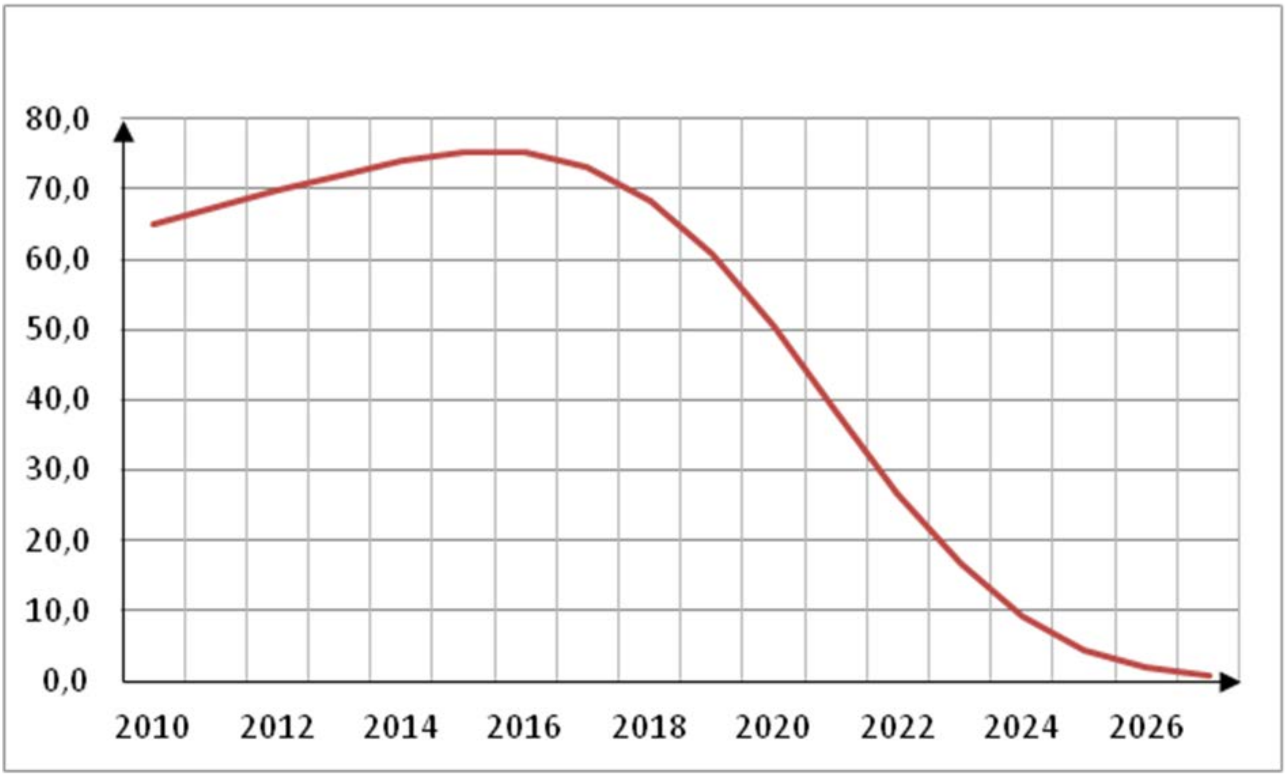
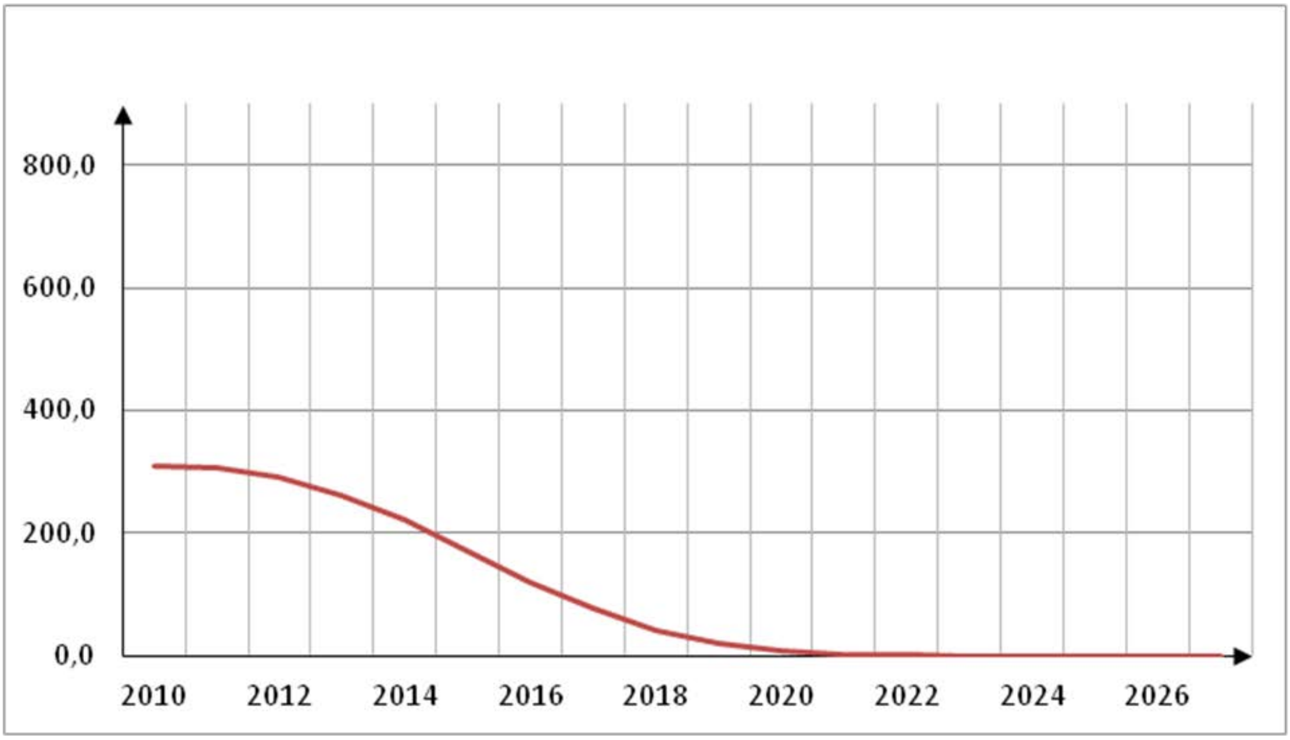


Figure 17: Estimation of the annual generation of HBCD in textile waste by 2020 (in tonnes)



The graphical representations (see Figure 13, Figure 14 and Figure 15) illustrate that even if HBCD is no longer in use or it will stop being used, the occurrence of the corresponding products in the waste streams will, depending on the product lifetime, last for a long time in the future. Moreover, it is clear that all uses are relevant in the project context. The relevance of EPS/XPS in other applications, HIPS in the electrical equipment and polymer dispersions in the textiles, is however irrelevant or has relatively low relevance compared to EPS/XPS applications in the construction sector.

The use of HBCD as flame retardants leads also to the occurrence of HBCD in sewage sludge. Available data show that the values in the UK and Ireland are approximately 10 times higher than the values in the other EU Member States (see Table 34). This is probably linked to the widespread use of HBCD flame retardants for textiles in the UK and Ireland. The washing of flame retarded textiles is seen as a major cause of the pollution of waste water with HBCD (see [DEPA 2013]).

Table 38: Overview of measured HBCD concentrations in sewage sludge

Country	Median	Unit	Source
Ireland	1,439	µg/kg DM	[ECB 2008]
UK	1,256	µg/kg DM	[ECB 2008]
Netherlands	21	µg/kg DM	[ECB 2008]
Norway	35	µg/kg DM	[ECB 2008]
Sweden	24	µg/kg DM	[ECB 2008]
Switzerland	149*	µg/kg DM	[DEPA 2013]

* Medium value

Quantities, disposal and utilisation of sewage sludge in Germany are shown in section 3.2.6. An assumption that the concentration of HBCD in sewage sludge in Germany is comparable to that in other European countries (except the UK and Ireland) can be used to estimate the HBCD load in sewage sludge. The average concentration measured in four European countries (NE, NOR, SE, SUI) is

57.2g/kg dry matter. Based on this concentration, it is calculated that the total volume of sewage sludge in Germany (1.89 million tonnes in 2010) contains around 108 kg/year of HBCD. This amount is distributed to disposal and recovery waste management operations as shown in Table 35. More than the half (53.2 %) of HBCD contained in sewage sludge should be destroyed by thermal disposal. About 30 % is used for agricultural purposes.

Table 39: Estimated distribution of HBCD streams in sewage sludge to disposal and recovery waste management operations in Germany in 2010

	Total sludge disposed	Use in agricul-ture	Agricultural building activities	Other recycling applications	Thermal disposal	Disposal
Amount (in t)	1,887,408	566,295	259,312	58,052	1,003,749	-
Share (in %)	100	30	13.74	3.08	53.18	-
HBCD load (in kg)	108.1	32.4	14.8	3.3	57.5	-

In 2013, a large scale experiment for the combustion of EPS and XPS in the municipal waste incinerator (MVA Würzburg) was carried out in Germany. In the test report, concentrations of HBCD in slag (“grate ash”), fly ash and filter residues were reported [Plastics Europe 2014]. The HBCD concentrations range from 1.22 to 2.66 µg/kg dw. They were in the similar range for slag (”grate ash”), fly ash and filter residues. Assuming that the average HBCD content in the combustion residue from municipal and hazardous wastes is 1.71 µg/kg, this would represent an annual load of 8.7 kg HBCD in over 5 million tonnes of combustion residues from municipal and hazardous waste incineration.

Table 36 gives an overview on the conclusions drawn regarding the relevance of possible HBCD occurrences.

Table 40: Conclusion on the relevance of possible occurrences (HBCD)

Possibly relevant occurrence	Assessment of the relevance
Expanded polystyrene foam (EPS) in construction	By 2015, high relevance in products and in the future due to the long lifetime for many decades in waste (about 160 t HBCD/year in 2012; about 960 t HBCD/year around 2050)
Extruded polystyrene foam (XPS) in the construction	By 2015, high relevance in products and in the future due to the long lifetime for many decades in waste (about 41 HBCD/year in 2012; approximately 460 t HBCD/year around 2050)
Use of EPS and XPS in non-construction	Currently no longer relevant in products; No longer relevant in waste due to limited lifetime of products (use mainly in packaging), (approximately 0.4 t HBCD/year in 2012) with further decreasing relevance
High Impact Polystyrene (HIPS)	Currently no longer relevant in products; former use in electrical products; compared to EPS/XPS minor relevance in waste (about 70 t per year in 2012 without further decreasing relevance). Imports could play a certain role in waste.
Polymer dispersions for Textiles	Since 2007 no longer relevant in products; until then the use was in the institutional sector (venues) and the automotive sector; due to the use quantity in Germany and the lifetime minor relevance in waste (approximately 290 t/per year in 2012 with further decreasing relevance)
Sewage sludge	Not relevant (currently approximately 0.1 t/a)
Combustion residues from waste incineration	Not relevant (currently approximately 0.01 t/a)

3.2.6 Expanded polystyrene foam (EPS) in construction

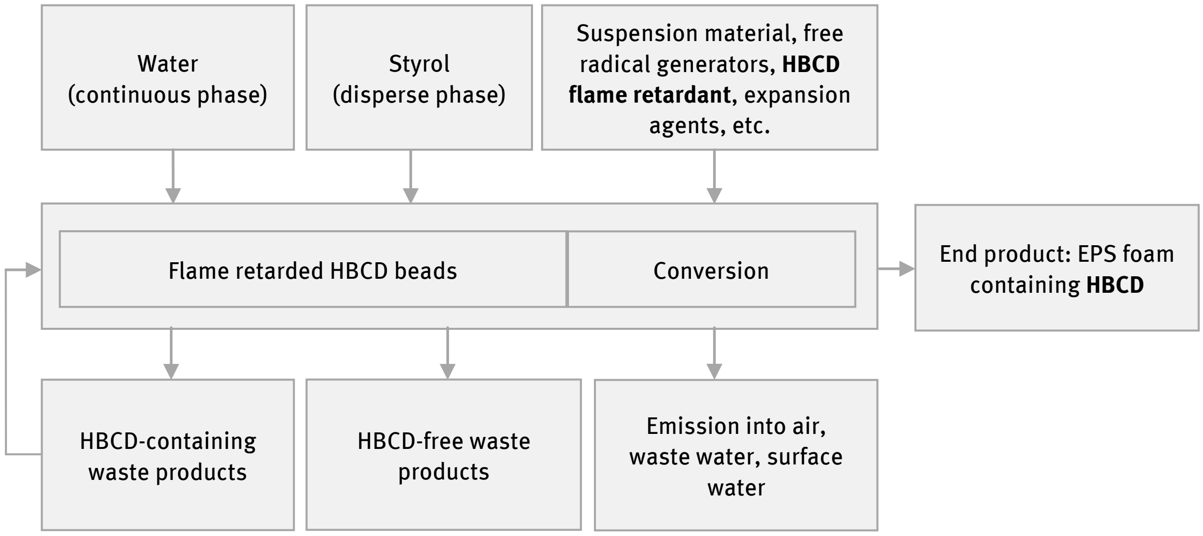
3.2.6.1 Background

EPS is a coarse pored foam or expanded polystyrene (EPS). EPS foam panels have been used because of their properties as insulating materials in the construction sector for a long time. Because of their high flammability EPS panels in Germany are flame retarded. For this purpose they typically contain 0.7 % HBCD as additive flame retardant (for more details: see sections 3.2.1 and 3.2.4).

3.2.6.2 Processes, inputs and outputs

The processes for the production of EPS are described in [BiPRO 2011]. Figure 16 illustrates the main input and output flows.

Figure 18: Relevant inputs and outputs in the production of EPS foams containing HBCD



3.2.6.3 Distribution and fate of substances/substance groups in products, waste and other output streams

HBCD emissions from the production and use of EPS and XPS insulation panels are comparatively low.

According to the "Voluntary Emission Control Action Programme (VECAP) 2012 Progress Report" the HBCD emissions from all sources have decreased in the period 2008-2012 from 179 g/tonne to 1 g/tonne (from [DEPA 2013]).

The „generation factor"[29] for EPS and XPS is 1 – 0.0001398 = 0.9998611. The emissions from the use of HBCD in the preparation, professional applications and during the service life of the products add up to the proportion of 0.01389% of HBCD consumption (calculated on the basis of [Swerea 2010]). At the end of its use life a product still contains EPS at about 99.986% of HBCD which was used in its manufacturing. Possible emissions during waste treatment (including demolition) are not taken into account. Hence there are considerable uncertainties (e.g. the relevant dust emissions during the demolition of buildings that are insulated with EPS/XPS insulation panels; see BiPRO 2011).

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[29] The generation factor describes how much HBCD is "generated" in waste considering emissions during production and use. The term is taken from an EU study [BiPRO 2011] being conscious that the substances (such as here in the case of HBCD) are no formed but simply used in the manufacturing.

This is similarly considered in [COHIBA 2011] [30]. Due to the low relevance of emissions during the product life time, emissions are not taken into account in the calculation of waste arisings.

With the average concentration of 0.7 % (w/w) of HBCD in EPS products, a ton of HBCD can be used to produce 143 tonnes of flame retarded EPS panels.

In the manufacturing all cut offs and other EPS wastes are recycled within the production processes. Cut offs from professional application (fitting of insulation panels) are collected through the EU-wide collection system and recycled [EUMEPS 2009]. The cut off quantities are about 2 %. At EU level thereof around 1 % is recycled and around 1 % is treated as waste. Cut off quantities are not considered in the calculations for the generated HBCD waste.

An unknown proportion of EPS and XPS products remains in the environment e.g. when the foundation insulation or the frost insulation of roads and rails is not removed completely during the demolition. Amounts that may persist in the environment are difficult to quantify and are not included in the calculation of material flows. This does not exclude that these quantities are not relevant.

3.2.6.4 Concentrations in products, waste and recyclates

In the safety data sheets of EPS, products from German producers, usually contain HBCD in a concentration below 1%[31].

In various literature sources, the usual concentration is 0.7 % to 1 % by weight, ([CeficEfra 206], [IOM 2008], [ECB 2008], [Albemarle 2009], [CPAN 2010], [Swerea 2010], [Morf et al. 2007]). On the basis of EU consumption data an average concentration of 0.51 weight percent was calculated for EPS [BiPRO 2011].

According to the German EPS manufacturers, HBCD is used in concentration of 0.7 % in EPS products for construction. This ensures appropriate flame retardance in the construction sector. This concentration is the basis for the calculation of the mass and material flows. Since 2013, the substitution of HBCD started. After August 2015, HBCD will no longer be used in German EPS products.

For concentrations in combustion residues from the waste incineration and sewage sludge see section 3.2.5.2.

3.2.6.5 Activity data

PS insulation products are manufactured at 4 locations in Germany (Leuna/Schkopau, Ludwigshafen, Marl, Wismar; see [PlasticsEurope 2012]). It is unclear whether there is a distinction between EPS and XPS foams. Another location in Germany where PS insulation is manufactured is Schwarzheide. This is where XPS insulation material is produced[32]. The German insulation industry has available data on the quantities of EPS and XPS used in the production (see [Dämmstoffindustrie 2013a] and [Dämmstoffindustrie 2013b]). In the reference year 2012, the amount of HBCD used in

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[30] “Emissions of HBCDs during demolition of buildings are seen as a major source. However, fate and behaviour of construction material from demolition of buildings has not been evaluated in a German context, so far” (Quotation from [COHIBA 2011]).

[31] See e.g. Concentration in EPS: Styropor* F215 L-N Hexabromcyclododecan content (W/W): <= 1%.

Further SDB and technical information:
http://www.plasticsportal.net/wa/EU~de_DE/Catalog/ePlastics/pi/BASF/prodline/styropor_peripor

Concentration in EPS: Neopor* 2200 Hexabromcyclododecan content (W/W): <= 1%

Fruther SDB and technical information:
http://www.plasticsportal.net/wa/EU~de_DE/Catalog/ePlastics/pi/BASF/prodline/neopor

[32] BASF produced XPS products „Styrodur“in Germany in Ludwigshafen and Schwarzheide [BASF 2012a].

EPS was in Germany 1,708 tonnes. In the same year, about 979 tonnes of HBCD was used in XPS (see Table 28).

Due to fire regulations in Germany, insulation panels must be flame retarded for the construction sector. In general, the flame retardant used so far was HBCD. Since early 2013 HBCD is substituted by an alternative flame retardant.

3.2.6.6 Waste management

In the construction sector generated post-consumer plastic waste (372 kt in 2011) is recovered energetically to 70.2 %, around 25.8 % is recycled (0% feedstock) and around 4% is disposed of to landfills [Consultic 2012]. According to recent figures in 2012, around 389 kt waste was generated, of this 70% recovered energetically, around 27% was recycled and 3% was disposed of to landfills. This information relates to the total amount of generated plastic waste from the construction sector. EPS and XPS waste represented only a fraction of this waste stream.

According to [Consultic 2013] in 2011 the construction sector used 271 kt of PS-E. This corresponds to a share of 9.7 % based on the total processed amount of plastic of 2,780 kt in the construction sector. In the same year, around 111 kt of PS-E waste was generated in Germany (all sectors including construction; share: post-consumer 83 kt, ~3 kt producers, processors ~ 25 kt; [Consultic 2012], p. 64).

In the manufacturing of PS-E all cut offs and other wastes are recycled during the production processes. Cut offs from professional applications (production of insulation panels) as well as other EPS waste (ASN 17 06 04) is collected through the EU-wide collection system and recycled [EUMEPS 2009]. For XPS insulation materials, there is no collection system (usually energy recovery because of the content of ozone depleting substances). The cut off quantities are about 2 %. At EU level around 1 % of EPS waste is recycled (e.g. application of mechanical recycling) and around 1 % is treated as waste (usually incinerated).

In practice in Germany EPS insulation waste is sometimes mixed with EPS packaging waste. This leads to the mixing of HBCD-free or low HBCD content waste (EPS packaging waste) with HBCD-containing waste (EPS insulation waste) and subsequently to relatively high content in PS regranulates (e.g. results of the chemical analyses of the samples 10 HBCD and 12 HBCD showed HBCD levels of about 0.44 % and 0.15 %; see section 5.3 for analysis results). It is not known how relevant such mixtures are in practice. In practice the mixing partly takes place intentionally (insulation materials are deliberately mixed with packaging waste before recycling processes), and some mixing occurs due to the introduction of clean insulating materials (e.g. cut offs) in the packaging waste stream. Packaging waste is usually difficult to distinguish from the clean insulation material waste.

No specific information is available on EPS and XPS waste amounts generated from demolition and restoration. Separated EPS/XPS wastes are categorised under the waste code 17 06 04, and mixed EPS/XPS wastes are categorised under 17 09 04. On the basis of data collected by the German insulation industry (see [Dämmstoffindustrie 2013a] and [Dämmstoffindustrie 2013b]) for EPS and XPS production until 2012, current and future waste quantities can however be estimated from the previous use levels and the lifetime (50 +/- 25 years), (see Figure 13 and Table 68). Consequently, current EPS-containing waste from the earlier use in construction amounts to 161 t of HBCD (reference year 2012). This corresponds to around 23,050 tonnes[33] of EPS waste (HBCD content of 0.7 %). Waste

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[33] Information on arisings, disposal and recovery of EPS wastes from the packaging and construction sector were presented during the final workshop of the research project (Consultic). Consultic estimates that the current waste amount of EPS from demolition and construction is about one third higher (35,900 t/a). This estimation is based on a relatively complex basis of broad secondary statistical data and specific primary analyses, such as conversations with different relevant institutions (personal notification Consultic, 16/09/2014).

quantities for XPS include the reference year 2012 and are estimated to 41 tonnes of HBCD (around 2,745 t of XPS waste with HBCD content of 1.5 %).

The German insulation industry believes that the demolition rate for EPS/XPS insulation materials in the demolition and repair activities is currently less than 1% of the annually installed quantity of thermal insulation composite systems (TICS). The frequent contamination of construction aggravates the recycling [Dämmstoffindustrie 2013a, Dämmstoffindustrie 2013b]. It is common practice to maintain existing thermal insulation composite systems (TICS) in restoration by "doubling" an additional TICS on the existing system. If HBCD-free TICS is doubled with HBCD-containing TICS, this can lead to complications in the final demolition (mixture of HBCD free and HBCD-containing TICS).

Plaster layers, reinforcement fabrics, adhesives, wall remains, etc. containing contaminated insulation materials have to be assigned to waste code number 17 09 04[34]. In construction waste EPS/XPS insulation materials are seen as contaminants or impurities. According to statements from demolition companies, EPS/XPS insulation is often removed during the demolition and separately prepared for recycling or disposal. The separate deconstruction is, however, costly and in practice often difficult. A certain proportion included in the construction and demolition waste is recycled through treatment plants or it is eliminated (method described in [UBA 2013]). About the amount of this proportion, there is no specific information. For the calculation of the mass and material flows the assumed share is less than 5 %. This share is not separated from the construction and demolition waste and is treated similarly to other post-consumer plastic waste from the construction sector.

Until 2005 foam waste was landfilled as mixed construction waste and today it is incinerated to recover energy [Dämmstoffindustrie 2013a, Dämmstoffindustrie 2013b]. For the calculation of the mass and material flows it is assumed that more than 95 % of the waste is separated during demolition and restoration and is thermally recovered.

In 2013, a large scale experiment for the combustion of EPS and XPS insulation panels in the state-of-the-art municipal waste incinerator (MVA Würzburg) was carried out in Germany (see PlasticsEurope 2014[35]). In the test report, concentrations of HBCD in slag ("grate ash"), fly ash and filter residues were reported (see [Plastics Europe 2014]). The HBCD concentrations range from 1.22 to 2.66 µg/kg dw. The HBCD concentrations in the cleaned flue gas were 1 to 8.3 ng/m^3. In the experiment, the concentrations were determined in three different cases (A) EPS/XPS is not incinerated with other wastes; (B) 1 % of EPS/XPS is co-incinerated; and (C) 2 % of EPS/XPS is co-incinerated. The authors concluded that both, the HBCD concentrations in the cleaned flue gas and in the combustion residues are independent of the amount of EPS/XPS. The calculated destruction rates for HBCD were for the respective concentrations (B) and (C) 99.99 %[36]. In the experiment, the possible emergence of other POPs (PCDD/Fs, PBCDD/Fs, PBDD/Fs, PCB, PBDE, PBB) was also monitored. The experiment results show that the incineration of EPS/XPS does not lead the increased concentration of these substances in the cleaned exhaust air. More details can be found in [Plastics Europe 2014]. According to the results, EPS and XPS insulation panels can be incinerated appropriately manner in state-of-the-art waste incineration plants up to a share of 2 % of the total waste. HBCD is largely destroyed (destruction rate > 99.99 %) and the incineration does not contribute to the generation of other POPs. Essential for the proper incineration is the preparation of a special blend in the bunker of incinerators. The incineration can be used without problems to manage commercially available insulation panels by using a fraction of 1 percent of weight (equivalent to about 15% per volume). Too high volumes could lead to disruptions in the operation of the waste incineration facility (e.g. clogging at the

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[34] Mixed buidling and demolition waste with those falling under 17 09 01, 17 09 02 and 17 09 03

[35] The publication Platics Europe 2014 has been withdrawn and it is currently under review. The technical publication is in preparation. A peer review was adopted. The release is expected at the end of 2014 / early 2015 (personal communication with Plastics Europe, September 2014)

[36] Personal communcation with Plastics Europe, September 2014

chute), eventually requiring the intervention by the operator. For Germany the authors recommend that the incineration of “old” [37] PS insulation panels is performed in state-of-the-art waste incinerators as a highly efficient treatment for the simultaneous destruction of HBCD and ozone-depleting substances (ODS).

Among the construction waste insulation material EPS / XPS is currently assigned the waste code 170604 (insulation materials other than those mentioned in 17 06 01 and 17 06 03).

170604 includes not only EPS/XPS but also other insulation materials[38]. The proportion of EPS/XPS insulation is unclear. Based on discussions with operators of construction waste sorting facilities, it can be understood that EPS/XPS insulation materials are in practice usually recovered and disposed as secondary fractions within other waste streams. Particularly relevant could be some great mass flows (17 01 07 and 17 05 04) as well as other construction waste streams.

The IPA report on the waste characteristics of 170604, were EPS/XPS insulation materials are assigned, plastics are not mentioned in the characterisation of the composition [IPA 2012a]. This can be seen as additional indication to the statements of operators of waste recycling facilities that the EPS/XPS insulation waste materials from restoration and demolition are insignificant by now also among insulation materials.

The total waste quantity generated in construction and demolition waste is estimated to amount to around 50 million tonnes. EPS and XPS are here not the primary target for the mechanical recycling. They are separated as far as possible from the mineral content and separately recovered or disposed. However, a clean separation in practice is very difficult due to the attachment to e.g. mineral components (concrete, brick, plaster, etc.). This leaves impurities in mineral fractions which enter the corresponding wastes and recyclates (because of the relatively small mass in very low concentrations).

An unquantifiable proportion of EPS waste is therefore recycled or disposed together with mineral construction and demolition waste. According to the German Landfill Ordinance, the loss of ignition may vary depending on the landfill class up to 3.5 or 10 %. For the landfill class 0 for inert waste TOC can be up to 3%. Accordingly it is possible to landfill mineral construction waste with organic contaminants such as EPS or XPS insulation up to a level of 3%.

In summary, it is assumed that 95% of EPS and XPS waste coming from the building sector are thermally recovered. For waste that is not already removed during demolition and restoration (< 5%), present disposal and recovery rates for post-consumer plastic waste from the construction sector are: 70.2 % and 25.8 % energy recovery and recycling, 4% landfilling [Consultic 2012]. As mentioned the proportion of the EPS/XPS products in the environment remains unknown (see section 3.2.6.3). Quantities which remain in the environment are difficult to estimate and are not included in the calculation of material flows. This does not exclude that these quantities cannot be relevant.

3.2.6.7 Substance flow

Figure 17 illustrates the resulting quantitative substance flow for HBCD in EPS, provided that a share of <5 % of EPS waste is treated similar to other post-consumer plastic waste from the construction sector. In 2012, about 1,700 t HBCD were consumed for the generation of EPS products for the construction sector. Approximately 160 t HBCD were contained in wastes from demolition and renovation. The majority of the waste was recovered thermally.

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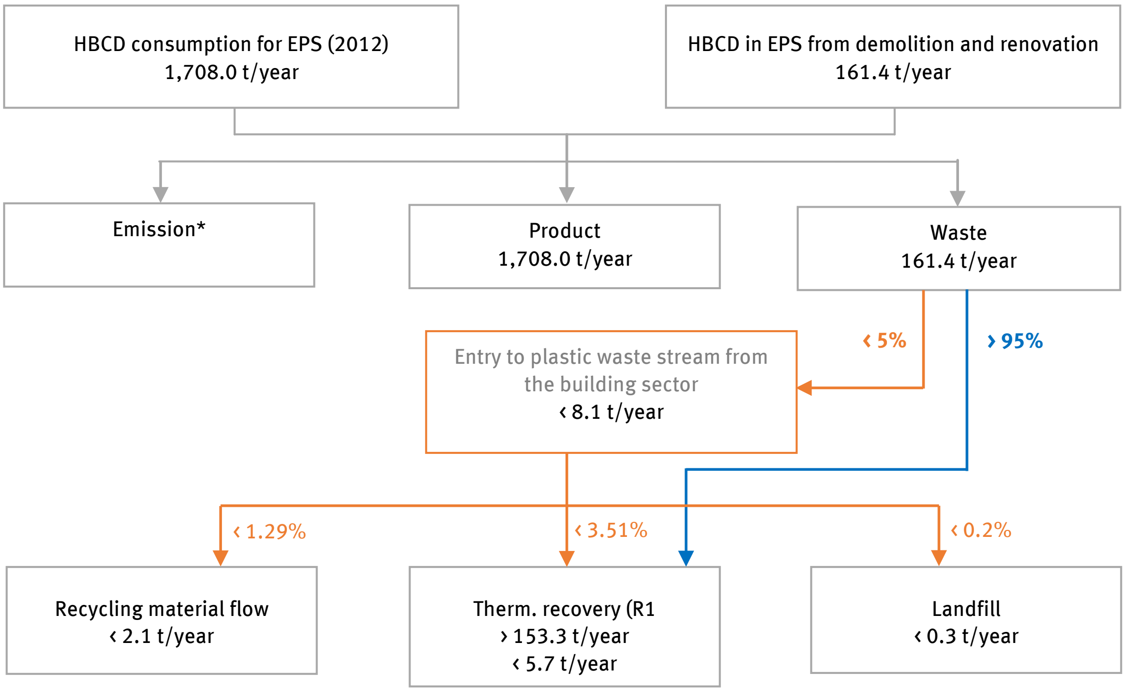
[37] “old” in this context are considered ODS-containing PS insulation panels designed by using the propellant gases and cell CFCs and HCFCs.

[38] The insulating materials include glass wool, rock wool and polystyrene. (Mineral fiber) insulation materials are regarded safe if produced after 01 June 2000. These insulation products meet the criteria of the Hazardous Substances Act and are not considered carcinogen or suspected carcinogen. Styrofoam is considered harmless. Non-hazardous insulation materials are assigned a waste code 170604. For their disposal is a container e.g. 2-20m^3 prescribed.

Figure 19: Estimation of the HBCD substance flow for EPS products from construction 2012

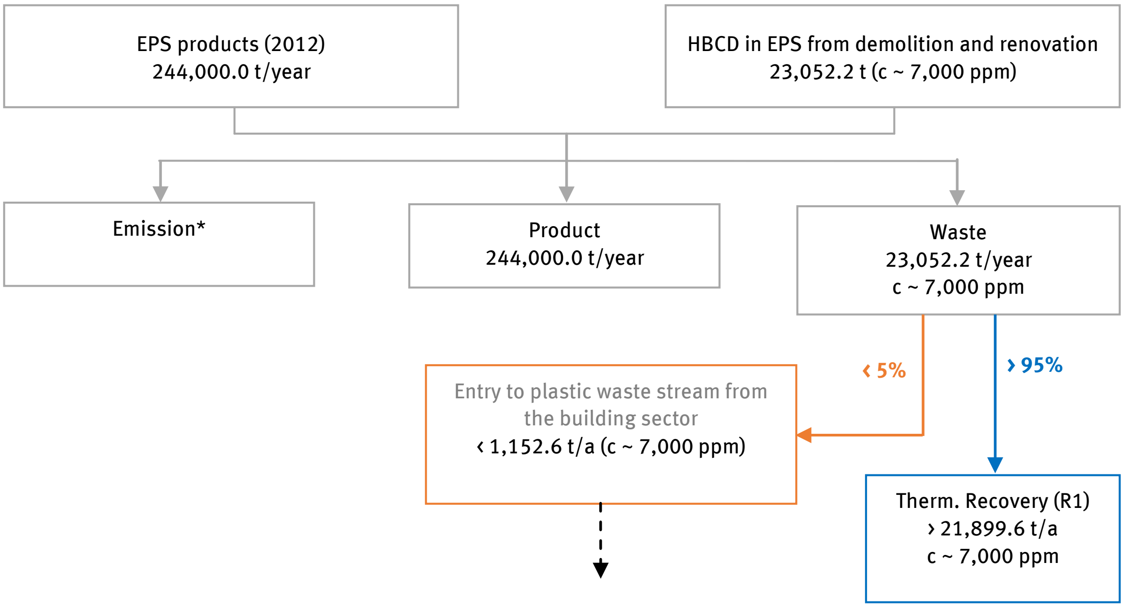


*quantitative without relevant meaning

3.2.6.8 Material flow

Figure 18 depicts the corresponding material flow:

Figure 20: Estimation of material flow for EPS products from construction 2012

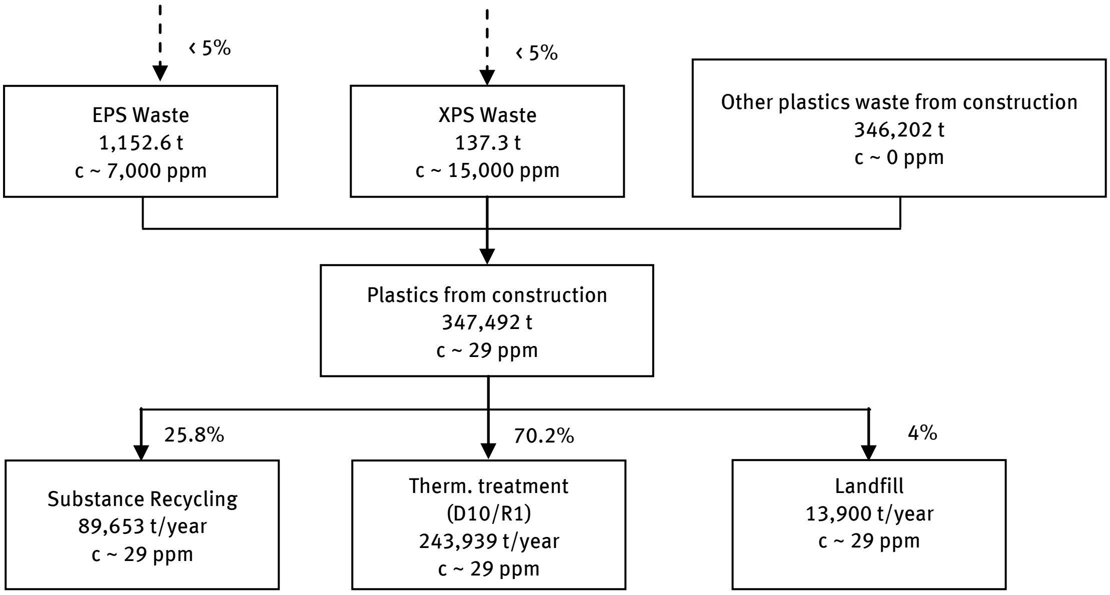


*quantitative without relevant meaning

Figure 19 illustrates the flow of materials for each <5 % of EPS and XPS waste for the year 2012, under the condition, that these will be eliminated and reused along with other plastic wastes from the building sector. Around 1,152 t of EPS waste (HBCD concentration: 7,000 ppm) and around 137 t of

XPS plastic fraction (HBCD concentration: 15,000 ppm, see section 3.2.7.8) enter the plastic waste fraction (total amount 347,492 t per year). The entry of these waste amounts into the HBCD free plastic waste fraction from the construction sector leads to a theoretical HBCD concentration of 29 ppm.

Figure 21: Estimated material flow for EPS and XPS products from construction 2012: entry into plastic waste fraction from construction



3.2.7 Extruded polystyrene foam (XPS) in the construction sector

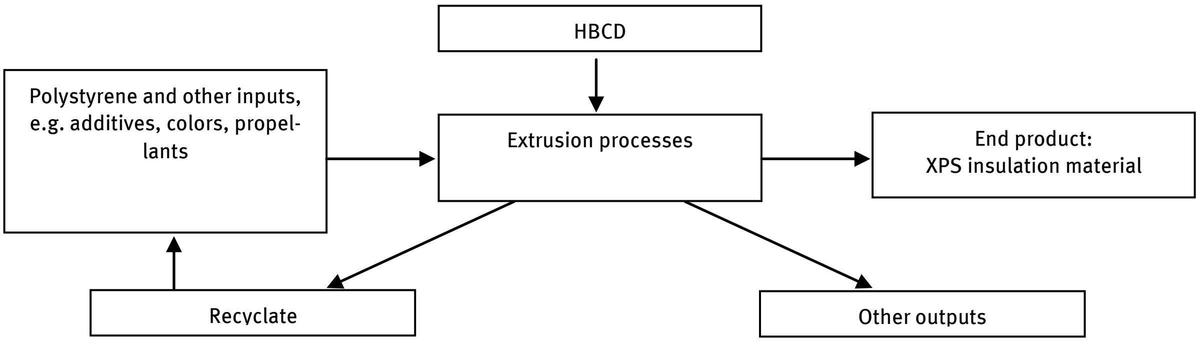
3.2.7.1 Background information

XPS is a fine-pored foam or extruded polystyrene (XPS) which is used mainly in the construction as an insulating material. Because of the high flammability XPS foam panels are flame retarded in Germany. For this purpose they contain on average about 1.5 % of the additive flame retardant HBCD.

3.2.7.2 Processes, inputs and outputs

The processes for the production of XPS are described in [BiPRO 2011]. Figure 20 illustrates the essential input and output flows.

Figure 22: Relevant HBCD-containing XPS foams production inputs and outputs



3.2.7.3 Distribution and fate of substances/substance groups in products, waste and other output streams

Most information applies analogously for EPS and XPS (see appropriate section on EPS; section 3.2.6.3). Only the relevant differences are mentioned in this chapter.

With an average concentration of 1.5 % HBCD in XPS products, one tonne of HBCD is consumed for the production of about 67 tonnes of flame retarded XPS panels.

The considerations regarding recycling, emissions, and fate in the environment apply here as for EPS products for the construction industry.

3.2.7.4 Concentrations in products, waste and recyclates

In a safety data sheet of an XPS product produced in Germany the HBCD concentration indicated is less than 1.5 %[39].

Various literature sources refer to usual concentrations between 1 and 3 % by weight (see Table 30).

According to the German XPS manufacturers, HBCD is used in XPS products for the construction sector in average concentrations of 1.5 %, thus ensuring appropriate flame retardancy. This concentration is used as a basis for the calculation of the substance and material flows. Since 2013 the substitution of HBCD has started. By August 2015 there will be no more XPS products manufactured in Germany containing HBCD.

For concentrations in combustion residues from the waste incineration see section 3.2.5.2.

For concentrations in sewage sludge, see section 3.2.5.2.

3.2.7.5 Activity data

See section 3.2.6.5.

3.2.7.6 Waste management

The situation for XPS waste is comparable to the situation for EPS waste (see section 3.2.6.6).

3.2.7.7 Substance flow

Figure 21 shows the resulting quantitative substance flow for HBCD in XPS, under the assumption that a proportion of <5 % of the XPS waste is treated similar to other post-consumer plastic waste separated from the construction sector. In 2012, about 980 t HBCD were consumed for the generation of XPS products for the construction sector. Approximately 41 t HBCD were contained in waste from demolition and renovation. The majority of the waste was recovered thermally.

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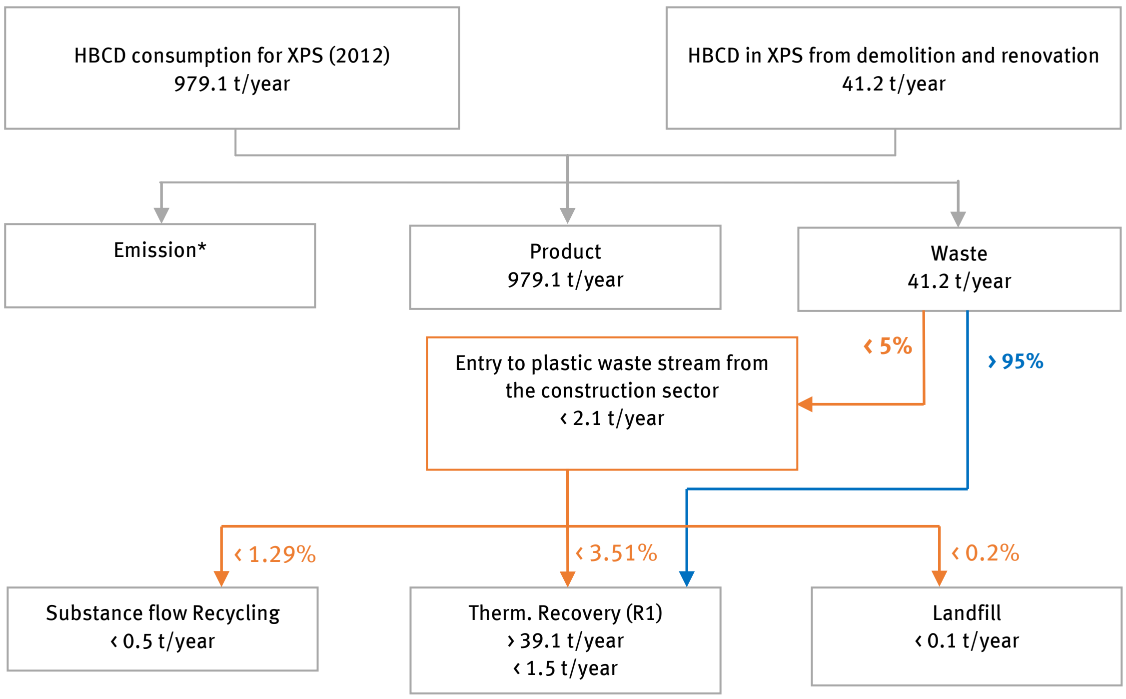
[39] Concentration in XPS: Styrodur* 3035 CS Hexabromcyclododecan content (W/W): <= 1.5% (see [BASF 2009])

Figure 23: Estimated HBCD material flow for XPS products from the building sector 2012

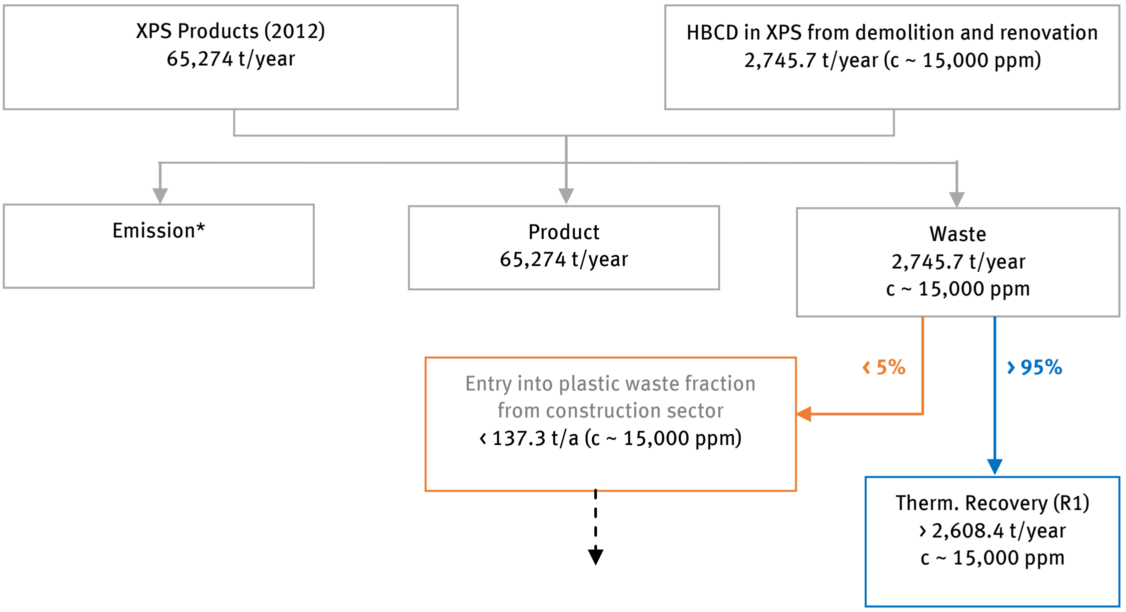


*quantitative without relevant meaning

3.2.7.8 Material flow

Figure 22 illustrates the corresponding material flow:

Figure 24: Estimated material flow for XPS products from construction 2012



*quantitative without relevant meaning

The detailed material flow for < 5 % of the XPS waste which is disposed of and recovered with other plastic waste from the building sector, is shown in section 3.2.6.8 together with EPS wastes (see Figure 19).

3.2.8 Use of EPS and XPS in other applications outside of construction sector

3.2.8.1 Background information

At European level, about 6 % of the HBCD consumption for EPS and XPS products is used outside of the construction sector. Relevant information regarding the European situation is presented in BiPRO 2011 and selected information is included in section 0 of this report.

According to industry data, the use of flame retarded PS foams outside the construction sector in Germany is essentially limited to EPS applications. XPS is of minor importance. Relevant are applications such as car seats, props for theatre, film and exhibitions. Additionally, possible applications are in rigid packing material for sensitive equipment or packaging material “chips” and moulded EPS parts.

The HBCD content of flame retarded EPS products is around 0.7 % (see Table 30).

Apart from packaging, the applications mentioned by the EU PS foam industry are considered to be of low relevance [PS foam 2011].

Industry is reporting that HBCD flame retardant packaging materials are not used in Germany. The current use of HBCD in EPS and XPS outside of the construction sector is therefore estimated to be generally low in Germany.

There is no specific information about the time when the use of HBCD ended in this sector. In the calculations it is assumed that the use has been already completely abandoned in 2012 and that the last use was in 2011.

Packaging is the most common non-construction related application of EPS/XPS. Accordingly, the lifetime for products in this sector, adopted in [BiPRO], is too long (0-20 years; see Table 29). Packaging is generally disposed of immediately after the use or within one year. In this relation, the estimate of the future relevance for the waste in this sector is too high as well. It is assumed that this sector is of minor importance and will no longer be relevant in future waste streams.

However, it cannot be excluded that HBCD-containing packaging materials (particularly EPS HBCD with content of 0.7 %) are imported to Germany and can enter the waste streams and thus recyclates. It can be also assumed that HBCD flame retarded products from used packaging and non-packaging sector reach the waste stream.

3.2.8.2 Waste treatment

Post-consumer plastic waste from packaging is to 57.8% energetically recovered; to 39.8% recycled, to 2.0% feedstock recovered and to 0.4% landfilled (source [Consultic 2012]). These shares are used to calculate the mass and material flows. Specific data for EPS packaging waste is not available.

For later re-use of packaging and moulded parts made of EPS, consumers can return it at collection points and recycling centres or dispose it in yellow bags. Additionally, the take back can be arranged by manufacturers. The recycling rate for polystyrene packaging in Germany is around 70 % and has a positive trend [IK 2014]. EPS packaging waste is assigned to waste code 15 01 02 (plastic packaging).

In practice, waste containing HBCD insulation materials is sometimes mixed with packaging waste and recycled together. This leads to mixing of HBCD-free or lightly loaded waste (PS-E packaging waste) with highly contaminated waste (PS-E insulating waste) subsequently leading to highly loaded PS re-granulates (see section 3.2.6.6).

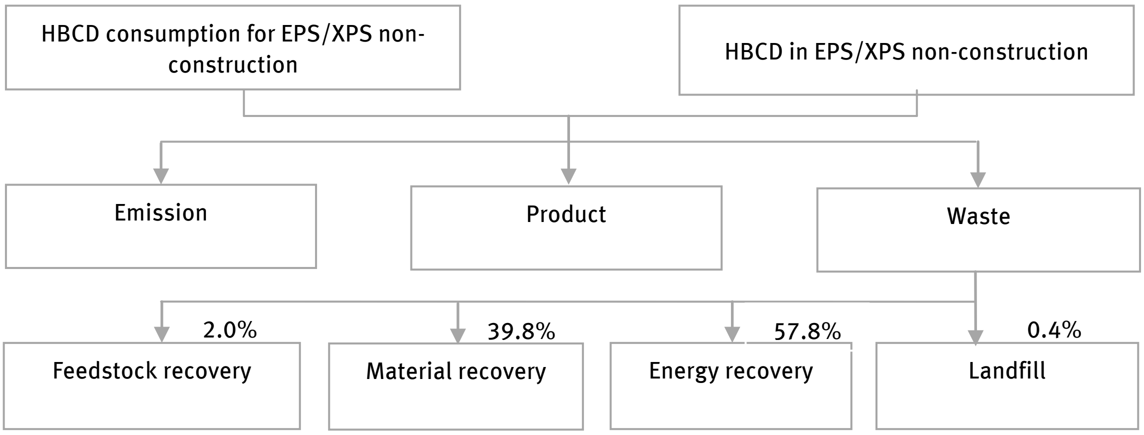
3.2.8.3 Substance and material flow

The non-construction related sector is dominated by EPS packaging. In 2011 about 13 % (41 kt) of PS-E was used for packaging.

Current estimates show that HBCD is not used in the non-construction sector and the life times of relevant products (EPS packaging) in this sector range between zero and a few years. This leads to the conclusion that there are no relevant waste amounts of HBCD from this sector.

Figure 23 shows the structure of possible substance and materials flows.

Figure 25: Structure of HBCD substance flow for EPS/XPS products for the non-construction related sector (usually EPS packaging)



The results from the chemical analyses of EPS packaging waste (see section 5.3) suggest that the average HBCD load of packaging waste could be about 10mg/kg. Based on the research results it can be assumed that HBCD is no longer used in the packaging sector. The load of the waste fraction may derive from imports, waste packaging, cross contamination from construction products or use of HBCD loaded recyclates. Where exactly HBCD enters the substance flow, cannot be ascertained on the basis of the research and analysis results and the substance flow is not presented accordingly. However, it can be estimated that the total collected packaging waste is roughly equivalent to the amount produced (41 kt in 2011), the total HBCD content in packaging waste with the average concentration of 10 mg/kg results in 410 kg/year. Figure 24 shows the above mentioned disposal and recovery rates. The HBCD content is mainly submitted to energy recovery (ca. 58%) and material or feedstock recovery (ca. 40% and 2% respectively). A small share of the HBCD is landfilled.

Figure 26: HBCD substance flow for separation and reuse of EPS/XPS wastes from the non-construction sector (usually EPS packaging)

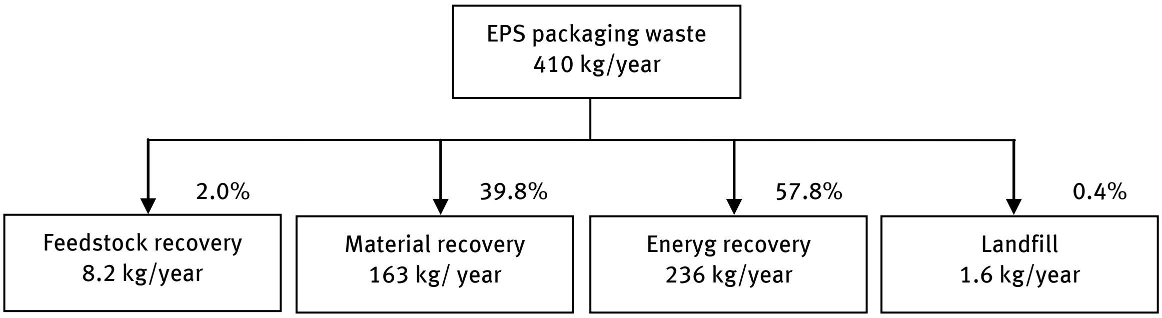
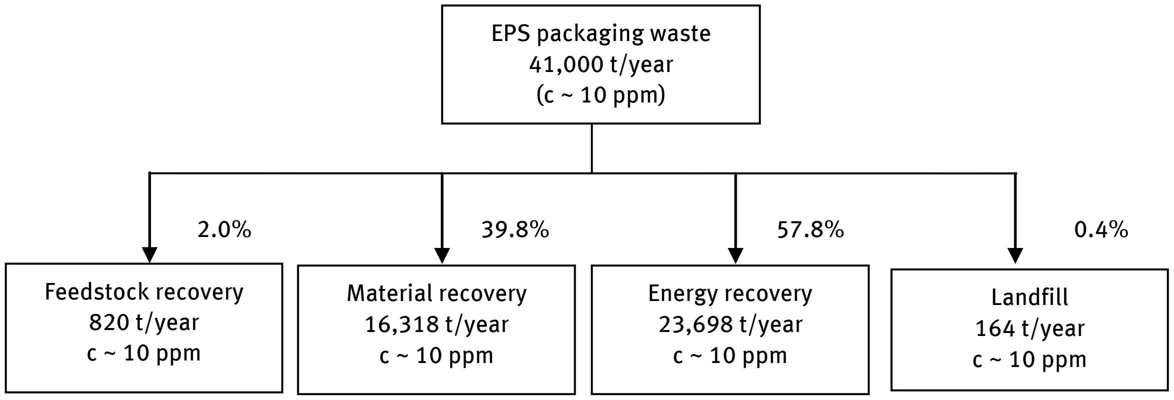


Figure 25 illustrates the corresponding material flow:

Figure 27: HBCD material flow for disposal and recycling of EPS/XPS waste for non-construction sector (usually EPS packaging)



3.2.9 High Impact Polystyrene (HIPS)

3.2.9.1 Background information

At European level, about 2 % of HBCD consumption is used for the production of HIPS products. Typical applications mentioned in the literature are for audio and visual equipment, distribution boxes for electrical lines in the construction sector and refrigerator lining. Information regarding the EU situation is presented in BiPRO 2011 and selected information is already included in section 0 of this report. Since HBCD is no longer used in Germany and Europe in HIPS products there is no need for a description of the processes, inputs and outputs.

The German Electrical and Electronic Manufacturers' Association (original designation in German: Zentralverband Elektrotechnik- und Elektronikindustrie e.V. (ZVEI)) requested its members to provided project relevant information (use in electrical sector, amounts, information on imports, waste streams and recycling). There is no specific information that HBCD is still used. However, the use cannot be ruled out[40].

At the European level, it is assumed that amounts of HBCD used in HIPS are not relevant. This assessment from the European Chemical Industry Council (CEFIC) dates from 2012. Since there is no specific information on the end of use, it is estimated that the use in 2012 was already abandoned and the last recorded use was in 2011. Alternatives for substitution are available (see [ECHA 2913a]).

During the use of HIPS, around 0.00028 % of the used HBCD amount is released as emissions to the environment (see [BiPRO 2011 and [Swerea 2010]). Because of this low emission rate and because HBCD is no longer used in Germany for HIPS, no relevant emissions for this sector are expected in Germany.

The HBCD content in HIPS products is between 1 and 7 % (see Table 30). With an average concentration of 4 % HBCD in HIPS products, one tonne of HBCD is consumed to produce 25 tonnes of flame retarded HIPS products.

Specific data from relevant waste streams is only sporadically available (see Table 37). Particular results are contained in a waste analysis bank (ABANDA) from North Rhine-Westphalia as well as from the feedback obtained from the survey of experts at international level.

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[40] ZVEI personal communication from 15.7.2013

Table 41: Measured HBCD concentrations in waste streams

Waste type	Unit	N	Min	Max	MW	Stan.deviation	Source
160216 [(a)]	µg/l	67	200,000	1,000,000	211,940	97,736	DE, NRW (ABANDA)
Bromine-containing plastics waste	ppm	4			‹ 10		BE [(b)]

(a) Removed from used equipment without 160215

(b) Email communication, Public Waste Agency of Flanders (OVAM BE), 4.4.2013; measured values from 2010; sampled waste containing mainly TBBPA and PBDE in measurable concentrations

For recycled products there is no specific data.

3.2.9.2 Waste treatment

The typical HIPS products are usually classified as electrical waste (e.g. waste codes 200123*, 200135*, 200136*) or on a small scale may be regarded as plastics in the construction waste (e.g. 17023). A certain proportion of electrical and electronic equipment ends up in the household waste. In general the plastic components in the construction waste and household waste are recovered energetically.

The usual treatment of plastics from the electronic waste includes the manual disassembly or the mechanical treatment in shredders. The shredding is done by large metal shredders or shredders for the particular electronic waste categories. The manual disassembly allows the manual separation of the individual plastic parts. Shredder processes are often associated with an automatic sorting process.

In the electrical sector the post-consumer plastic waste (241 kt in 2011) was to 90.0 % energetically recovered, to 7.5 % recycled (0% feedstock) and to 2.5 % landfilled (Source: [Consultic 2012]). These shares are the basis for the calculation of the mass and material flows.

Mostly the plastics from WEEE are used for energy recovery. In the individual cases, HIPS are recovered from the treatment of the electrical waste, for the production of PS-recyclate. In addition to the plastic mixture from the treatment of the WEEE, a corresponding recyclate was analysed for the content of HBCD (for the analysis results see section 5.3).

According to Annex VII of the Directive 2012/19/EU of the European Parliament and the Council on waste electrical and electronic equipment on the selective treatment for materials and components of electrical and electronic equipment in accordance with Article 8 (2), plastics containing brominated flame retardants have to be removed from any separately collected waste including electrical and electronic equipment. This obligation includes, among other things, plastics containing HBCD as brominated flame retardants. Since in practice not all brominated plastics are separated, it can be assumed that HBCD appears in recyclates.

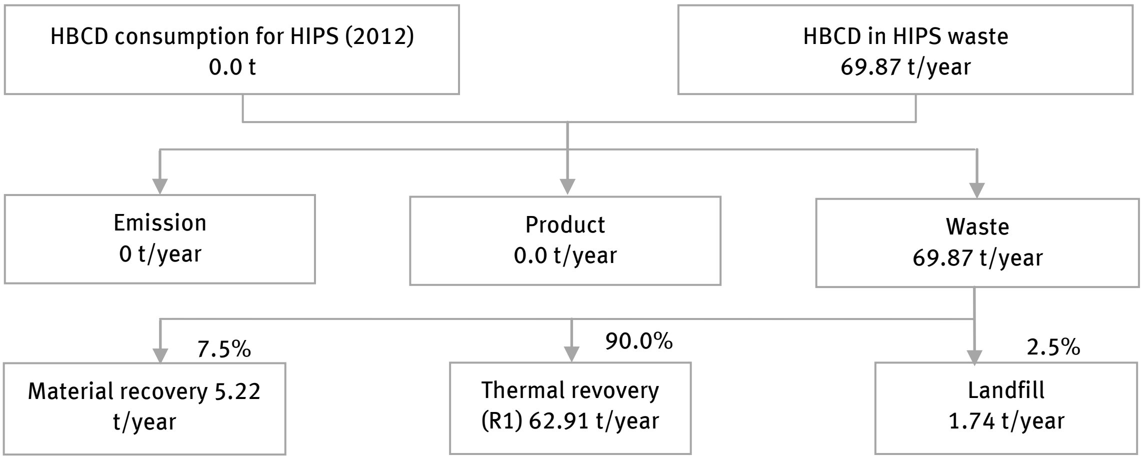
A relevant part of used electrical appliances is exported from Germany. In the countries these appliances meet the waste management structures that are below standards, that the European Community considers minimum to ensure the appropriate level of protection. The disposal of WEEE in the receipt countries may lead to risks for human health and the environment (see [UBA 2010]). Linked to that is also the adverse effect related to POPs such as PBDE and HIPS containing HBCD that appear in the environment through the export of the electrical and electronic waste. Quantitative data on exports of HIPS in electrical appliances or electrical waste is not available and is not included in the substance flow. Basically, corresponding exports should be limited to countries partly due to the POP related issues in which the appropriate recovery and disposal of electrical and electronic equipment is ensured.

3.2.9.3 Substance flow

It seems that HBCD is no longer used in HIPS. Nevertheless, it is expected that HBCD from previous uses may continue to appear in the waste streams and recycled materials due to the assumed lifetime of electrical appliances (9 +/- 5 years) and from imports. Since there is no specific data on the present end use it is assumed that the last use was in 2011.

Figure 26 illustrates the estimated substance flow (imports not included) from the year 2012. In 2012, about 70 t HBCD were contained in waste from HIPS from the electrical sector. The majority of the wastes was recovered thermally (90 %) and minor amounts were directed to material recovery (7.5 %) or landfills (2.5 %).

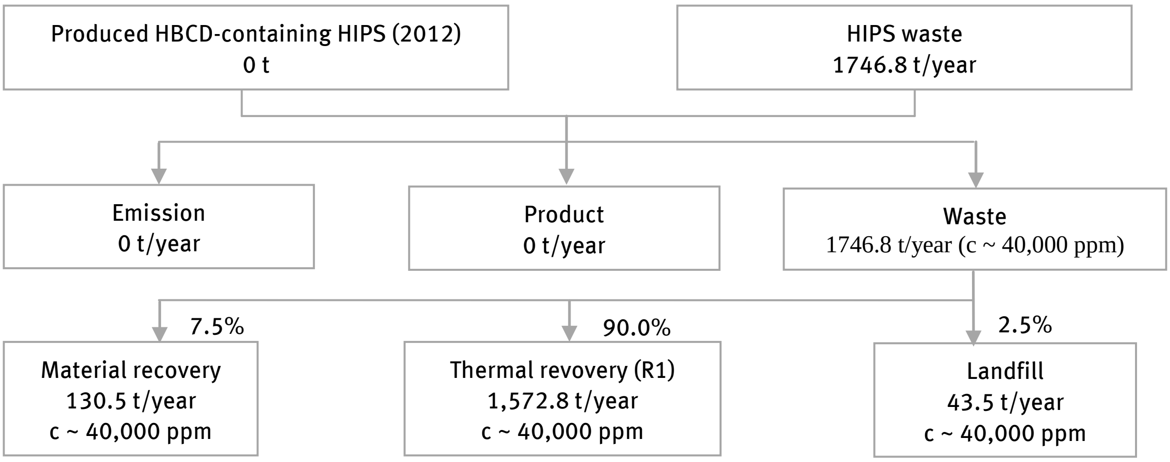
Figure 28: HBCD substance flow for HIPS products in the electrical sector, 2012



3.2.9.4 Material flow

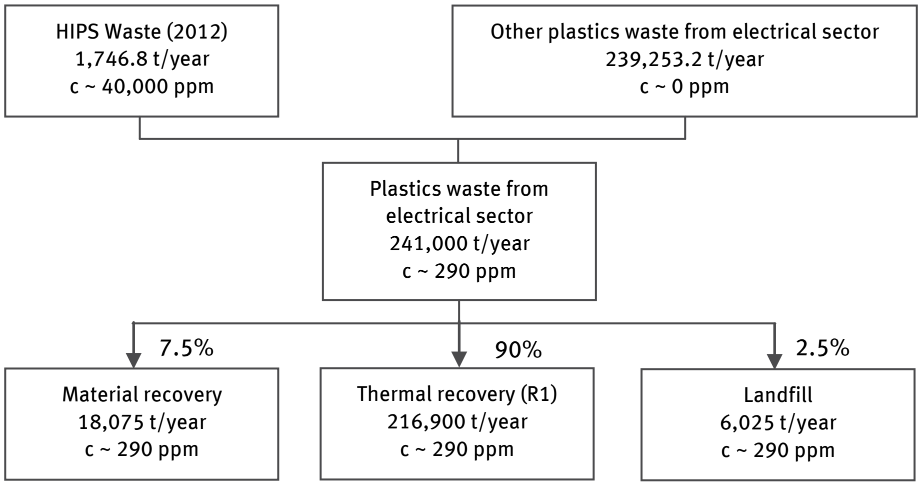
Figure 27 shows the corresponding theoretical material flow with the average HBCD concentration of 4 % (for the unrealistic case in which HBCD-containing HIPS from electrical waste are treated separately from the post-consumer plastics from the electrical sector (241 kt).

Figure 29: Material flow for HIPS products in the electrical sector in 2012



The following material flow is developed using the relations shown in Figure 27 and under the assumption that HBCD-containing HIPS from the electrical appliances are removed and recycled together with the total plastic waste component from the electrical sector (241 kt). Further, 1,746 t/year of HIPS products (HBCD concentration 40,000 ppm) which enter in the plastic waste component unloaded with HBCD (about 241 kt/year) of the electrical sector results with a theoretical HBCD concentration of 290 ppm. The corresponding material flow is used as a basis for the calculations of materials flows and scenarios as presented in Figure 28:

Figure 30: HBCD material flow for HIPS products in the electrical sector 2012: Entry into total plastic waste component from the electrical sector



3.2.10 Polymer dispersions for textiles

3.2.10.1 Background information

At European level, about 2% of HBCD consumption for the production of polymer dispersions is used for textiles. The polymer dispersions are processed in the textile industry and used especially for upholstered furniture, upholstered seats in transportation, curtains and drapes, mattress ticking, home textiles and automotive textiles [IOM 2008]. Relevant information for Europe is presented in [BiPRO 2011] and selected information is included in section 0 of this report. As HBCD is no longer used in Germany and Europe for textiles, a description of the processes including inputs and outputs is omitted here.

According to industry information, HBCD is no longer used for textiles in Germany since 2007 [41].

Even before 2007, the use of HBCD has declined in previous years in the EU. Manufacturers of HBCD-containing polymer dispersions were inter alia in Germany (4 German manufacturers). However, it seemed that the industrial use was mainly taking place in Belgium and the United Kingdom (24 industrial users of HBCD-containing polymer dispersions, including 15 in Belgium, and 9 in the UK (see [IOM 2008] and [ECB 2008]).

Also at European level it is assumed that HBCD is currently not used in polymer dispersions for textiles. Alternatives for substitution are available (see [ECHA 2013A]).

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[41] Personal information TEGEWA, 2013 (TEGEWA e.V. – Association of manufacturers of textile, paper, leather and fur and coatings, surfactants, chelating agents, antimicrobial agents, polymer flocculants, cosmetic and ppharmaceutical raw materials or related products)

Based on the information from TEGEWA, it is assumed that the use in Germany was already completed in 2007 and that the last use was in 2006. In particular, HBCD was used in Germany in the institutional sector, in meeting rooms, as well as in the automotive sector.

From the use of HBCD as flame retardant for textiles, a certain proportion (0.01294 %) of used HBCD appears as emissions in the environment. The major emissions happened during the industrial use for the coating of textiles (see [BiPRO 2011] and [Swerea 2010]). Emissions during the lifetime of textiles are therefore irrelevant. As HBCD is no longer used in Germany for textile coating, no relevant emissions are expected from this sector in Germany.

An important application of HBCD-containing polymer dispersions is the coating of fabrics for upholstery fabrics, mattresses, curtains, wall coverings, etc. particularly in the institutional area (theatres, concert halls, cinemas, town halls and other places for gathering). In the Sample Assembly Ordinance (MVStätV from June 2005) minimum fire protection requirements are formulated for public places which among other things means that meeting rooms textiles and furniture must meet certain fire safety requirements [42]. In other EU countries, for example, in the United Kingdom and Ireland, the law prescribes the use of HBCD for the home textiles.

For flame retarded textiles in the automotive industry until around 2007 HBCD was especially used for seat covers, door panels and carpet in the rear, trunk and engine compartments whereas textiles which are used as headliner and airbag were not affected. Measurements for HBCD content of the shredder light fraction in Germany are not available. For measurements that were carried out in 2007 and 2008 in Norway to characterise the shredder light fraction from the metal recycling, HBCD was only detected in one of six samples above the limit of detection (2 µg/kg DM) at the concentration of 22 µg/kg DM (see [NPCA 2008]). The analysis results indicate that HBCD is not more relevant in the shredder light fraction from the old cars.

For quantitative use of HBCD in the specific textile applications no specific information is available[43]. Therefore, it is not possible to make quantitative statements regarding the use of HBCD in the automotive sector in comparison with the institutional area. HBCD containing waste from flame retarded textiles from both sectors can still be relevant for several years. It is assumed that HBCD was equally used in the automotive and institutional sectors (there is no specific information).

The HBCD content in the polymer dispersion is on average about 25 %, which leads to a content of about 7 to 9 % in the coated textiles. For the calculation of substance and material flows an average concentration of 8 % is assumed. One tonne of HBCD is consumed to produce about 12.5 tonnes of flame retarded textiles.

3.2.10.2 Waste management

HBCD flame retarded textiles are used for upholstery fabrics, curtains, wall coverings, etc. especially from the institutional sector (theatres, concert halls, cinemas, town halls, other public places, etc.) and in the automotive sector for seat covers, door panels and carpets.

Textiles were classified under the waste code 19 12 08. Fire-retardant textiles from the institutional sector are not exclusively, but often classified as bulky waste (waste code 20 03 07) or mixed municipal waste (waste code 20 03 01), (household waste and similar commercial, industrial and insti-

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[42] Meeting places are according to MVStätV (1) assembly facilities with meeting rooms that can hold individually more than 200 visitors, (2) meeting venues with several meeting rooms that can accommodate a total of more than 200 visitors, (3) outdoor meeting places with scene surfaces whose visitor area hold more than 1,000 visitors and wholly or partially of building structures and (4) sports stadiums that hold more than 5,000 visitors.

[43] Personal information TEGEWA, March 2014

tutional wastes). Details from different collection sites confirm fire retardant textiles are not collected separately but are disposed of as mixed municipal waste or bulky waste.

Specific quantitative data on the utilisation and disposal of HBCD flame retarded textiles is not available. If one would calculate the substance and material flows according to the share [DESTATIS 2013A] of recovered and disposed bulky waste, the following distribution would be used: recycling 53.8 %, 22.5 % energy recovery, thermal recovery 18.4 %, treatment for disposal 5.2 % and 0.1 % landfilling. These shares are similar to those of the total municipal solid waste (recycling 63 %, energy recovery 16 %, thermal elimination 16.8 %, treatment for disposal 3.7 % and 0.5 % landfilling).

The above shares – for both the bulky waste as well as for the entire municipal waste – seem not realistic for flame retarded textiles. This is due to the fact that the high share of recycling of municipal waste results from recycling of the recyclable fractions (e.g. packaging, metals, etc.).

Considering only the two waste codes above “20 03 01” mixed municipal waste and “20 03 07” bulky waste, the proportion of almost 65 % for the thermal waste treatment (D10 and R1) is found in [DESTATIS 2914]. Around 15 % are supplied to mechanical-biological waste treatment plants in Germany or treated in sorting. It can be assumed that the proportion of flame retarded textiles, which are separated for further material recovery is relatively small. Rather, it can be assumed that a large part of the flame-retarded textiles after passing through these facilities, supply energy recovery/incineration. Another 5 % of the waste amount under two codes are supplied to other treatment plants in Germany. Due to the absence of any specific information, it is assumed that the flame retarded textiles in Germany are to more than 90 % incinerated (D10 or R1) or landfilled. A share of less than 10% of the waste amount could therefore essentially be recycled. A small proportion could also be deposited (the landfilling share could be about 0.5 %, which is in line with the rate for landfilling of the municipal waste).

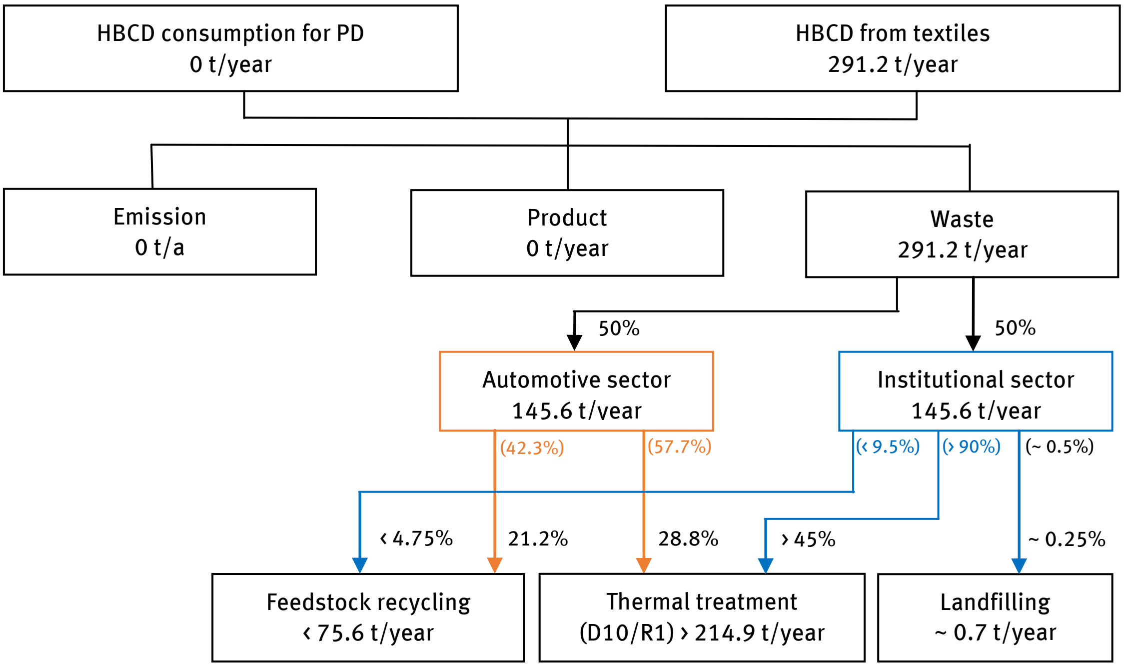
Fire-retarded textiles from the automotive sector are usually removed and recycled during ELV treatment. These fabrics usually end up in the shredder light fraction and are generally incinerated or disposed of in Germany. In Germany other input materials are also shredded in the shredder plant in addition to residual bodies. The shredder light fraction from ELVs (in Germany in 2011 total: 141,745 t) is recycled (42.3%), thermally eliminated (11.3%) or incinerated (46.4%). This is about 36% of the total incurred shredder light fraction of around 400,000 t (from ELVs and other input material from the shredder plants) (see [UBA 2013B]).

3.2.10.3 Substance flow

HBCD is no longer used in the production of textiles since 2007. Already in the years before the use levels have declined. Nevertheless, it is expected that HBCD from previous uses may continue to appear in the waste streams and recycled materials due to the assumed lifetime of textiles (10 +/- 3 years) and from imports. The lifetime of 10 +/- 3 years is the basis for the flame retarded HBCD textiles from the institutional sector. For the lifetime of flame retarded textiles in the automotive sector there is no further information. According to [BiPRO 2011] the average lifespan of a vehicle is about twelve years. On this basis it is assumed that the average life time of flame retarded textiles from the automotive sector and the institutional sector are similar. For the presentation of the substance and material flows a lifetime of 10 +/-3 years is used for both sectors.

Figure 29 shows an estimated substance flow (imports not included) for 2012. About 290 t HBCD was contained in wastes from relevant textiles in 2012. Depending on their use (automotive or institutional sector), these wastes were either directed to thermal recovery or feedstock recycling. A small amount of ca. 0.25% was landfilled.

Figure 31: HBCD substance flow for PD in textiles 2012



3.2.10.4 Material flow

Figure 30 shows the corresponding material flow for PD in textiles in 2012.

Figure 32: HBCD material flow for PD in textiles 2012

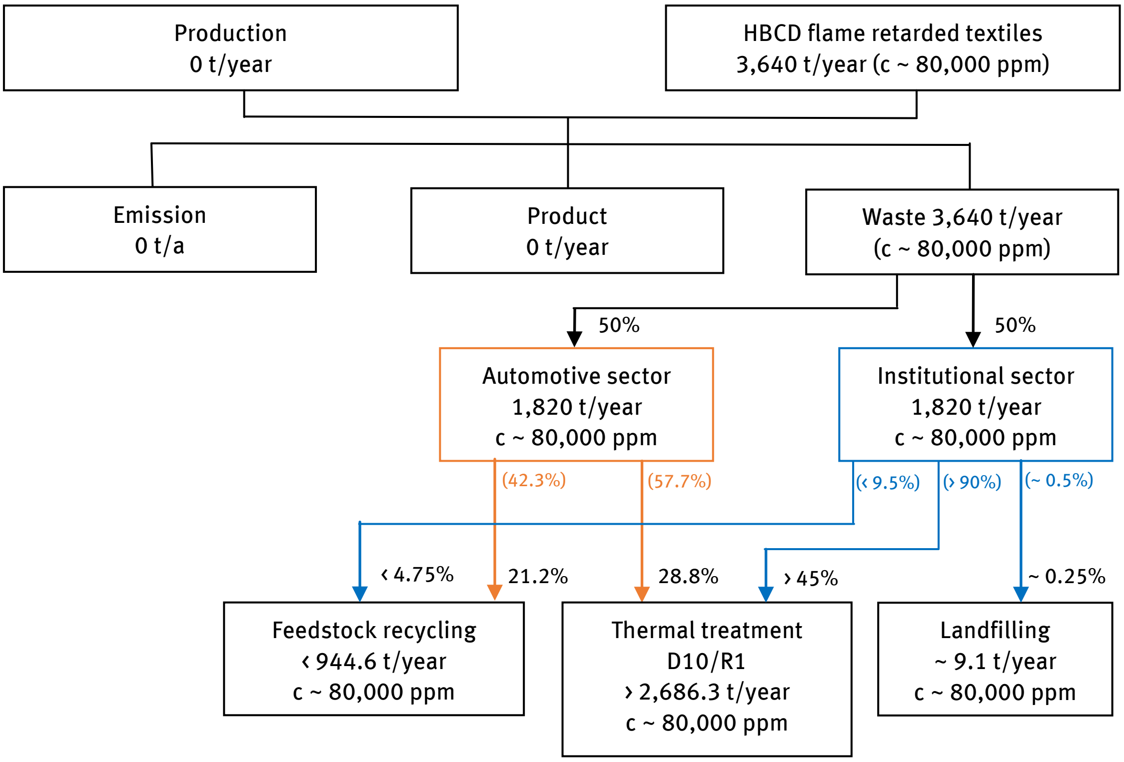


Figure 31 illustrates the flow of materials for HBCD flame retarded textiles from the automotive sector, under the realistic assumption that they are treated together with the total shredder light fraction (total ~ 400,000 t/ year). By entering the total waste volume with about 1,820 t/year, flame retarded textiles (HBCD concentration: 80,000 ppm) in the HBCD unloaded shredded light fraction result in a theoretical HBCD concentration of 364 ppm. The bulk of the shredder light fraction is treated thermally (ca. 58%). However, a considerable share is directed to feedstock recycling (ca. 42%).

Figure 33: HBCD material flow for PD in textiles 2012: Entry into the shredder light fraction from the automotive sector

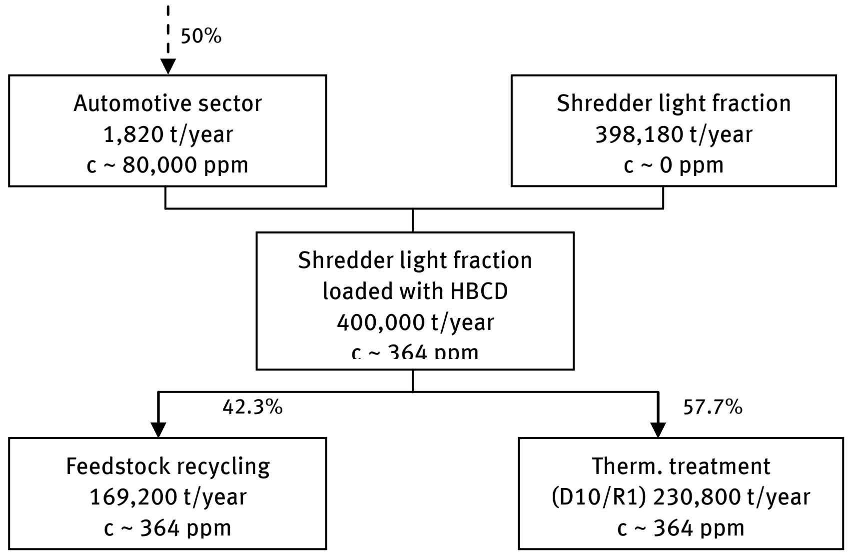
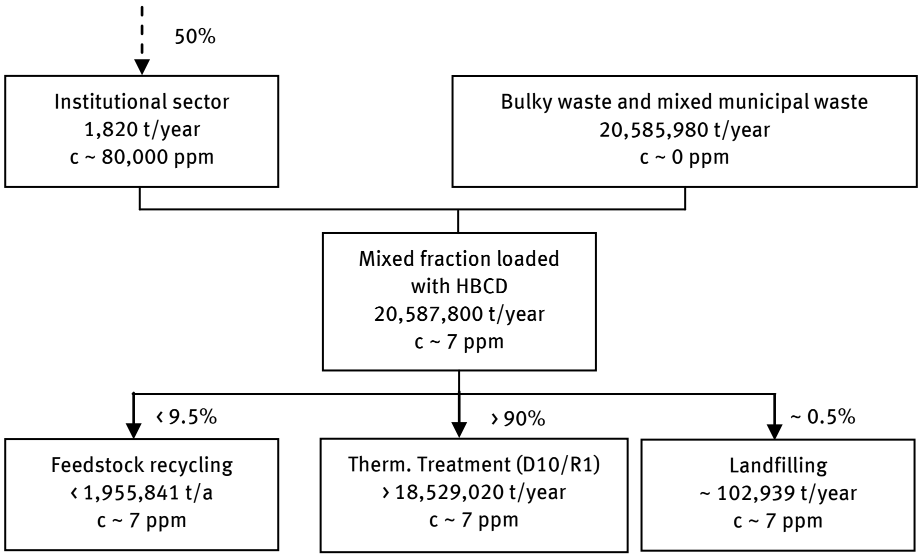


Figure 32 illustrates the material flow for HBCD flame retarded textiles from the institutional sector, under the realistic assumption that they are treated together with the total amount of bulky waste and mixed municipal waste in Germany (total about 20,587,800 t/year). Flame retarded textiles (HBCD concentration: 80,000 ppm) enter the waste stream with the volume of about 1,820 t/year which finally results in a theoretical HBCD concentration of 7 ppm. The bulk of this waste stream is treated thermally (>90%); small shares are directed to feedstock recycling (<9.5%) and landfills (ca. 0.5%).

Figure 34: HBCD material flow for PD textiles in 2012: Entry into the bulky waste and mixed municipal waste from the institutional sector



3.3 Hexachlorobutadiene (HCBD)

3.3.1 Manufacture and use

Production

Anthropogenic sources of HCBD are the targeted production, the unintentional generation as well as waste from historical uses. There are no natural sources of HCBD in the environment [UNEP/POPS/POPRC.8/16/Add.2]. In Germany there is currently no intentional production or use of HCBD [UBA 2006a], respectively it has never been intentionally manufactured or used [BUA 1991]. In Europe the intentional production and use of HCBD ended in the late 1970s [UNEP/POPS/POPRC.8/16/Add.2].

In the European chemical Substances Information System (ESIS)[44] HCBD is listed as low production volume chemical (LPV). An LPVC is a chemical which has been produced in or imported into the EU with a tonnage > 10 t/year but never more than 1,000 t/year. According to the European Chemicals Agency (ECHA) HCBD is listed under the pre-registered substances, aimed registration date was 2010. Up till now no application for registration has been submitted to ECHA. This means that no company within the EU is importing or manufacturing HCBD even though there is obvious interest – whether for strategic matters or due to an actual obligation for registration is unclear. Altogether 65 so-called “notifiers” are listed in the Classification and Labelling Inventory of the ECHA.

The worldwide unintentional production or manufacture as a by-product in industrial processes was 10,000 t/year in 1982 [IPCS 1993]. This amount occurred as by-product during chlorination processes [Euro Chlor 2004], [BUA 1991]. The unintentional production in Germany, in the late 1970s, was estimated to be 4,500 t/a whereof 1,000 t/year were exported and the rest incinerated (circa 3,400 t/a) respectively deposited (circa 100 t/a) [BUA 1991]. In the beginning of the 90s in Germany the total amount was estimated to be 550 – 1,400 t/year whereof 300 t/year were exported and the remaining quantity was directed back into the production process. [BUA 1991]

Use

In the past HCBD has historically been used as intermediate product for lubricants and rubber compounds containing fluorine, solvent for elastomers, heat transfer fluid, cooling agent in transformers, hydraulic fluid, fluid for gyroscopes, absorbent to retain gas impurities, as biocide to prevent algae formation in industrial water reservoirs and cooling water systems as well as, in some European countries (France, Italy, Greece and Spain), plant protection product in viticulture [UNEP/POPS/POPRC.8/16/Add.2], [UBA 2006a] [UNECE 2007]. Furthermore HCBD was used to remove hydrocarbons from gases and to recover chlorine-containing gas in the chlorine manufacturing process [UNEP/POPS/POPRC.8/16/Add.2], [UNECE 2007]. In the past HCBD was also used in industrial production of aluminium and graphite rods [UNECE 2007], [UBA 2006a].

HCBD can also occur or be produced as unintended by-product in the synthesis of organochlorine compounds [UNEP/POPS/POPRC.8/16/Add.2], [UBA 2006a], during incineration processes [UBA 2006a] or during the production of magnesium [UNECE 2007].

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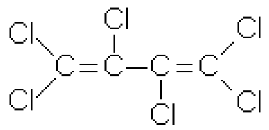
[44] ESIS: European chemical Substances Information System http://esis.jrc.ec.europa.eu/

3.3.2 Chemical characteristics

HCBD is a toxic and bioaccumulative organic compound belonging to the halogenated aliphatic unsaturated hydrocarbons. It appears as a clear, colourless, oily liquid with a mild turpentine-like odour, which is non inflammable, poorly soluble in water as well as marginally volatile (see [UBA 2006a], [UNECE 2007], [Euro Chlor 2004], GESTIS[45]).

Common name:	Hexachlorobutadiene
IUPAC name:	1,1,2,3,4,4-hexachlorobuta-1,3-diene
Synonyms:	HCBD; HCDB, perchloro-1,3-butadiene; perchlorobutadiene; 1,3-hexachlorobutadiene;, 1,1,2,3,4,4-hexachloro-1,3-butadiene, hexachloro-buta-1,3-diene; tripen ([UNEP/POPS/POPRC.8/16/Add.2], [UNECE 2007], [UBA 2006a], [Euro Chlor 2004], [IARC 1999])
CAS registry number:	87-68-3
EINECS Number:	201-765-5
Previous trade names:	*C-46, Dolen-pur, GP40-66:120, UN2279,* [UNECE 2007] [Euro Chlor 2004]
Chemical Structure:	

Figure 35: Chemical structure HCBD



Molar mass:	*260.76 g/mol [UNEP SC 2012], GESTIS*
Molecular formula:	C_4Cl_6

Physical-chemical properties:

Table 42: Physical-chemical properties of HCBD

Physical-chemical properties of HCBD		Sources
Melting point	-21 °C	[UNEP SC 2012], GESTIS
Boiling point	215 °C	[UNEP SC 2012], GESTIS
Density (at 20 °C)	$1.68\ g/cm^3$ $1.55\ g/cm^3$	[UNEP SC 2012], GESTIS [Euro Chlor 2004]
Vapour pressure (at 20, 30, 50 °C)	0.36, 0.75, 2.80 mbar	GESTIS
Vapour pressure (at 20 °C) Vapour pressure (at 100°C)	0.2 mbar 29.26 mbar	[UNEP SC 2012], [UNECE 2007] [UNEP SC 2012]
Ignition temperature	610 °C	GESTIS, [Euro Chlor 2004]
Partition coefficient Log Kow	4.78	GESTIS, [Euro Chlor 2004]

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[45] GESTIS = Information system on hazardous substances of the German statutory accident insurance (original designation: Gefahrstoffinformationssystem der Deutschen Gesetzlichen Unfallversicherung) http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Stoffdatenbank/index.jsp

Water solubility (at 20 °C)	0.50 g/L	GESTIS
	2.55 mg/L	[Euro Chlor 2004]
Water solubility (at 25°)	3.20 mg/L	[UNEP SC 2012], [UNECE 2007]
Henry´s law constant	1044 Pa m^3/mol	[UNEP SC 2012], [UNECE 2007]

3.3.3 Legal background

The European Union and its Member States submitted a proposal to list hexachlorobutadiene (HCBD) in Annex A, B and/or C of the Stockholm Convention on 10 May 2011 [UNEP/POPS/POPRC.7/3] [UNEP/POPS/POPRC.7/INF/4]. In October 2013 the POPRC Committee (Persistent Organic Pollutants Review Committee) reached the recommendation to list HCBD in Annex A (Elimination) and C (Unintentional Production) of the Stockholm Convention (see [UNEP/POPS/POPRC.9/13/Add.2]). The listing of HCBD under the Stockholm Convention is very likely.

According to Regulation EC No 850/2004 on persistent organic pollutants the production, trade and use of HCBD is prohibited since 2012 in the European Community.

Substantially on the initiative of Japan and Canada HCBD is currently under a review process for inclusion under the Rotterdam Convention (see [UNEP/POPS/POPRC.9/13/Add.2]). The Convention sets out that certain hazardous chemicals and pesticides have to undergo a procedure of prior informed consent, exporting countries have to inform importing countries prior to importation of certain substances. The regulation shall prevent uncontrolled imports of substances.

In the context of the EU Water Framework Directive 2000/60/EC establishing a framework for Community action in the field of water policy and defining priority pollutants, HCBD is classified as priority hazardous.

According to §7a of the Water Resources Act (original title in German: Wasserhaushaltsgesetz; WHG, 2005) of the German Federal Government the permission required for the discharge of wastewater is only attributed if the pollutant load is reduced according to the state of the art. The appropriate emission-related state of the art requirements are laid down in the German Waste Water Regulation (original title: Abwasserverordnung; AbwV, 2004). The AbwV further supports the implementation of various EC Directives and defines analysis techniques for water, waste water and sludge testing. Annex 48 (use of specific hazardous substances, requirements for halogenated organic compounds) defines product-specific requirements for HCBD (1.5 g/t for the production of PER and CCl_4 through perchlorination).

HCBD is part of the substances that require approval according to the Indirect Discharge Regulation of the German federal states (original title: Indirekteinleite-Verordnung; VGS) prior to water discharge.

Emission limit values and quality objectives for HCBD are set out in the EU Directive 88/347/EWG for different industrial firms.

After the Commission Decision EU-EPER 2000/479/EC on the implementation of a European Pollutant Emission Register (EPER) according to EC-RL 96/61 HCBD emissions into water that are higher than 1 kg/year have to be reported.

The EU-E-PRTR Directive 166/2006/EC concerning the establishment of a European Pollutant Release and Transfer Register (PRTR) lays down reporting obligation threshold values for HCBD releases as follows: Releases to water 1 kg/year, releases to land 1 kg/year.

HCBD is listed in the so-called Master List of the UBA on Carcinogenic, Mutagenic or Toxic for Reproduction (CMR) and other problematic substances (see [UNEP/POPS/POPRC.9/13/Add.2]).

In the regulation TA-Luft (Technical Instructions on Air Quality Control; original title: Technische Anleitung zur Reinhaltung der Luft) HCBD is limited to a maximum mass flow of 0.1 kg/hour respectively a mass concentration of 20 mg/m^3.

The German Chemicals Prohibition Ordinance (ChemVerbotsV; original title in German: Chemikalienverbotsverordnung), the German Hazardous Substances Ordinance (GefStoffV, original title: Gefahrstoffverordnung) and the German Commodity Ordinance (BedGgstV; original title: Bedarfsgegenständeverordnung) all prohibit the use of HCBD in decorative articles and toys.

3.3.4 Occurrence (manufacture, import/export, consumption, relevance of occurrence in Germany)

Trade

In accordance with Regulation EC No 850/2004 of the European Parliament the trading of HCBD is prohibited in the European Union and thus since 2012 in Germany.

Production

Literature shows that the global HCBD production was estimated, in 1982, to be 10,000 t/year [IPCS 1993]. This amount resulted mainly as by-product during chlorination processes [Euro Chlor 2004], [BUA 1991].

In Germany there is currently no intentional production of HCBD. However, in the late 1970s about 4,500 t/year of HCBD occurred during the low-pressure chlorolysis for combined production of perchloroethylene (PER) and tetrachloromethane (TETRA). Of such, 1,000 t/year were exported, 3,400 t/year were incinerated and circa 100 t/year were deposited [BUA 1991]. In the beginning of the 1990s the total amount in Germany was estimated to be only about 550 – 1,400 t/year, whereof 300 t/year were exported and the remaining quantity was directed back into the production process. These 300 tonnes were used as auxiliary agent to produce rubber, but this export was terminated in 1990 [BUA 1991].

According to estimations of the UNEP POPRC Committee there is no intentional production of HCBD anymore in Germany and the entire UNECE region, even though the production and use, especially of small amounts, cannot be excluded [UNEP/POPS/POPRC.9/5 2013].

Use

Already in 1987 it was noted that HCBD wasn’t used anymore in Germany. Important historic uses of HCBD were as cooling agent in transformers (in combination with trichloroethene), as polymer solvent, as non-flammable insulating oil and as hydraulic fluid [BUA 1991]. Specific quantitative information on the different uses couldn’t be investigated.

Use in the agricultural sector

The last known intentional use of HCBD was as fumigant in viniculture [WWF 2005], [UNECE 2006], [UNECE 2007], [Haskoning 2002b], [ATSDR 1994].

The main user was the former USSR with an application rate of 100-350 kg/ha [UNECE 2007], but also France, Italy, Greece and Spain have used HCBD for this purpose. In France HCBD has been used until 2003 [INERIS 2005]. HCBD has also been applied in the past as biocide for prevention of algae production in industrial reservoirs and cooling water systems, as well as in graduation houses for salt production [BUA 1991], [UBA 2006a].

No evidence has been found that HCBD has ever been intentionally used in the German agricultural sector.

Use as chemical intermediate in industrial manufacture

An important application of HCBD has been its use as chemical intermediate in several industrial manufacture processes.

Some sources report that HCBD was also used as a chemical intermediate in the synthesis of rubber compounds ([WWF 2005], [UBA 2006a], [Euro Chlor 2004], [ATSDR 1994], [Haskoning 2002b]). Since the produced rubber compounds are not specified research about potential producers could hardly be conducted.

Other sources also indicate that HCBD was used as solvent for rubber [Euro Chlor 2004], polymers ([UNECE 2006], [UNECE 2007]) and elastomeric plastics [UBA 2006a]. One source indicated that HCBD still can be present in rubber compounds in marginal amounts according to the national association on rubber and polymers in France (Syndicat National du Caoutchouc et des Polymères) [INERIS 2005].

Further, HCBD has been applied as chemical intermediate during the production of lubricants ([ATSDR 1994], [Haskoning 2002], [WWF 2005], [INERIS 2005], [UBA 2006a]). HCBD has also been used in small amounts in the manufacture of chlorofluorocarbons ([WWF 2005], [Euro Chlor 2004]). Furthermore, HCBD was also used in the production of aluminium and graphite rods ([INERIS 2005], [UBA 2006a]).

Use in the purification of gas streams

According to the relevant literature one of the main applications of HCBD was the recovery of “snift”, a chlorine-containing gas in chlorine plants. For this purpose HCBD has been used mainly in the USA prior to 1975 ([WWF 2005], [Euro Chlor 2004], [UNECE 2006/7]) but probably also outside the USA [UNECE 2006/7]. In addition HCBD has been applied as washing liquor for purifying gas streams and for removing hydrocarbons (C4 and longer chain hydrocarbons) [Euro Chlor 2004], [UNECE 2006/7], [UBA 2006a], [WHO 2003].

Use in electrical equipment

Historically HCBD has been used for several technical applications in electrical equipment. Inter alia as heat-transfer liquid particularly in transformers ([Haskoning 2002b], [WWF 2005], [UNECE 2006/7], [Euro Chlor 2004, [INERIS 2005], [UBA 2006a], [IARC 1999]). HCBD has also been used as hydraulic fluid and liquid in gyroscopes ([WWF 2005], [UBA 2006a], [INERIS 2005], [UNECE 2007], [Euro Chlor 2004]) and as insulating liquid [INERIS 2005].

Unintentional production

At the present the most relevant source of HCBD - besides releases due to former uses - is assumed to be unintentional production during different processes.

HCBD occurs unintentionally as by-product during manufacture of chlorinated chemicals, from where it can enter waste streams or be released to the environment. To the greatest possible extent manufacturing plants are able to mostly destroy or recover HCBD in the process. Through technological measures environmental releases can be kept at a minimum (see [UNEP/POPS/POPRC.9/5 2013]). It is possible that incineration residues (slag[46]) that occur from the production of chlorinated organic compounds contain HCBD.

According to different publications HCBD can be unintentionally produced in the manufacture of magnesium ([Euro Chlor 2004], [UBA 2006a], [UNECE 2006], [UNECE 2007]) as well as during the manufacture of plastics and the release of motor vehicle emissions [WWF 2005].

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[46] Ashes are fed back into the incineration process in German plants. Slag is the only waste-relevant output from the incineration process.

Several sources report the unintentional production of HCBD during the manufacture of magnesium ([Euro Chlor 2004], [UBA 2006a], [UNECE 2006], [UNECE 2007]). According to information from the UBA 15 to 20 g of HCBD arise per tonne of manufactured magnesium [UBA 2006a]. In the past, magnesium has been produced by the German company Metaleurop, since 2007 rebranded to the Recylex business group. Currently Germany is not producing primary magnesium [MPK 2015]; accordingly magnesium production is no potential source of HCBD in Germany.

Likewise incineration processes (e.g. releases from vehicles, incineration of acetylene and waste containing chlorine) are sources of unintended HCBD releases [BiPRO 2011].

Another unintentional release of HCBD can result from sewage sludge during industrial or municipal waste water treatment.

3.3.5 Selection of relevant products, wastes and recyclates in Germany

In Germany, the intentional production and manufacture of HCBD is no longer relevant. In principle, therefore the following sources are possible:

- products form historical uses that enter the waste stream
- unintentional production – manufacture of chlorinated solvents
- unintentional production – incineration processes
- unintentional production – manufacture of rubber compounds
- sewage sludge from waste water treatment

Products from historical uses that enter the waste stream

HCBD releases can arise from the disposal of old HCBD-containing products such as hydraulic, cooling and absorbent liquids. Already in 2002 the UBA suspected that these releases “play a minor role in quantitative terms” [UBA 2002].

Unintentional production – manufacture of chlorinated solvents

The most frequent references in literature for unintentional generation of HCBD are related to the manufacture of chlorinated solvents [UNEP SC 2012], [UNECE 2007]:

- trichloroethene (TRI, trichloroethylene)
- tetrachloroethylene (PER, tetrachloroethene, perchloroethylene or perchloroethene)
- tetrachloromethane (TETRA, carbontetrachloride, Halon 104, Freon 10)

The IUCLID platform (International Uniform Chemical Information Database) that belongs to the European chemical Substances Information System ESIS provides data on safety data sheets from German companies for the above mentioned substances (see Table 39). This suggests that these companies trade or even produce the relevant substances. Apparently this information hasn’t been updated since 2000:

Table 43: German companies with safety data sheets for TRI, PER and TETRA (Source: ESIS, IUCLID Dataset)

Company	Place	TRI	PER	TETRA	Source
DOW DEUTSCHLAND INC., PLANT STADE	21683 STADE		x	X	ESIS / IUCLID
BASF AG	67056 LUDWIGSHAFEN	x			ESIS / IUCLID
HUELS AG	45764 MARL		x	X	ESIS / IUCLID
CELANESE GMBH	65926 FRANKFURT AM MAIN			X	ESIS / IUCLID

CHEMIEWERK NUENCHRITZ GMBH	01612 NUENCHRITZ			X	ESIS / IUCLID
HOECHST AG	65903 FRANKFURT/MAIN			X	ESIS / IUCLID
BRENNTAG INTERNATIONAL CHEMICALS GMBH	45472 MUELHEIM	x	x		ESIS / IUCLID
BRENNTAG AG	45427 MUELHEIM A. D. RUHR	x			ESIS / IUCLID
HELM AG	20097 HAMBURG		x		ESIS / IUCLID
WACKER - CHEMIE GMBH	84480 BURGHAUSEN	x	x		ESIS / IUCLID

TRI is being used as starting material for the manufacture of fluorocarbons or as solvent for high precision surface cleaning and degreasing [SAFECHEM 2014]. Furthermore it is applied in laboratories for asphalt density detection [BG RCI 2012].

In Germany, in 1990, the output was around 58,000 t/year [GeoDZ 2015]. Due to stricter environmental regulations and substitution through other chemicals the production in Europe has decreased to 25,000 t/year in 2006. Meanwhile the only European companies still producing trichloroethene are DOW EUROPE and another Romanian producer (Chimcomplex Borzesti), it is registered under REACH [ECSA 2011], [ECSA 2014]. Specific figures for the current production output are not available.

Tetrachloroethylene is a solvent which is used in the textile, movie, optical and metal sector. Because of its highly degreasing power PER is being applied as degreasing agent. The optical manufacturing uses tetrachloroethylene to clean lenses and prisms prior to connecting these to optical elements via cementing or contact bonding.

Because of its carcinogenic and toxic properties, as well as its ozone depleting potential tetrachloromethane may not be used anymore. The application as fire-extinguishing, degreasing, cleaning, solving and diluting agent is only allowed for research purposes due to its toxicity and unfavorable environmental properties.

According to Euro Chlor, the only remaining significant source of HCBD is the low pressure chlorolysis for the combined production of tetrachloroethylene and tetrachloromethane. The residues of the low pressure chlorolysis contain 0.2-0.5 % HCBD. After further distillation the residues contain 7-10 % HCBD. The HCBD-containing residues are generally destroyed on-site by incineration at high temperatures of about 1,200 °C or internally recycled [Euro Chlor 2004].

On behalf of Dow Deutschland waste gas samples from a waste incineration plant using tetrachloroethene and tetrachloromethane in the production were analysed for HCBD. During the incineration of 650 kg waste material, containing 480 kg hexachlorobenzene and hexachlorobutadiene per hour at 1,400°C, the air flow was 2,950 m^3 per hour. Different volume samples of waste gas were taken: one sample on the 24.03.1992 had a volume of 10 m^3 and two samples on the 22.07.1992 had a volume of 10 l. In both cases no HCBD was proved. The detection limit for the 10 m^3 sample was 0.5 µg HCBD absolute, the detection limit for the 10 l samples was 0.01 µg/sample (= 1 µg/m^3) (Dow 1992 b from [BUA 1991/2006]). For this reason no considerable HCBD releases in the atmosphere from incineration are to be expected.

A communication from the Dow Deutschland company is mentioning HCBD releases from the incineration of production waste resulting from tetrachloroethene and tetrachloromethane manufacture. According to this, in 1998, 60 g of HCBD was emitted into the atmosphere that resulted from production waste containing circa 50% hexachlorobenzene and circa 40% HCBD besides hexachloroethane (Dow 2005 cited from [BUA 1991/2006]).

Dow produces these kinds of substances at two plants in Germany. Production residues are directly incinerated on-site. Ashes don't accrue during this process since they are being redirected to incineration. The only solid residue from incineration is slag. Routine tests are conducted to check on halogenated organic compounds, no relevant amount is detectable. HCBD is not considered. Specific measurements of HCBD concentration in the incineration residues are not available. On the basis of available data an assessment of HCBD releases via ashes/slag from the production process of organic solvents is not possible.

Whether there are relevant amounts of HCBD in waste therefore remains unclear. In consultation with the UBA it was agreed to take samples of occurring slag. Two slag samples have been procured and analysed for HCBD concentration (sample 14 and 15HCBD). No HCBD concentration above the detection limits was found (detection limits 8.87 µg/kg and 9.24 µg/kg). According to these analytical results it can be concluded that there are no relevant amounts of HCBD in incineration residues from the the incineration of production waste generated in the manufacture of chlorinated solvents in Germany (based on two random samples).

Unintentional production – incineration processes

The unintentional generation of HCBD has repeatedly been reported in the literature e.g. [Euro Chlor 2004], [Lenoir et al. 2001]. The formation of organochlorine compounds, including HCBD, during the incineration of acetylene has been described. Acetylene is a component of all incinerations [Lenoir et al. 2001]. Other sources also report the release of HCBD from incineration processes without defining them in more detail [WWF 2005] [INERIS 2005] [UBA 2006a]. One source indicates that, in France, HCBD occurred during the incineration eliminating chlorinated residues in 2003 [INERIS 2005]. Another source reports that HCBD generation during incineration processes is similar to the generation of dioxins, furans and hexachlorobenzene [CEPA 1999].

HCBD is suspected to be developed under similar incineration conditions like dioxins and furans, thus it can occur during waste incineration (e.g. incineration of municipal waste, clinical waste and hazardous waste) and might enter the waste stream through incineration residues (ashes and slag). HCBD is not a standard parameter for the analysis of solid residues.

Research conducted in the context of this project has shown that there is no specific information on the HCBD contamination of waste streams from incineration processes. Specific measured values are not available. Therefore it remains unclear whether relevant amounts of HCBD occur in waste.

In Germany, around 30,000 t/year of incineration residues from clinical waste incineration plants (1) (whereof 1,500 t/year results from the incineration of infectious waste), (2) over 4 million t/year incineration residues from municipal waste incineration plants and (3) up to 440,000 t/year incineration residues from hazardous waste incineration plants occur. Especially due to those high amounts, relevant amounts of HCBD might occur.

In order to clarify the potential relevance of waste incineration processes, samples (ashes and slag) from municipal waste incineration plants (two plants) and hazardous waste incineration plants (two plants) were acquired. One of these plants for the incineration of municipal waste had separate ovens for the incineration of clinical wastes. Off-gas purification for municipal and clinical waste incineration takes place together and the incineration residues accrue as mixture. On the basis of the information available there is no German plant that treats off-gases from clinical waste incineration separately or takes separate samples of incineration residues.

The obtained samples (samples No. 18 to 22HCBD/PCN) were analysed for HCBD concentrations in order to estimate the potential relevance of waste incineration processes[47]. No concentrations above the detection limits were found (detection limits ranging from about 9 to 10 µg/kg). The analytical results imply that HCBD is not present in incineration residues from municipal waste incineration in relevant quantities in Germany (on the basis of five random samples).

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[47] The same samples shall be analysed for PCNs concentration (see section 3.4.5)

Unintentional production – manufacture of plastics

Regarding the generation of HCBD in the manufacture of plastics, [WWF 2005] refers to a preliminary document from Environment Canada[48]. The final document [Environment Canada 2000] doesn't mention the manufacture of plastics anymore. Apart from this there is no specific indication that HCBD occurs during the manufacture of plastics. Accordingly the recent Draft Risk Management Document of the Stockholm Convention doesn't quote plastics manufacture as potential source of unintentional HCBD production anymore [UNEP/POPS/POPRC.9/5 2013]. Thus plastics manufacture is not considered as relevant source of HCBD.

Waste-water treatment plants (sewage sludge)

Sewage sludge doesn't occur as uniform picture, it is highly dependent on the catchment area, the share of residential population connected as well as the amount and type of companies connected. Literature reports HCBD occurrences both in industrial and municipal waste-water treatment plants.

The European Pollutant Release and Transfer Register (E-PRTR) [49] of 2010 contains information about one company for the production and treatment of metals that releases an HCBD amount of 17.0 kg into water. Another company from the chemical sector (industrial production of basic organic chemicals or basic plastics) reported the release of 2.35 kg HCBD into water. Nine municipal waste-water treatment facilities reported the release of 69.5 kg HCBD into water. The reporting facilities are located in Portugal, France, Italy, Belgium, Poland, Slovakia and Czech Republic. No German company reported HCBD releases in the E-PRTR.

In Germany this Pollutant Release and Transfer Register is implemented via the web-based portal www.thru.de. The first reporting period was 2007, since 2007 no PRTR company has reported emissions of HCBD.

In the context of a research project regarding investigations on releases and elimination of hazardous substances in municipal sewage treatment plants, measurements were performed for two waste water treatment facilities in North Rhine-Westphalia. Only in one influent sample (n=38) HCBD could be detected in a concentration of 0.20 µg/l [UBA 2006a]. In examinations on drains of municipal sewage treatment plants in Hesse, in 2002 and 2003, no sample exceeded the detection limits of 0.05 µg/l respectively 0.1 µg/l. Also in an analysis in Saxony in 2002 no sample was above the detection limit [UBA 2006a]. In Hesse one sample (n=9) was measured above the detection limit during sewage sludge analyses in 2002 [UBA 2006a]. ABANDA provides data on measurements of sewage sludge from municipal waste-water (0.01 mg/kg) as well as on 22 measurements of sewage sludge from a treatment of industrial waste-water (n = 22; average 0.193 mg/kg). There is no specific data available for Europe. An investigation of the Irish EPA didn't measure HCBD in sewage sludge samples above the detection limit (0.1 mg/kg)[50]

In Germany annually 2 million tonnes of sewage sludge accrue, whereof around 30% are recovered in agriculture and 70% are thermally recovered.

Individual information on HCBD contents in sewage sludge is available for China (average 39 µg/kg DM; [Cai et al. 2007]) and the USA (0.6 µg/kg; [IPCS 1994]).

If a concentration of 0.6 µg/kg DM is taken as basis for Germany it can be assessed that the overall amount of sewage sludge (1.89 million tonnes in 2010) contains an HCBD freight of about 1.1 kg. This freight can be assigned to the different disposal and recovery pathways as set out in Table 40.

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[48] Environment Canada & Health Canada (EC & HC). (2000), Priority Substance List Assessment Report for Hexachlorobutadiene. Draft for Public Comment, June 2000

[49] http://prtr.ec.europa.eu/

[50] Personal communication Irish EPA on 22.02.2011

More than half of the HCBD contained in the sewage sludge (53.2%) should be destroyed through thermal disposal. Around 30% of the sewage sludge is being recovered in agriculture.

Table 44: Estimated distribution of the HCBD freight in sewage sludge among disposal and recovery pathways in Germany in 2010

	Sewage sludge disposal Total	Agricultural recovery	Landscaping measures	Other material recovery	Thermal disposal	Landfill
Amount (in t)	1,887,408	566,295	259,312	58,052	1,003,749	-
Share (in %)	100	30	13.74	3.08	53.18	-
HCBD freight (in kg)	1.1	0.3	0.2	0.0	0.6	-

Since there is no specific data available from Germany and Europe, this estimation seems not very reliable.

Due to the large quantities of sewage sludge that accrue in Germany, sewage sludge samples were taken in a huge German municipal waste-water treatment facility in order to improve the evidence base. The provided sample was analysed for its HCBD content in order to support estimations on the relevance of sewage sludge in the context of the present project. HCBD was not measured above the detection limit (0.54 µg/kg) in the samples. This analytical result gives no evidence that HCBD occurs in relevant amounts in municipal sewage sludge in Germany.

Table 41 gives an overview on the conclusions drawn regarding the relevance of potential HCBD occurrences.

Table 45: Conclusion of the relevance of potential occurrence (HCBD)

Potentially relevant occurrence	Estimated relevance
products form historical uses that enter the waste stream	Already not relevant for a long time.
unintentional production – manufacture of chlorinated solvents	Not relevant; Analytical results give evidence that, in Germany, HCBD doesn't occur in relevant amounts in incineration residues from incineration of residues from manufacture of chlorinated solvents.
unintentional production – incineration processes	Not relevant; Analytical results give evidence that, in Germany, HCBD doesn't occur in relevant amounts in incineration residues from municipal waste incineration.
unintentional production – manufacture of plastics	Not relevant.
sewage sludge from waste water treatment	Not relevant; The analytical result (one random sample) gives evidence, that in Germany, HCBD doesn't occur in relevant amounts in municipal sewage sludge.

3.4 Polychlorinated naphthalenes (PCN)

3.4.1 Manufacture and use

Production

PCN arise out of anthropogenic sources. In a natural way PCN can eventually arise from the incineration of wood e.g. during forest fires [Environment Canada 2011]. There are no indications that PCN are nowadays intentionally produced or used. Until the 70s of the past century PCN were produced as „High Production Volume“ chemical with about 9,000 t/year in the 1920s and 150,000 t/year in the 1970s. In the late 70s the production figures significantly decreased. Small amounts of up to 300 t/year have been produced for the manufacture of paints by Bayer until the beginning of the 1980s. Roughly around 1983 the production of PCN was stopped.

Use

In the past, PCN have been used for several different purposes including cable insulation, wood preservation, impregnation of paper (e.g. for oilpaper-capacitors), dielectric for capacitors, in products to recast electronic or automotive parts, in the manufacture of precision casts, in flame retardants, as masking compound for the carburising of metals, as additive in engine oils, as additive for waterproof metal paint (e.g. in ship industry), as additive for surface treatment and galvanisation, as lubricant for cutting or grinding, as refracting index oils as well as binder for the manufacture of ceramic products [Environment Canada 2011].

According to [Brinkmann and Reymer, 1976] PCN were employed in diverse uses, i.e. as separator in storage batteries, as impregnating agent for capacitors, as high-temperature and flame resistant seals for condensers and coils, as binders for electrical-grade ceramics and sintered metals, in cable-covering compositions, to impregnate wood, paper and textiles (they impart waterproofness, flame resistance and fungicidal and insecticidal properties) as well as insecticide in agriculture. Furthermore PCN were compounded with resins, rubber, plastics, talc, kaolin and PCBs to process different mouldable masses. In addition PCN were used to dissolute sludge and varnish from petroleum oils and as ingredients in motor tune-up compounds and photoelastic fluids. Also they were used as plasticisers, in automobile and gear oils and cutting oils, as well as in paints and underwater coatings. Moreover, PCN were employed as flame retardant organic fillers and as raw material for dyes [Brinkman and Reymer 1976].

PCN were also used in the defence industry, e.g. in the production of smoke grenades.

PCN can be formed unintentionally during various thermal processes, e.g. waste incineration and other combustion processes taking place domestically or in the industry [UNECE 2007], [Haskoning 2002a]. Other potential sources are melting processes in the secondary non-ferrous metal industry (e.g. copper) and the aluminium manufacture as well as the manufacture of cement and magnesium. Additionally the coke manufacture and chlor-alkali industry are reported to be sources of PCN emissions (see [UNEP/POPS/POPRC.9/4 2013] and [Brack et al. 2003]). Incineration processes, especially waste incineration, are considered to be the most important sources. It is assumed that PCN arise under similar conditions like dioxins and furans (see [UNEP/POPS/POPRC.9/4 2013])

The chlor-alkali industry in the former GDR was identified as potentially essential source of PCN (see [Brack et al. 2003]). However, also many other references give hints on the potential formation of PCN during the chlor-alkali process when graphite electrodes are used (see [Kannan et al. 1998]).

3.4.2 Chemical characteristics

Polychlorinated naphthalenes are a group of compounds based on the naphthalene ring system, where one or several hydrogen atoms have been replaced by chlorine. There are 75 possible congeners of PCN which, according to the amount of chlorine atoms in the molecule, can be subdivided in eight homologous groups. While PCN are considered as a class, physical-chemical and toxicological properties vary strongly by congener and homologous group [Environment Canada 2011], [UNECE 2007].

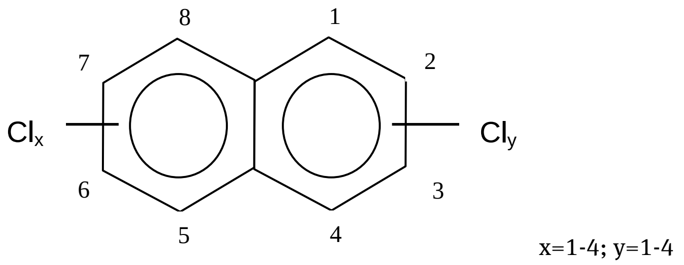
Polychlorinated naphthalenes are hydrophobic and have high thermal and chemical stability and low flammability. Most of the industrially manufactured and used PCN are mixtures of several isomers. The industrial use ranges from low viscosity oils to wax like solids with high melting points [NICNAS 2002]. Liquid PCN are soluble in most organic solvents, whereas the wax like solid PCN are soluble in chlorinated solvents.

Table 46: Names, CAS numbers and trade names for PCN

Name	Polychlorinated naphthalenes
CAS number	The individual PCN and their mixtures have different CAS numbers and names [UNEP/POPS/POPRC.8/2 2012]
Synonyms	Mono- to Octa-chlorinated naphthalenes, Mono-Octa-CN [UNECE 2007]
Previous trade names	Halowax, Nibren Waxes, Seekay Waxes [UNECE 2007]

Chemical structure:

Figure 36: Chemical structure PCN



Generic molecular formula: $C_{10}H_{8}$-nCl_{n} (n=1-8)

Names and molecular formulas

Table 47: Names and molecular formulas for PCN groups

Name	Molecular Formula
Monochloronaphthalene	$C_{10}H_7Cl$
Dichloronaphthalenes	$C_{10}H_6Cl_2$
Trichloronaphthalenes	$C_{10}H_5Cl_3$
Tetrachloronaphthalenes	$C_{10}H_4Cl_4$
Pentachloronaphthalenes	$C_{10}H_3Cl_5$
Hexachloronaphthalenes	$C_{10}H_2Cl_6$

Heptachloronaphthalenes	$C_{10}H_1Cl_7$
Octachloronaphthalene	$C_{10}Cl_8$

Physical-chemical properties:

Table 48: Physical-chemical properties of PCN groups

Group	Molecular weight [g/mol]	Melting point [C°]	Boiling point [C°]	Water solubility [mg/L]	Vapour pressure [kPa]	Henry's Law Constant [Pa m^3/mol]	LogK_{ow} partition coefficient (octanol/ water)
Mono-CN	162.61	-2.3-60	259-260	0.28-9.2 x 10^{-2}	2.1 x 10^{-3}- 3.9 x 10^{-3}	36	3.9
Di-CN	197.00	37-138	287-298	8.5 x 10^{-3}- 8.6 x 10^{-2}	1.7 x 10^{-3}	n.a.	4.19-6.39
Tri-CN	231.50	68-133	ca. 274	1.6 x 10^{-2}- 6.7 x 10^{-2}	1.3 x 10^{-4}	n.a.	5.35-7.56
Tetra-CN	266.00	115-198	n.a.	3.7 x 10^{-2}- 8.0 x 10^{-2}	n.a.	n.a.	5.50-8.58
Penta-CN	300.40	147-171	ca. 313	7.3 x 10^{-3}	4.2 x 10^{-6}	11.9	8.73-9.06
Hexa-CN	335.00	194	ca. 331	1.1 x 10^{-4}	9.5 x 10^{-7}- 3.0 x 10^{-9}	8.8	6.98-10.37
Hepta-CN	369.50	194	ca. 348	4.0 x 10^{-5}	3.7 x 10^{-7}	n.a.	7.63-8.3
Octa-CN	404.00	192	440	8.0 x 10^{-5}	1.3 x 10^{-7}	4.8	n.a.

Ca.= circa: denotes an estimated or calculated value n.a.= not available

3.4.3 Legal background

On 10 May 2011, the member states of the European Community submitted a proposal to list PCN in the Annexes A, B and/or C of the Stockholm Convention [UNEP/POPS/POPRC.7/3], [UNEP/POPS/POPRC.7/INF/4][51]. In October 2013, the POPRC Committee reached the proposal to list PCN in Annex A (Elimination) and C (Unintentional Production) (see [UNEP/POPS/POPRC.9/13/Add.2]). The listing of PCN under the Stockholm Convention is very likely.

In December 2009, PCN were proposed to be listed in Annex 1 (Ban of production and use) of the Aarhus protocol on persistent organic pollutants that is part of the UNECE Convention on Long-Range Transboundary Air Pollution. The proposal will enter in force as soon as two thirds of the members ratify the proposal.

Waste management

Following Annex VIII of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, wastes containing polychlorinated naphthalenes are classified as hazardous. The threshold is 50 mg/kg.

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[51] The proposal applies to Di- to Octa-chlorinated naphthalenes

3.4.4 Occurrence (manufacture, import/export, consumption, relevance of occurrence in Germany)

PCN were commercially produced as mixtures of several congeners with different product names, e.g. Halowax, Nibren Waxes, Seekay Waxes and Cerifal Materials. Until the 1970s PCN were produced as „High Production Volume“ chemical with about 9,000 t/a in the 1920s and 150,000 t/a in the 1970s [NICNAS 2002]. The German company Bayer produced PCN in ranges of 100-300 t/a until 1984, the exact production site is unknown [Haskoning 2002a], [UNECE 2007]. These amounts were mainly used to produce paints and coatings. Since 1989 PCN are not produced in Germany anymore [NICNAS 2002].

Currently, there is no targeted production and use of PCN in Germany, respectively within the UNECE [UNECE 2009], accordingly there are no emissions resulting from intentional production or use of PCN [UNECE 2007]. The only source of PCN emissions that has to be taken into account is the unintentional release, e.g. during incineration processes [UNECE 2007], [NICNAS 2002] and other high temperature processes, e.g. the secondary manufacture of non-ferrous metals or the manufacture of cement and magnesium. The synthesis of PCN during these processes is assumed to be similar to the generation of PCDD/Fs [UNEP/POPS/POPRC.9/4 2013].

3.4.5 Selection of relevant products, wastes and recyclates in Germany

Former uses in different applications

PCN haven’t been produced or used in over 30 years. It can be assumed that the bulk of PCN-containing products has already been disposed of [GRL 2004], [BiPRO 2011]. Due to the wide range of applications (see e.g. [Brinkmann and Reymer 1976]) it is possible that a certain proportion of PCN is still used in products. However, sufficient information for the estimation of affected quantities is not available [BiPRO 2011]. Given the limited time-span of relevant products, it can be assumed that the remaining amounts of PCN in products are very low and that currently only negligible quantities enter the waste streams in this way.

Former use in the electrical industry

PCN have especially been used during the 1940s and the 1950s in the electrical industry. The applied quantities were only relevant until the 1970s, afterwards the use has significantly decreased. PCN were substituted especially with PCB. The last PCN-containing applications are small amounts in the electrical industry and were reported in the beginning of the 1990s [Weistrand et al. 1992].

Commercial PCB mixtures didn’t contain traces of PCN (0.01-0.09% [Falandysz 1998], [Kannan et al., 2000], [Yamashita et al., 2000]). The worldwide amounts of PCN contained in PCB that have ever been produced are estimated to be between 100 and 170 tonnes. It is therefore possible that there are PCN traces in PCB-containing waste (see e.g. [BiPRO 2011] and [UNEP/POPS/POPRC.9/4 2013]).

According to Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT), meaning the disposal of all PCB-containing products until 2010, it can be assumed that no or negligibly few PCN-containing products are still circulating.

Unintentional production

Apart from the releases of PCN through former uses numerous industrial processes can be identified in the literature as potential sources for the unintentional production of PCN. Especially thermal processes play an important role. Examples are:

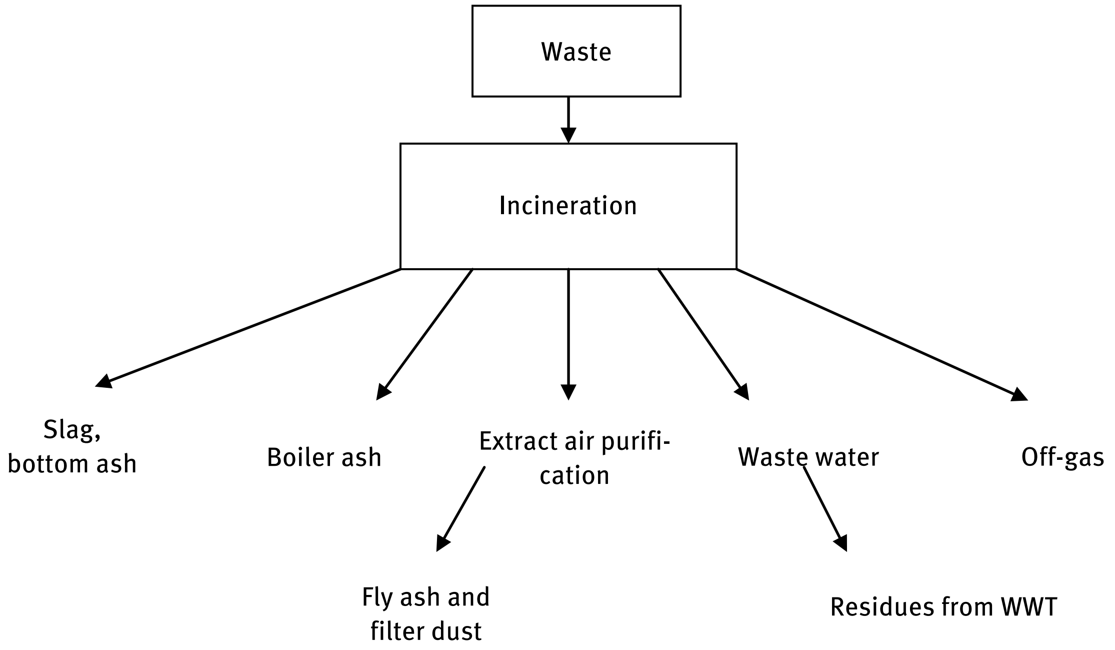
- waste incineration
- manufacture of secondary copper
- manufacture of secondary aluminium

- chlor-alkali electrolysis
- metallurgical processes for the magnesium production (currently magnesium production does not take place in Germany and thus is no potential source for PCN; for furhter details see [BiPRO 2011]).

3.4.6 Incineration of municipal waste/hazardous waste/clinical waste

Neither during the incineration of municipal waste nor during the incineration of hazardous waste, PCN are standard parameters for the analysis of incineration residues. Accordingly there is no current data for German facilities. In general the substances shown in Figure 35 occur during incineration processes:

Figure 37: Overview of substances occurring during waste incineration



Every thermal waste treatment facility operated in Germany meets the requirements of the European Industrial Emissions Directive (2010/75/EC). The state of the art on the European level is written down in the Reference Document on the Best Available Techniques for Waste Incineration. Like dedicated waste incineration, co-incineration of wastes is regulated in the 17th BImSchV (Ordinance for the Implementation of the German Federal Immission Control Act; original title in German: Bundesimmissionsschutzverordnung) in Germany. It takes place in coal-fired power plants, cement plants and other industrial incineration facilities.

According to information of the ITAD e.V. typically 292 kg incineration residues accrue per tonne of incinerated waste from waste incineration facilities (thereof 250 kg/t slag, 10 kg/t bottom ash, 20kg/t filter ash and 12.5 kg/t solid residues from flue gas scrubbing).

Municipal waste incineration in Germany takes place in 68 facilities with an overall capacity of around 19.6 million t/year [UBA 2014]. Accordingly due to the incineration of about 16.5 million tonnes of municipal waste in 2011 [DESTATIS 2013a] 4.8 million tonnes of incineration residues occurred (4.1 million tonnes of slag; 0.5 million tonnes of ash; 0.2 million tonnes of solid residues from flue gas scrubbing).

BDSAV is the association of publicly accessible hazardous waste incineration plants in Germany (original designation in German: Bundesverband Deutscher Sonderabfallverbrennungs-Anlagen e.V.). The incineration capacity of the members of the union amounts to ca. 0.7 million t/year. Thus the BDSAV represents about half of the available hazardous waste incineration capacity in Germany and the major proportion of all publicly accessible facilities. The overall capacity of the approximately 30 hazardous waste incineration facilities in Germany amounts to ca. 1.5 million t/year [UBA 2014]. The overall capacity is far from being fully utilised. Under the assumption of around 1 million t/year hazardous waste generated annually and the specific amounts (292 kg/tonne of waste) as well as the relations of incineration residues like in usual waste incineration facilities, an amount of 0.292 million tonnes incineration residues arises from hazardous waste incineration (0.25 million tonnes of slag; 0.03 million tonnes of ash; 0.01 million tonnes of solid residues from flue gas scrubbing).

The composition of clinical waste generally varies considerably and constitutes of a mixture of plastics (e.g. urine and blood bags etc.), pulp (diapers, dressing material, etc.), metals (needles, syringes) but also other materials. A maximum of five percent (around 5,000 t/year) of the overall waste generated in hospitals and other health facilities is infectious waste, which is classified as hazardous waste according to the German List of Wastes Ordinance (original title in German: Abfallverzeichnisverordnung, AVV), due to its high risk of infection. Accordingly the overall amount of clinical waste is about 100,000 t/year (without biological waste; in 2010 clinical and biological wastes in Germany amounted to 269,000 t; see section 3.1.4). If collection, storage and transport are conducted with appropriate care, the far larger waste quantity of approximately 95,000 t/year can be disposed of and recovered together with municipal waste in thermal waste treatment facilities.

Around 5,000 t/year of infectious hospital waste is incinerated in dedicated municipal waste incineration facilities (2 facilities in Germany). They are equipped with separate ovens for clinical waste incineration. The off gas treatment is carried out jointly with the off gas treatment of municipal waste incineration. Part of the infectious waste is directed to thermal disposal in specialised waste incinerator plants (so called hazardous waste incineration plants). If an annual infectious clinical waste amount of about 5,000 t/year, the same specific amounts (292 kg/t waste) and the same relation in waste incineration residues like in other waste incinerators are assumed, around 1,462 t incineration residues (1,250 t slag; 150 t ash; 62 t of solid residues from flue gas scrubbing) accrue during the incineration of infectious hospital waste. However, the incineration residues don’t occur separately but in two especially dedicated municipal waste incineration facilities, respectively partly in hazardous waste incineration plants together with other accruing incineration residues.

PCN can on the one hand be originally contained in the waste to be incinerated, on the other hand it can be assumed that PCN are mainly destroyed during incineration but can also arise analogously to the formation of PCDF/PCDD.

PCN are not a standard parameter for the analysis of solid incineration residues. In both the European and the German pollutant release and transfer registers PCN are not listed. ITAD (Community of Interest of the German Thermal Waste Treatment Facilities; original designation in German: Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland) and BDSAV lack data on PCN contents in incineration residues from German facilities (municipal waste incineration plants, refuse derived fuel power plants, sewage sludge incineration plants, hazardous waste incineration plants).

According to several authors, PCN occur in incineration residues from municipal waste incineration ([Noma et al. 2004]: 0.95, 1.20 and 1.70 ng/g boiler ash/slag; [Noma et al. 2004]: 0.17 to 0.96 ng/g boiler ash; [Schneider et al. 1998]: 0.40 to 87.0 ng/g fly ash; [Benfenati et al. 1991]: 0.05 to 75 ng/g fly ash). [BiPRO 2011] calculated an average concentration value of 1.28 ng/g slag and 20 ng/g fly ash. By far higher contamination levels (5,439 ng/g) for fly ash from a medical waste incinerator have been reported in Canada (see [Helm et al. 2003]).

If average contaminations of 1.28 ng/g slag and 20 ng/g boiler ash and fly ash are assumed, incineration residues from municipal waste incineration would contain an annual load of circa 15 kg PCN (around 5.3 kg PCN in slag and 9.9 kg in ashes) and residues from hazardous waste incineration would contain circa 0.9 kg PCN (around 0.3 kg in slag and 0.6 kg in ashes).

If average contaminations of 1.28 ng/g slag and 5,400 ng/g of boiler and fly ash are assumed, the incineration residues from infectious clinical waste incineration would contain an annual load of circa 0.8 kg PCN (around 0.81 kg in ashes). Taking the annual incineration of clinical waste (circa 100,000 t/year) into consideration, the overall load would be 20 times higher (circa 16 kg PCN in ashes).

Waste treatment of incineration residues

Usually the accruing slag/bottom ashes from thermal treatment are used in road and path construction. Furthermore steel and non-ferrous metals can be recycled and recovered from slag. Table 45 shows the relations between the different treatment options for incineration residues in Germany (reference year 2010; see section 3.1.7):

Table 49: Treatment of incineration residues in Germany (2010)

Energy recovery (R1)	Recovery except energy recovery	Incineration / disposal (D10)	Disposal
2.14%	66.98%	0.01%	30.87%

Due to the high mass flows in the field of waste incineration, relevant amounts of PCN can be contained in the waste streams. It can be expected that the concentrations in incineration residues are comparably low (average contamination up to 20 ng/g).

In order to clarify the potential relevance of waste incineration processes, samples (ashes and slag) from municipal (two facilities; samples 18 to 22 HCBD/PCN) and hazardous (two facilities; samples 23 and 24 HCBD/PCN) waste incineration facilities were procured. In one of the municipal waste treatment facilities clinical waste is also incinerated in a separate oven. The off gas treatment from municipal and clinical waste incineration takes place jointly and the incineration residues accrue as mixture. According to information available there is no facility in Germany that treats off gas from clinical waste incineration separately, therefore samples can't be taken separately.

The procured samples were analysed for their PCN content in order to be able to assess the relevance of waste incineration[52]. The municipal waste incineration samples didn't contain investigated congeners above the detection limits (detection limits 4.94 µg/kg, 4.91 µg/kg, 4.81 µg/kg, 4.70 µg/kg respectively 4.46 µg/kg). Likewise the investigated congeners in hazardous waste incineration samples were not above the detection limits (detection limits 4.69 µg/kg respectively 4.92 µg/kg). Based on these analytical results it can be concluded that PCN don't occur in incineration residues from waste incineration in Germany, or at least not in relevant amounts (on the basis of seven random samples).

3.4.7 Secondary copper production

Potential PCN emissions have been reported by several sources [UNECE 2007], [GRL 2004], [Haskoning 2002a] and have been described in detail for Europe in [BiPRO 2011]. The relevant processes and aspects in secondary copper production are described in the recent BREF (Best Available Techniques Refence Document) draft [BREF NFM 2013].

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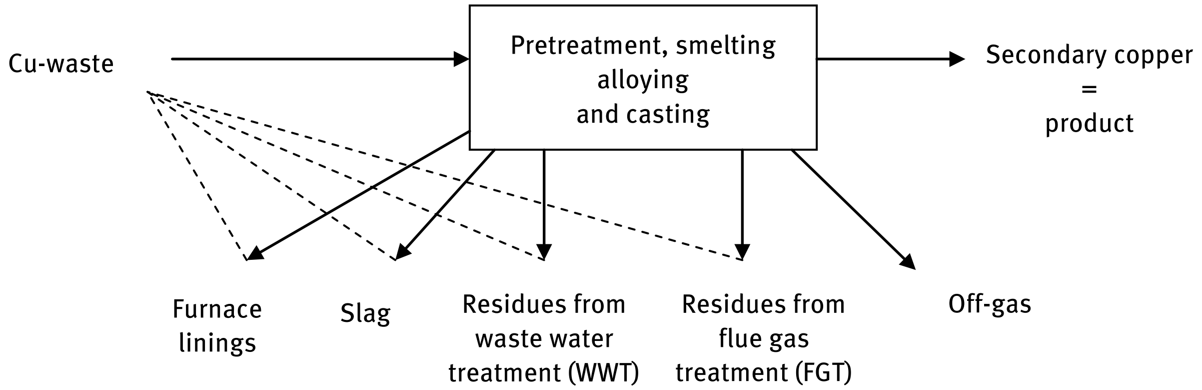
[52] The same samples are also being analysed for HCBD concentration (see section 3.3.5)

In summary, [BiPRO 2011] describes the formation of PCN during the production of secondary copper. PCN formation is assumed to be similar to the formation of PCDD/PCDF. Copper is used as catalyst, the formation of PCN is due to the presence of chlorine from plastics and trace oils in the feed material. The process input and output materials are described in Figure 36 (for the European level):

Figure 38: Overview of the secondary copper production



In 2007, approximately 378,000 t secondary copper were produced in Germany [BREF NFM 2013]. The production residues per tonne of produced copper are indicated [BiPRO 2011] as follows (total ca. 728 kg/t):

Slag:	~ 620 kg/t
Filter dust:	~ 6 kg/t
Furnace linings:	~ 6 kg/t
Furnace oxide:	~ 96 kg /t
WWT residues (acid sludge) :	no information available

Specific data on contamination of slag from copper production are only available for a red siliceous slag residue, which was obtained during copper ore smelting in World War Two. [Theisen et al. 1993] reported a contamination value of 4.224 mg/kg (sum of tetra to octa PCN) for typical Kieselrot.

[Nie et al. 2012] analysed ashes from secondary metal recovery installations (“thermal wire reclamation“) in China. The contamination values of the two ash samples were 66 respectively 195 ng/g (sum PCN). [Ba et al. 2010] also reported on ash contamination from secondary copper production in China. The PCN contents of fly ashes from five facilities show high degree of variation and amount from 9.5 ng/g to 20,830 ng/g respectively. According to [Ba et al. 2010], the lowest PCN contamination (9.5 ng/g) can be associated to a comparatively modern system technology. It does not seem useful to take a mean value as a basis for the assessment of PCN mass flows in Germany. [Ba et al. 2010] indicate emission factors for PCN emissions into the air. Emission factors for fly ash are not reported since fly ash is recycled during the production process and thus no PCN emissions via this path occur. This situation also applies similarly for Germany. Filter dusts are normally recycled during the process (see below).

There are no further data on PCN contents available for the above mentioned residues in secondary copper production. It does not seem useful to draw conclusions on the situation in Germany on the basis of the available data. Assuming that production residues could have a hypothetical contamination value of 10 ng/g, this would lead to approximately 3kg of PCN per year.

Normally filter dust is recycled, meaning that it is led back into the process. Occasionally filter dusts are highly contaminated with arsenic und have to be disposed of as hazardous waste. The so-called “furnace-oxides” are used to produce secondary zinc and lead. The furnace linings are recycled or disposed of as well as the solid residues from waste water treatment. Generally the slag is being recycled, e.g. in road construction. No exact figures are available.

In consultation with the UBA it was agreed to procure two samples (filter dust and slag) from a German secondary copper production plant. This implies the consent of the plant operators. The corresponding German plant operators were asked to provide information and samples. No samples or information have been provided. If it is assumed that German plants have a comparatively advanced system technology, the PCN contents of production residues might be comparatively low (e.g. following [Ba et al. 2010] with ca. 10ng/g). However, due to lacking chemical analysis, this cannot be assessed.

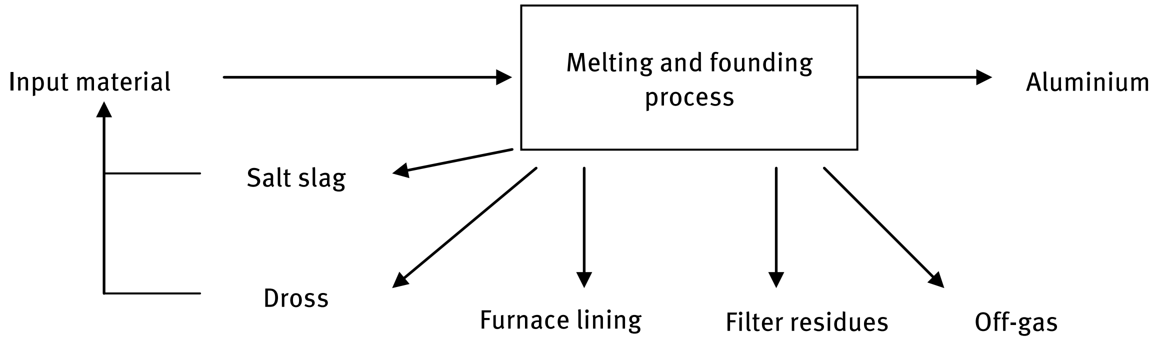
During the final workshop of this research study on the part of the metal industry it was stated that the process of secondary copper production is not relevant for the formation of PCN-containing waste or emissions [WV Metalle 2014]. The secondary copper industry stated that within the secondary copper production, fully established and tested procedures like the Kayser Recycling System (KRS) are being used, which on the one hand effectively decompose dioxins in the process and on the other hand effectively prevent the formation of new dioxins through fast cooling down of off-gas. This has also been proved through analyses of off-gases and flue dust. It can be assumed that the formation of PCN can be prevented under these circumstances. Yet, since there are no specific figures available for PCN, representative analyses on flue dust are currently being conducted on behalf of the secondary copper industry which shall be included in future discussions [Aurubis 2014].

3.4.8 Secondary aluminium production

The situation in secondary aluminium production is comparable to the situation in copper production. The simplified process has been described in [BiPRO 2011] and is described in detail in the recent BREF draft [BREF NFM 2013]. In essence PCN can occur through thermal decomposition of plastic contaminants in the feed material.

Figure 37 describes the simplified process of secondary aluminium production:

Figure 39: Overview on secondary aluminium production



In Germany, around 634,400 t of secondary aluminium were produced in 2011 [GDA 2015]. As set out in [BiPRO 2011] the following production residues arise during the process (Totals):

Furnace linings:	ca. 4.7 kg / tonne aluminium produced
Filter dust:	ca. 20.9 kg / tonne aluminium produced
Sewage sludge:	ca. 2.7 kg / tonne aluminium produced
Salt slag:	ca. 310 kg / tonne aluminium produced

For these types of residues from secondary aluminium production, no figures are available regarding their PCN contents.

[Ba et al. 2010] reported analytical results for fly ash from secondary aluminium production. The figures from four different facilities range from 6.9 to 6,000 ng/g (6.9, 91.6 and 6,000 ng/g). It doesn't seem useful to take a mean value resulting from these figures as basis for the assessment of the PCN mass flows in Germany. If the average hypothetical content of production residues was 10 ng/g, this would correspond to circa 2 kg of PCN per year.

Salt slag and dross are internally recycled and re-used as a process input. Furnace linings are recycled and partly deposited together with dross. Filter dust is possibly partly recycled in the process respectively directly, or after pre-treatment, used to 18% in mine filling, to 53% in underground disposal and to 29% as construction material in the construction of landfills (see [BiPRO 2011] and [BREF NFM 2013]).

In consultation with the UBA it was agreed to procure three samples (filter dust, salt slag and sludge from waste water treatment) from a German secondary aluminum production plant. The corresponding German plant operators were contacted via the German Aluminium Industry Association (original title in German: Gesamtverband der Aluminiumindustrie) in order to provide information or samples. The association and the plant operators are interested in collaborating. From the point of view of the plant operators the amount of sludge from waste water treatment is not relevant (quantitatively). Two samples (filter dust and salt slag) from a plant were provided and analysed for their PCN content in order to assess the potential relevance of secondary aluminium production. The investigated congeners were not found above the detection limits (detection limits 4.71 µg/kg respectively 5.03 µg/kg). These analytical findings do not indicate that PCN occur in filter dust and salt slag from secondary aluminium production in relevant amounts (on the basis of two random samples)

3.4.9 Chlor-alkali electrolysis

The chlor-alkali industry of the former GDR was identified as potential source of PCN (see [Brack et al. 2003]). Also other sources report the formation of PCN during the chlor-alkali process when graphite electrodes are used (see e.g. [Kannan et al. 1998]). However, according to [Falandysz 1998] due to the congener pattern it can be assumed that PCN are not generated in the process but occur in graphite sludge when formulations containing technical PCBs (i.e. Aroclor 1268) or possibly technical PCN (Halowax 1051) have been used as lubricant for the graphite electrodes (see [Falandysz 1998]). It can be assumed that for a long time period, the chlor-alkali electrolysis hasn't been an emission source for PCN since neither PCBs nor PCN are used in this process anymore. Furthermore, graphite electrodes were replaced in the 1970s by metal electrodes. Prior to the 1970s PCDD/Fs, PCN and other graphite sludges contaminated with organochlorine compounds were partly deposited unsecured which led to substantial PCN-contaminated sites (see [BREF CAK 2013]). Chlor-alkali electrolysis plants that are operated according to the state-of-the-art are therefore no relevant sources of PCN.

Table 46 gives an overview on the conclusions drawn regarding the relevance of potential PCN occurrences.

Table 50: Conclusion of the relevance of potential occurrences (PCN)

Potentially relevant occurrence	Estimated relevance
Historical uses in different areas	Not relevant.
Electrical industry	Occurrence in historical PCB uses possible; quantitatively not relevant
Waste incineration	Not relevant. Due to the high mass flow in the area of waste incineration relevant amounts of PCN can occur in the waste flow. Yet the analytical results of random samples indicate that PCN don't occur in relevant amounts in incineration residues from waste incineration in Germany.
Secondary copper production	Possibly relevant. Samples for verification of the assessment couldn't be procured due to the non-cooperation of the plant operators.
Secondary aluminium production	Not relevant. The analytical results from random samples indicate that PCN don't play a relevant role in wastes from secondary aluminium production.
Chlor-alkali electrolysis	Not relevant.

3.5 Pentachlorophenol (PCP)

3.5.1 Manufacture and use

Manufacture

Information on the current global production of PCP is lacking. In 1981 around 90,000 t PCP were manufactured globally. According to more recent information, available for the UN-ECE region, PCP is currently exclusively produced in one company in the USA. Approximately 7,250 t PCP were manufactured in 2009 and placed on the market in the USA, Canada and Mexico for wood preservation [UNECE 2010], [UNEP Canada 2013]. According to [UNEP POPRC.7/4 2011], around 10,000 t PCP were manufactured worldwide in 2011.

In Germany the production of NaPCP and PCP ceased in 1985/86. The only German producer was the company Dynamit Nobel AG. The manufactured PCP was marketed under the trade name Withophen P and NaPCP under the trade name Withophen N [LfU 1996]. Six years after the manufacture had ended in Germany, the production was also stopped in the entire EU. However, imports and use of PCP and NaPCP still continued for several years. In 1989, Germany set out mandatory provisions concerning PCP (original title of the regulation in German: PCP-Verbotsverordnung). The regulation prohibited manufacture, marketing and use of PCP and PCP-containing products. Nevertheless, it cannot be excluded that products containing PCP are still imported to Germany [BLfU 2003], [BLfU 2008].

Table 47 summarizes the PCP volumes produced in Germany for the time period 1974 – 2002. Further, the table contains important milestones of the PCP production in Germany and partly also for the entire EU.

Table 51: PCP production in Germany ([LfU 1996], [IEP 2002], [BLfU 2008])

Year	PCP production in [t]	Additional information / Milestones
1974	4,000 – 6,500	ca. 60% exported
1975	3,000	
1976	4,400	
1977	4,100	
1978	3,700	
1979	2,100	ca. 500 t used in Germany
1980	2,300 – 4,500	ca. 350 t used in Germany
1981	2,200 – 2,250	ca. 300 t used in Germany
1982	1,300 – 1,950	ca. 250 t used in Germany
1983	1,800 – 3,800	ca. 250 t used in Germany
1984	1,550 – 1,750	ca. 190 t used in Germany
1985	~1,000	ca. 80 t used in Germany
1986	-	Production stop in Germany
1989	-	Manufacture, marketing and use of PCP and PCP-containing materials prohibited in Germany
1992	-	Production stop of PCP and NaPCP in EU (PCPL production continued)
1996	-	378 t NaPCP and ~ 30 t PCP imported to EU (28 – 30 t PCP synthesised to ~46 t PCPL; < 2 t used for wood preservation)

Year	PCP production in [t]	Additional information / Milestones
1999	-	324 t NaPCP and 20 t PCP imported to EU (for production of ~30 t PCPL)
2000	-	PCPL manufacture ceased in EU
2002	-	No imports of PCPL to EU

Use

PCP was used in its phenolic form (PCP), as salt sodium (NaPCP) and ester laurate (PCPL). It was available in form of flakes, granulate, powder or as a dilutable liquid [LfU 1996]. It was used in various areas of application, due to its excellent bactericidal and fungicidal properties. However, it was mainly used for preservation of wood and wood structures and textile and leather impregnation as well as for the treatment of pulp, paper and cardboards. In addition, it was applied in joint sealants, casting compounds, adhesives, varnishes and paints [BLfU 2003].

PCP was the most widely used active substance in wood preservatives for a long time period. Before coming into force of mandatory provisions concerning PCP in 1989, PCP-containing wood preservatives were applied in residential areas in considerable amounts. Until 1977, most wood preservatives used contained Lindan as insecticide and PCP as fungicide in a ratio of around 1:10 [BLfU 2008]. NaPCP was often used for wood treatment, due to its better water solubility compared to PCP. PCPL was generally preferred for textiles [LfU 1996].

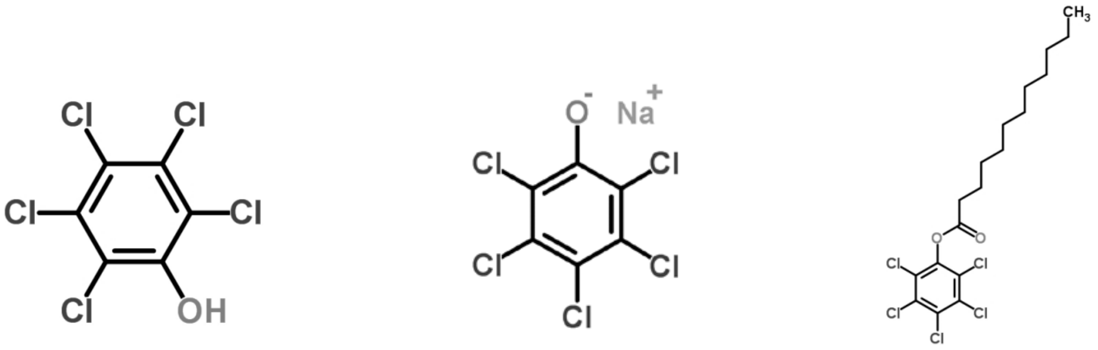
The application of PCP for specific industrial uses (e.g. preservation of wooden poles) is for instance still registered in Canada. The industrial preservation of wood is also reported to be the only still relevant area of application for PCP in the entire UN-ECE region. In Germany, PCP was mainly used for wood preservation (ca. 61 % in 1983) and treatment of industrial textiles (ca. 13 % in 1983). However, the use of PCP ended in Germany already in 1989.

3.5.2 Chemical characteristics

There are no natural environmental sources of PCP. PCP is an aromatic hydrocarbon of the chlorophenol family, at ambient temperature solid and liposoluble. PCP is not flammable and slightly soluble in water [BLfU 2004], [GESTIS 2013].

Chemical formula:	PCP	C_6Cl_5OH
CAS registry numbers:	PCP	(CAS No.87-86-5)
	NaPCP	(CAS No.135-52-2)
	PCPL	(CAS No.3772-94-9)

Figure 40: Chemical structures of PCP, NaPCP and PCPL



Molecular mass:	PCP	266.34 g/mol
	NaPCP	288.32 g/mol
	PCPL	448.64 g/mol

Table 48 summarizes the chemical and physical properties of PCP.

Table 52: Chemical-physical properties of PCP

Chemical-physical properties of PCP		Source
Appearance	solid	[UNECE 2010], [GESTIS 2013]
Melting point	191 °C (pure PCP)	[UNECE 2010], [GESTIS 2013]
Density	1.987 g/ml at 22 °C	[UNECE 2010], [GESTIS 2013]
Boiling point	310 °C	[UNECE 2010], [GESTIS 2013]
Vapour pressure	2 mPa at 20 °C 16 mPa at 100 °C	[UNECE 2010], [GESTIS 2013]
Log Kow	5.12-5.18	[UNECE 2010], [GESTIS 2013]
Solubility	Slightly soluble in water (20 mg/l; 20 °C)	[UNECE 2010], [GESTIS 2013]
Henry's law constant	$3.4 * 10^{-6}$ atm m^3/mol	[IEP 2002]

3.5.3 Legal background

International/EU

Stockholm Convention

PCP is proposed as candidate POP under the Stockholm Convention. For further information related to the Stockholm Convention and the POP Protocol see Section 1 (Background and Objectives).

Rotterdam Convention

PCP, NaPCP und PCPL are listed in Annex III of the Rotterdam Convention [UNEP POPRC.7/4 2011]. The chemicals listed in Annex III include for instance certain hazardous chemicals as well as pesticides that have been banned or restricted. All involved parties are required to ensure that their exports of those chemicals do not take place contrary to an importing party's decision. The exporting countries need to inform importing countries in advance and ask for the permission for shipments. The main objective is to prevent uncontrolled import of substances [UNECE 2010].

REACH-Regulation, 1907/2006, Annex XVII, Number 22, 28, 29 and 30 [GESTIS 2013]

- *"Pentachlorophenol shall not be placed on the market, or used*
  - as a substance
  - as a constituent in other substances, or mixtures, in a concentration equal to or greater than 0.1 % by weight"
- " Substances and formulations which are put in circulation and are intended for sale to the general public must not contain the substance in the individual concentration given in the Directive 67/548/EEC or Directive 88/379/EEC"

Germany

PCP-Guidelines

The PCP-Guideline (original title in German: PCP Richtlinie) for the assessment and remediation of PCP-contaminated building materials and components was developed as a technical rule in 1996 by the project team for hazardous substances called ARGEBAU (original title in German: Arbeitsgemeinschaft der für das Bau-, Wohnungs- und Siedlungswesen zuständigen Minister der Länder). The guidelines contain provisions and advice on how to assess PCP-containing buildings, undertake remediation measures, which protective measures to apply, how to deal with wastes and waste water and how to monitor the success/progress of the remediation measures. The PCP-Guideline was adopted into building laws of the most German federal states [Richtlinie 1996], [BLfU 2008].

Wood Waste Ordinance (original title in German: Altholzverordnung; AltholzV)

The ordinance regulates the (material and energy) recovery and disposal of wood waste in Germany. It applies to producers, owners, operators of wood waste treatment facilities, public waste management organisations as far as they recover or dispose of wood waste and relevant third parties, associations and self-governing bodies [AltholzV 2002]. Further information related to recovery and disposal of wood waste is included in section 3.5.6.6.

Prohibitions of Chemicals Ordinance (original title in German: Chemikalienverbotsverordnung; ChemVerbotsV), Annex re Art.1, para.15 [GESTIS 2013]

„Amongst others it is prohibited to put in circulation:

- *the substance*
- *formulations with 0.01% by weight pentachlorophenol, its salts and compounds*
- *manufactures, treated with a formulation containing the above-mentioned substances"*

Hazardous Substances Ordinance (original title in German: Gefahrstoffverordnung; GefStoffV), Annex II, Art.3 [GESTIS 2013]

"Beyond the use prohibition according to Article 67 in combination with Annex XVII Number 22 of Regulation (EC) No. 1907/2006 such articles shall not be used which have been treated with a preparation containing pentachlorophenol, sodium pentachlorophenol or one of the other pentachlorophenol compounds and whose parts affected by the treatment contain more than 5 milligrams per kilogram of these substances. "

Further, the waste samples database of the German federal state North Rhine – Westphalia (ABANDA) contains a compilation of relevant guidance-, limit-, assignment-, orientation-, inspection-, concentration- and minor threshold limit -values for PCP (see Table 49).

Table 53: PCP values in different bodies of legislation in Germany [ABANDA 2013a]

Parameter: PCP Pentachlorophenol	Unit	Sig.	Value
OTD-OTD-BY-09: Guidance limit values for landfills (landfill class DK I and II, according to the German Landfill Regulation (Deponieverordnung; DepV from 27.04.2009); Bavarian EPA, 15.12.2009)			
Guidance limit values (landfill class DK I, according to the German Landfill Regulation (Deponieverordnung; DepV from 27.04.2009) – list not exhaustive	mg/kg	<=	2.5
Guidance limit values (landfill class DK II, according to the German Landfill Regulation (Deponieverordnung; DepV from 27.04.2009) – list not exhaustive	mg/kg	<=	5.0
OTV-AHolzV-02: Wood Waste Ordinance (original title in German: Altholzverordnung; AltholzV); 15.08.2002			
Limit value for woodchips and shavings for manufacture of derived timber products	mg/kg	<=	3.0
OTV-LAGA-ESB-97: Benchmarks and criteria for energy recovery of wastes in cement kilns; 31.10.1997			
Contaminant guidance value (relating to a calorific value of 10 MJ/kg)	mg/kg	<=	100.0
BÜB-LAGA-BÜB-01: Classification of wastes to waste categories from mirror entries, draft recommendations from the waste technology working board/committee (LAGA); 04.12.2001			

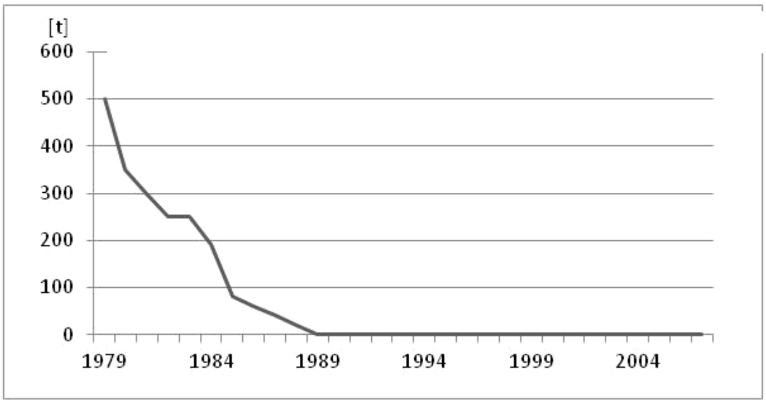
Parameter: PCP Pentachlorophenol	Unit	Sig.	Value
Assignment criteria for differentiation of waste requiring special supervision and waste not requiring special supervision (eluate/solid)	mg/kg	<=	5.0
BÜB-BÜB-BW-02: Classification of wastes to waste categories from mirror entries, preliminary guidelines from the Ministry for Environment and Transport Baden-Württemberg; 28. 10.2002			
Orientation value for differentiation of waste requiring special supervision and waste not requiring special supervision (eluate/solid)	mg/kg	<=	5.0
BÜB-BÜB-BB-02: Recommendations for classification of waste to waste categories from mirror entries; Ministry of Agriculture, Environmental Protection and Regional Planning; 18.11.2002			
Threshold limit value for classification of waste to waste categories from mirror entries (eluate/solid)	mg/kg	<=	5.0
BO-BBodSchV-99: Soil Protection and Contaminated Sites Ordinance (original title in German: Bundesbodenschutz- und Altlastenverordnung; BBodSchV), 1999			
Inspection value for soil (industrial real estate)	mg/kg	<=	250.0
Inspection value for soil (children's playgrounds)	mg/kg	<=	50.0
Inspection value for soil (parks and recreational areas)	mg/kg	<=	250.0
Inspection value for soil (residential areas)	mg/kg	<=	100.0
BO-VwV-OW98: Administrative regulation for guidance limit values for handling contaminated sites and cases of damage; 01.03.1998			
Guidance limit values for soil/area, background values soil (solid)	mg/kg	<=	0.004
Guidance limit values for soil/area	mg/kg	<=	0.2
Guidance limit values for leak water/underground water	mg/l	<=	0.0001
BO-CH-AltlV-98: Contaminated Sites Ordinance (original title in German: Altlasten-Verordnung; AltlV); 28. 03. 2000			
Threshold limit value for the assessment of impacts of contaminated sites on water bodies	mg/l	<=	0.001
WW-LAWA-GFS-04: Derivation of minimis thresholds for underground water; LAWA, December 2004			
Minimis thresholds for the assessment of local underground water contamination according to Annex 2, Part 1-3	mg/l	<=	0.0001

3.5.4 Occurrence and relevance of PCP and its derivatives

PCP is currently neither produced nor used in Germany. The production of NaPCP and PCP was stopped already in 1985/86. Information on produced and used PCP volumes is summarised in section 3.5.1 and Table 47. In addition, Table 47 contains information on imports and exports of PCP/PCPL in the past.

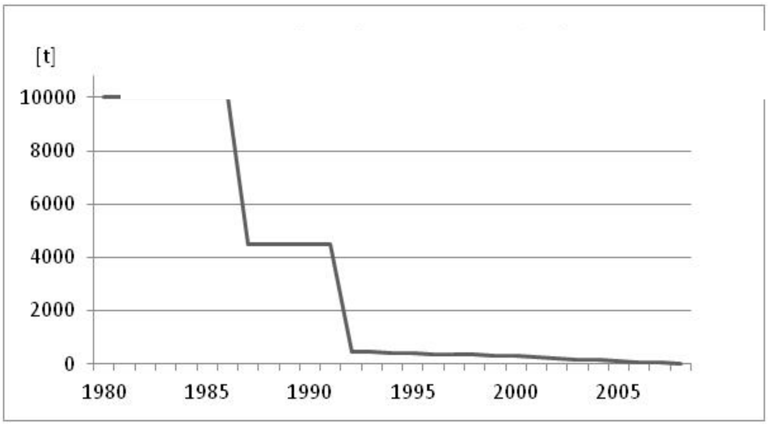
In 1979, around 500 t PCP was used in Germany. In contrary to the EU, the use of PCP in Germany already significantly declined at the beginning of the 80s. For instance, in 1983, only approximately a half of the indicated tonnage from 1979 was used and two years later only around 80 t PCP was still used in Germany (see Figure 39). PCP was mainly used for preservation of wood (ca. 61% in 1983), [LfU 1996], [IEP 2002], [BLfU 2008].

Figure 41: Use of PCP in Germany (1979 – 2007)



PCP was used as starting product for the manufacture of NaPCP. Figure 40 shows the total volumes of NaPCP used in the EU during the time period 1980 – 2008 [BiPRO 2011].

Figure 42: Use of NaPCP in EU27 (1980 – 2008)



The use patterns in Germany were quite similar to the use patterns in the EU, with the main difference that production of PCP and NaPCP ended earlier and with coming into force of the Ordinance on the ban on PCP, additional mandatory provisions for marketing and use of PCP, NaPCP and PCP-containing products were introduced. During the 90s, PCP and NaPCP were only imported and used in relatively low volumes in France, Portugal, Great Britain and Spain, [IEP 2002], [TNO 2005].

3.5.5 Selection of relevant products, wastes and recyclates in Germany

Products

The use of PCP in Germany ended many years ago. In the past, PCP was mainly used for preservation of wood and wood structures as well as for textile and leather impregnation. In 1983, approximately 61 % of the total PCP volume was used for wood preservation. The remaining volume was used in textiles (13 %), leather (5 %), mineral oil (6%) and adhesives (6 %). PCP was not applied in paints and pulp since the end of 70s.

[BLfU 2008] assumes that PCP is still contained in certain products imported from the USA, France, India, Taiwan or China. Imports of contaminated products cannot be completely excluded; however, it is not possible to quantify the relevant import streams. Therefore, imports of possibly contaminated products to Germany are not further considered in this study.

Waste streams

With regard to contaminated waste streams, a number of analytical measurement results can be retrieved from the analytical database for waste (ABANDA). ABANDA was initiated in 1993 and contains, in addition to waste analytics, also information on the origin, generation and fate of different waste streams. The excerpt from the database given in Table 50 summarizes measurement results for PCP in different waste streams.

Table 54: Measured PCP concentrations in different waste streams [ABANDA 2013b]

Waste	Unit	N	Min	Max	Average	Standard deviation
Method: original material/solid						
020202 animal-tissue waste	mg/kg	2	0.005	0.02	0.0125	0.0106
030105 sawdust. shavings. cuttings. wood. particle board and veneer other than those mentioned in 03 01 04	mg/kg	64	0.05	6.0	1.5252	1.3502
050103 tank bottom sludges	mg/kg	4	5.0	5.0	5.0	0.0
050115 spent filter clays	mg/kg	1	0.5	0.5	0.5	0.0
050603 other tars	mg/kg	1	1.0	1.0	1.0	0.0
070103 organic halogenated solvents, washing liquids and mother liquors	mg/kg	1	1.0	1.0	1.0	0.0
070108 other still bottoms and reaction residues	mg/kg	3	0.05	1.0	0.6833	0.5485
070208 other still bottoms and reaction residues	mg/kg	5	0.01	0.5	0.232	0.2467
070608 other still bottoms and reaction residues	mg/kg	1	1.0	1.0	1.0	0.0
080113 sludges from paint or varnish containing organic solvents or other dangerous substances	mg/kg	11	0.01	0.5	0.1827	0.1652
120112 spent waxes and fats	mg/kg	1	10.0	10.0	10.0	0.0
120114 machining sludges containing dangerous substances	mg/kg	2	0.005	0.1	0.0525	0.0672
120116 waste blasting material containing dangerous substances	mg/kg	2	0.02	0.02	0.02	0.0
120117 waste blasting material other than those mentioned in 12 01 16	mg/kg	1	5.0	5.0	5.0	0.0
120118 metal sludge (grinding, honing and lapping sludge) containing oil	mg/kg	1	0.05	0.05	0.05	0.0
130501 solids from grit chambers and oil/water separators	mg/kg	2	0.01	0.2	0.105	0.1344
150102 plastic packaging	mg/kg	1	0.6	0.6	0.6	0.0
150110 packaging containing residues of or contaminated by dangerous substances	mg/kg	21	0.01	6,000.0	287.4862	1,308.9059
150202 absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances	mg/kg	171	0.001	33.0	1.3331	3.7975
150203 absorbents, filter materials, wiping cloths and protective clothing other than those mentioned in 15 02 02	mg/kg	1	0.1	0.1	0.1	0.0
160305 organic wastes containing dangerous substances	mg/kg	50	1.0	3.0	1.18	0.4375

Waste	Unit	N	Min	Max	Average	Standard deviation
161101 carbon-based linings and refractories from metallurgical processes containing dangerous substances	mg/kg	1	0.02	0.02	0.02	0.0
170106 mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances	mg/kg	3	0.5	1,094.0	366.5	630.0375
170201 wood	mg/kg	8	0.05	1.0	0.8813	0.3359
170204 glass, plastic and wood containing or contaminated with dangerous substances	mg/kg	72	0.01	5,400.0	128.5098	652.5401
170303 coal tar and tarred products	mg/kg	4	0.06	0.39	0.1625	0.1528
170503 soil and stones containing dangerous substances	mg/kg	8	0.001	9.0	1.2039	3.1547
170903 other construction and demolition wastes (including mixed wastes) containing dangerous substances	mg/kg	14	0.05	2,200.0	280.8093	696.723
180202 wastes whose collection and disposal is subject to special requirements in order to prevent infection	mg/kg	1	0.1	0.1	0.1	0.0
190107 solid wastes from gas treatment	mg/kg	1	0.5	0.5	0.5	0.0
190110 spent activated carbon from flue-gas treatment	mg/kg	2	0.1	0.5	0.3	0.2828
190113 fly ash containing dangerous substances	mg/kg	1	0.5	0.5	0.5	0.0
190204 premixed wastes composed of at least one hazardous waste	mg/kg	1	0.05	0.05	0.05	0.0
190205 sludges from physic-chemical treatment containing dangerous substances	mg/kg	1	1.0	1.0	1.0	0.0
190207 oil and concentrates from separation	mg/kg	2	0.2	1.0	0.6	0.5657
190208 liquid combustible wastes containing dangerous substances	mg/kg	4	0.05	0.1	0.075	0.0289
190209 solid combustible wastes containing dangerous substances	mg/kg	2	0.1	0.1	0.1	0.0
190805 sludges from treatment of urban waste water	mg/kg	99	0.01	0.01	0.01	0.0
190813 sludges containing dangerous substances from other treatment of industrial waste water	mg/kg	1	0.23	0.23	0.23	0.0
191003 fluff-light fraction and dust containing dangerous substances	mg/kg	7	0.01	1.0	0.2157	0.3475
191206 wood containing dangerous substances	mg/kg	17	0.05	1.29	0.3153	0.3461
191211 other wastes (including mixtures of materials) from mechanical treatment of waste containing dangerous substances	mg/kg	16	0.05	10.0	1.345	2.4221
191301 solid wastes from soil remediation containing dangerous substances	mg/kg	1	0.1	0.1	0.1	0.0
200113 solvents	mg/kg	1	1.0	1.0	1.0	0.0
200127 paint, inks, adhesives and resins containing dangerous substances	mg/kg	1	0.01	0.01	0.01	0.0
200399 municipal wastes not otherwise specified	mg/kg	34	0.01	0.01	0.01	0.0

Waste	Unit	N	Min	Max	Average	Standard deviation
Method: original material/liquid						
070101 aqueous washing liquids and mother liquors	mg/l	1	9.5	9.5	9.5	0.0
130702 petrol	mg/l	1	1.0	1.0	1.0	0.0
190702 landfill leachate containing dangerous substances	mg/l	16	0.0	0.0009	0.0002	0.0003
191307 aqueous liquid wastes and aqueous concentrates from groundwater remediation containing dangerous substances	mg/l	3	10.0	10.0	10.0	0.0

The highest PCP concentrations were measured in waste classes 150110 (packaging containing residues of or contaminated by dangerous substances), 170106 (mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances), 170204 (glass, plastic and wood containing or contaminated with dangerous substances), 170903 (other construction and demolition wastes -including mixed wastes- containing dangerous substances). The measurement results show partly a significant margin of deviation and provide evidence that PCP concentrations in wastes can exceed several 1,000 mg/kg. It is assumed, that the highest concentration measured of 6,000 mg/kg was detected in a packaging containing PCP residues. Currently, relevant stocks of packaging containing PCP are not expected. The remaining measurement results above 1,000 mg/kg result mainly from PCP-contaminated wood waste from construction and demolition waste. However, it cannot be excluded that the presented measurement results are relatively out-dated (e.g. 1993), as the exact year in which measurements were performed is not enclosed in the ABANDA database.

Product life cycle times are significant in order to estimate the relevance of PCP in different waste streams and recyclates. After the end of their useful life time, products become waste which needs to be managed. This may possibly lead to a contamination of waste streams and recyclates. Especially those products with long life cycle time, as for instance PCP impregnated construction wood, can still enter waste streams and need to be treated in the future. For instance, PCP has been detected during recycling of construction waste in the German federal state Mecklenburg-Western Pomerania [MVR 2013]. Further, PCP has been in particular identified during documentation and verification in wood preservatives in Rhineland-Palatinate, often in combination with lindane [RLP 2013]. Therefore, in agreement with the UBA, it was decided to analyse PCP concentrations in three waste wood samples from waste management facilities for construction and demolition wastes and in one material sample from a recycled wood product (chipboard).

In 2000, the production of PCPL ended in the entire EU. However, PCPL was still imported and used by the European textile industry until 2002, especially in Great Britain. PCPL was mainly used for preservation of industrial textiles [UBA 2006b]. The majority of PCP treated textiles was used in Great Britain and France, but was also exported to non-EU countries. [BiPRO 2011] considers the application of PCPL in textiles and estimates relevant waste amounts which have been already treated as well as future waste amounts which still need to be treated in the EU27. In contrary to the European situation, due to earlier regulation of PCP and PCPL in Germany, relevant waste amounts are not expected. Relevant amounts of waste could still be expected in countries, where application of PCPL was allowed until 2008 (i.e. Spain, Portugal, France and Great Britain). In Germany, especially textiles used by the military could possibly be relevant. In agreement with the UBA, it was decided to analyse PCP concentrations in two textile samples from second-hand textiles used by the military.

Application of PCP in pulp, paper and cardboards was reported decades ago but could not be confirmed. This also applies to a number of other applications of PCP, for instance in leather, paints and adhesives. Due to relatively short life cycle times of most relevant products, it is assumed that associated wastes have been already disposed of and/or recovered. Therefore, these areas of application are not further considered.

Recyclates

Annex II re Article 3 para. 1 of the German Wood Waste Ordinance (AltholzV) sets a limit value of 3 mg PCP/kg DM for woodchips and shavings for manufacture of derived timber products. Plant operators need to ensure compliance with the set limit value. However, it cannot be completely excluded that derived timber products contain PCP in higher concentrations. An important area of application for woodchips and shavings is the manufacture of chipboards. Therefore, wood samples from chipboards were taken and analysed regarding PCP.

3.5.6 Wood impregnation

3.5.6.1 Background information

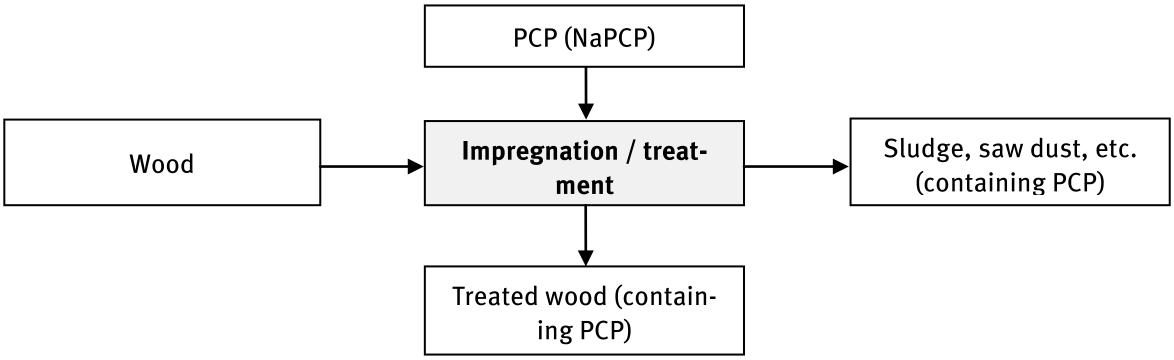
Due to architectural trends during the 60s and 70s, wood was increasingly used in inner and outer areas of buildings. Consequently, also the consumption of chemicals for wood preservation increased. Typically used wood preservatives were Xyladecor and Xylamon, representing temporarily a market share of 50 %. PCP and lindane were often used in combination as active components [BLfU 2003], [BLfU 2004].

High volumes of PCP-containing wood preservatives were used in living areas. Basically, the application was required only in outer areas and damp locations of buildings, however, PCP-containing preservatives were also used in inner areas of buildings. High volumes were applied in buildings with a high percentage of wood materials such as barracks, halls, silos, etc. Upper layers of treated wood could contain PCP in concentration in a range of several 1,000 mg/kg [BLfU 2008].

3.5.6.2 Processes, inputs and outputs

Figure 41 shows a simplified input/output diagram for industrial wood impregnation/ treatment with NaPCP.

Figure 43: Inputs and outputs of PCP wood treatment



The main inputs to the process were different kinds of wood and NaPCP solution, in typically applied concentrations of around 2-5 % [OSPAR 2001]. The main outputs were PCP impregnated wood and PCP-containing wastes and sludges (in case of further processing, possibly also contaminated saw dust).

3.5.6.3 Generation factors

Losses during product life time due to wear out are considered to be approximately 2 % (see [BiPRO 2011]). Consequently, around 98 % of initially used PCP remains in waste. Due to lack of more precise information, a factor of 0.98 is used for further estimations.

3.5.6.4 Contamination data (products, wastes and recyclates)

The outer layers of treated wood contain up to several hundred mg/kg PCP. The concentrations decline in inner layers of treated wood, already after a few millimetres [BLfU 2008], [UNECE 2010]. [BiPRO 2011] estimates an average PCP concentration in treated and air-dried wood of around 625 ppm. This value is also used for the estimation of relevant waste amounts in Germany. For recyclates, no specific information on PCP concentration is available. According to AltholzV, a limit value of 3 mg PCP/kg dry mass for wood chips used in the manufacture of derived timber products must not be exceeded.

3.5.6.5 Activity data

Depending on the type of use, product life cycle times of PCP treated wood may vary between 5 and more than 30 years. [TNO 2005] estimates an average life cycle time of 15 years, however, construction wood can have significantly higher life times of 30 or more years (e.g. wooden window frames, wooden roof structures).

3.5.6.6 Waste management

AltholzV regulates the recovery and disposal of waste wood in Germany. In order to comply with the requirements under Article 3, AltholzV, the operator of waste wood treatment installations needs to ensure that only permissible waste wood categories are used for the intended recovery and that the waste wood used has all interfering substances removed and is free of PCBs.

Waste wood is classified in different categories, depending on the content of contaminants, in categories AI – AIV and waste wood containing PCBs. In Annex III, AltholzV contains examples of usual assignment of the common types of waste wood (see Table 51).

Table 55: Usual assignment of common types of waste wood according to Annex III, AltholzV [BLfU 2012, Table 1]

Cat.	Definition	Examples of common types of wood waste
AI	Waste wood in its natural state or only mechanically processed which, during use, was at most insignificantly contaminated with substances harmful to wood	- Cuttings, shavings from solid wood in its natural state - Palettes made from solid wood (e.g. Europalettes) - Boxes for fruit and vegetables - Cable reels made from solid wood (made after 1989) - Waste wood in its natural state from building sites - Furniture, solid wood in its natural state
AII	Bonded, painted, coated, lacquered or otherwise treated waste wood with no halogenated organic compounds in the coating and no wood preservatives	- Boards, planks from interior work (with no harmful contaminants) - Palettes made from derived timber products - Profile boards for the fitting out of rooms (with no harmful contaminants) - Boards, false ceilings, planks from interior work, door leaves and frames (with no harmful contaminants) - Chipboards used in construction - Furniture, with no halogenated organic compounds in the

Cat.	Definition	Examples of common types of wood waste
		coating
AIII	Waste wood with halogenated organic compounds in the coating, with no wood preservatives	- Other palettes with composite material - Furniture, with halogenated organic compounds in the coating - Waste wood from bulky refuse (mixed)
AIV	Waste wood treated with wood preservatives, such as railway sleepers, telephone masts, hop poles, vine poles as well as other waste wood which, due to its contamination, cannot be assigned to waste categories AI, AII or AIII, with exception of waste wood containing PCBs	- Wood used in construction for load-bearing elements - Windows, window posts, outer doors - Impregnated wood used in external structures - Various wood used in horticulture and landscaping, impregnated garden furniture - Railway sleepers, telephone masts - Various wood used in agriculture - Cable reels made from solid wood (made before 1989) - Ammunition boxes - Waste wood from damaged structures (e.g. burnt wood)
Waste wood containing PCBs	Wood waste which constitutes waste wood containing PCBs within the meaning of the PCB/PCT Waste Ordinance (PCB/PCT-Abfallverordnung)	- Insulating boards and sound insulating boards treated with agents containing PCBs

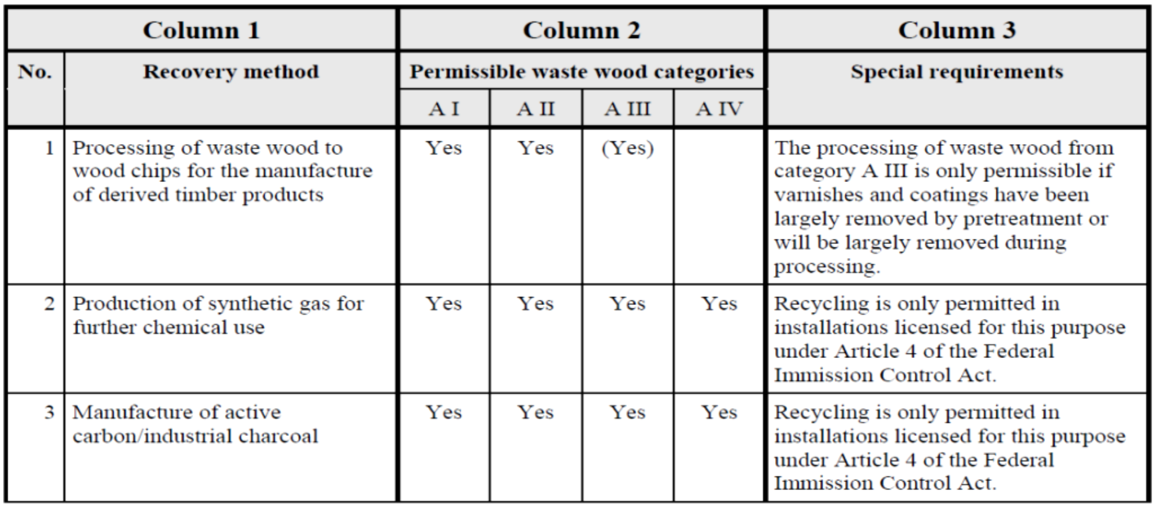
Considering different wood waste categories and examples for usual assignments, PCP contaminated wood waste should be assigned to the category AIV and managed accordingly.

Waste wood from the construction industry should be assigned to the waste code 17 02 04* (mixed waste from construction 17 09 03*). PCP-contaminated wood waste from mechanical waste treatment should be assigned to the waste code 19 12 06*.

Material Recovery

In order to ensure safe wood waste recycling, the requirements of Annex I, AltholzV must be complied with. In accordance with Annex I, only the waste wood categories in column 2, taking into account the special requirements for recycling of wood waste listed in column 3, may be used for the recovery methods indicated in column 1 (see Table 52).

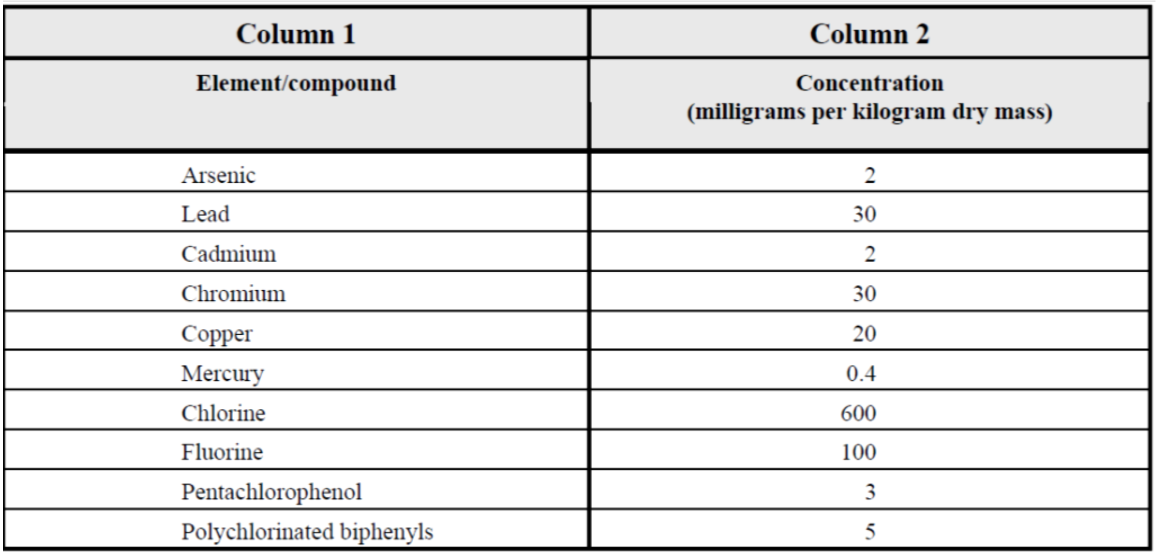
Table 56: Methods for the substance recycling of waste wood (Annex I re Article 3 para. 1. AltholzV)



Column 1		Column 2				Column 3
No.	Recovery method	Permissible waste wood categories				Special requirements
		A I	A II	A III	A IV	
1	Processing of waste wood to wood chips for the manufacture of derived timber products	Yes	Yes	(Yes)		The processing of waste wood from category A III is only permissible if varnishes and coatings have been largely removed by pretreatment or will be largely removed during processing.
2	Production of synthetic gas for further chemical use	Yes	Yes	Yes	Yes	Recycling is only permitted in installations licensed for this purpose under Article 4 of the Federal Immission Control Act.
3	Manufacture of active carbon/industrial charcoal	Yes	Yes	Yes	Yes	Recycling is only permitted in installations licensed for this purpose under Article 4 of the Federal Immission Control Act.

For processing of waste wood to wood chips for the manufacture of derived timber products only waste wood from categories AI and AII can be directly used. The processing of waste wood from category AIII is only permissible if varnishes and coatings have been largely removed by pre-treatment or will be largely removed during processing (see Table 52). Further, the wood chips processed for the manufacture of derived timber products may not exceed the limit values for specific elements/compounds specified in Annex II, AltholzV (see Table 53). For PCP, a limit value of 3 mg/kg dry mass is set.

Table 57: Limit values for wood chips used in the manufacture of derived timber products (Annex II re Article 3 para. 1. AltholzV)



Column 1	Column 2
Element/compound	**Concentration (milligrams per kilogram dry mass)**
Arsenic	2
Lead	30
Cadmium	2
Chromium	30
Copper	20
Mercury	0.4
Chlorine	600
Fluorine	100
Pentachlorophenol	3
Polychlorinated biphenyls	5

In order to not exceed the set limit values, the operator of the waste wood treatment installation must conduct internal monitoring and analyse samples in accordance with para.6 of the AltholzV. The samples taken shall undergo a colour test to establish whether creosote is present and shall be tested for compliance with the limit values in Annex II of the AltholzV. Wood chips may subsequently only be used in the manufacture of derived timber products if the tests and examinations do not indicate any contamination with creosote or that the limit values in Annex II have been exceeded. If these tests and examinations reveal that the limit values have been exceeded, the sampled batch must be assigned to wood waste category AIV. Further, independent monitoring needs to be conducted quarterly [BLfU 2012].

Even though the limit value is clearly defined, it cannot be excluded that derived timber products contain PCP in higher concentrations. Therefore, it has been agreed with the UBA, to analyse the PCP content of one derived timber product (i.e. chipboard).

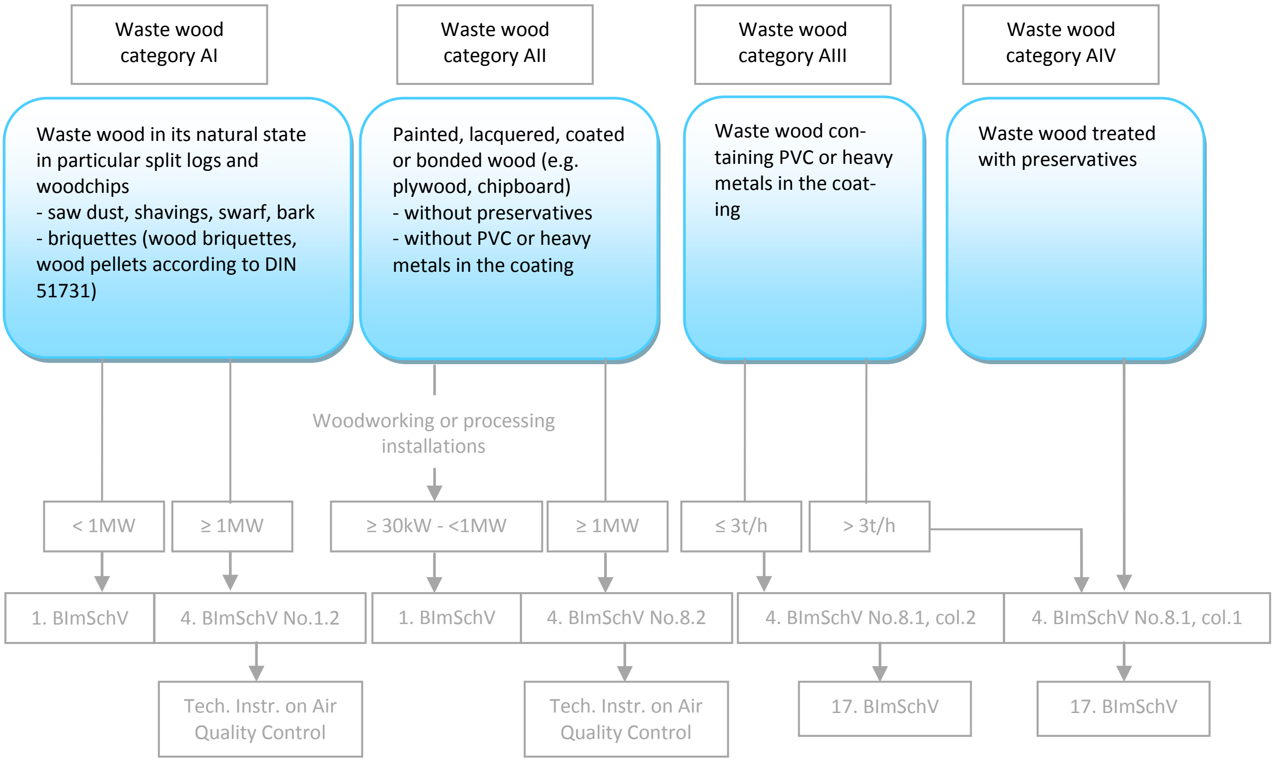
In general, it is possible to recycle end of life chipboards. These are, however, only conditionally suitable for recycling as it is not possible to produce wood chips in their natural state anymore. Further, it should be avoided, that the formaldehyde content in newly manufactured products increases due to the use of end of life chipboards in the production. Therefore, the recovery of chipboard focuses mainly on energy recovery [BaWü 2013].

Other possible recovery operations according to AltholzV are the production of synthetic gas for further chemical use and manufacture of active carbon/industrial charcoal (see Table 52). Both recovery operations play a minor role in practice. Due to the high quality requirements of activated carbon (especially in the food industry) some manufacturers deliberately refuse to use waste wood in the production [Donau Carbon 2013]. Due to partly very high operating temperatures (> 900 °C) is not expected that PCP remains in the newly produced activated carbon. It can also be excluded, that PCP is released into the environment during the production process [AdFiS 2013]. The same also applies for the pyrolysis and gasification for the production of synthesis gas, where similar process temperatures prevail to the temperatures during thermal disposal and /or energy recovery of waste.

Energy recovery

In small combustion plants, not requiring a permit, only wood waste categories AI and AII can be managed, whereat wood waste of the category AII may only be managed in combustion plants with a rated heat output of ≥30 kW and only in dedicated woodworking and processing installations. Wood waste treated with preservatives, wood waste containing halogenated organic compounds or heavy metals in the coating may only be treated in installations in accordance to the 17.BImSchV (Federal Emission Control Act). If waste wood is incinerated, in a plant which is restricted to certain waste wood categories, the operator of the waste wood treatment installation must test the crushed waste wood in batches to ensure that all wood has been properly assigned (Art. 7, AltholzV). The sampled batch may subsequently be taken for further energy recovery only if the proportion of waste wood from higher waste wood categories does not exceed 2 % in total. In small combustion plants in accordance to 1.BImSchV no waste wood of higher categories may be contained [BLfU 2012]. Figure 42 graphically illustrates the assignment of the different waste wood categories to installations.

Figure 44: Assignment of waste wood categories to installations in accordance with the Federal Emission Control Legislation [BLfU 2012. Fig.1]



The recovery of waste wood can also be performed abroad, if done in compliance with the provisions of the Council Regulation on waste shipments and the German waste shipment law. Depending on the intended method for waste management, the state of destination and the classification of waste wood, the shipments of waste are either subject to information obligations or a procedure with prior written notification and consent of the competent authorities. Waste wood of the category AIV is hazardous waste and subject to obligations to keep records and to provide proof. It can only be transported commercially with a transport permit [BLfU 2012].

Waste wood generation and treatment

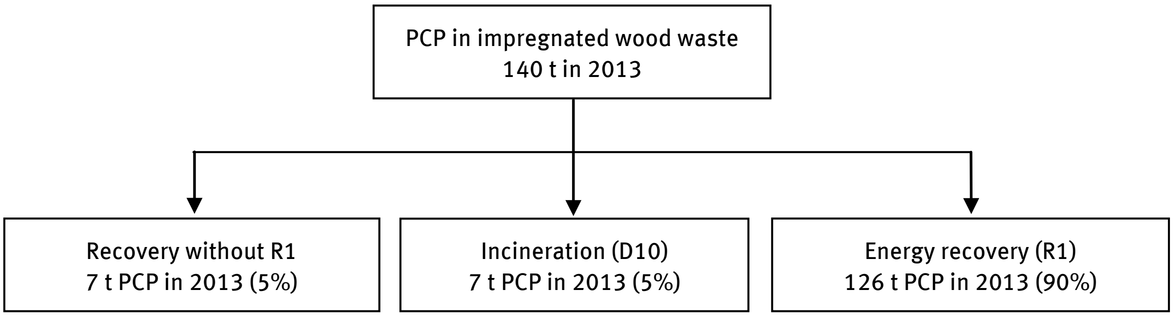
Statistical data on waste wood generation and treatment in Germany can for instance be retrieved via EUROSTAT. National statistical institutes collect, analyse, review and communicate statistical data to Eurostat. In 2010 the total volume of waste wood in Germany, taking into account all NACE activities (statistical classification of economic activities in the European Community) and all households, was around 10.8 million tonnes. Thereof, around 9.7 million tonnes (~ 90 %) were declared as hazardous waste and about 1.1 million tonnes (~10%) as non-hazardous waste. In Germany, a total of ~9.9 million tonnes of waste wood was managed. Thereof, about 6.9 million tonnes were incinerated with energy recovery (R1), ~0.16 million tonnes incinerated/ disposed (D10) and ~ 2.84 million tonnes recovered (without R1). A negligible amount of waste wood was disposed of to landfills. Approximately 1.15 million tonnes of hazardous waste wood (~90%; 1,029,468 t) was used to generate energy. The remaining 10% were incinerated (~ 57,507 t) and recovered without energy recovery (~ 60,872 t), [EUROSTAT 2013].

At EU level, it was assumed that the entire PCP-contaminated waste wood is incinerated with energy recovery [see BiPRO 2011]. Taking the available statistical data into account and assuming that the quantities of waste wood generated and treated have remained relatively constant in Germany, it is expected that the relevant waste stream is incinerated with energy recovery to 90% (R1), incinerated without energy recovery to 5% (D10) and recovered (without energy recovery) to 5%. Due to applicable legal requirements (see Appendix I re Art. 3 para. 1, AltholzV) it can be further assumed that the remaining 5% of the recovered waste wood is used for the production of synthesis gas and manufacture of activated carbon.

3.5.6.7 Substance flow

According to [BiPRO 2011], around 878 t PCP was managed in the EU in 2013. In case the estimated tonnage is proportional to the share of population (share Germany ~16% of the EU28), roughly around 140 t PCP per year can be derived based on EU data (see Figure 43).

Figure 45: PCP substance flow diagram

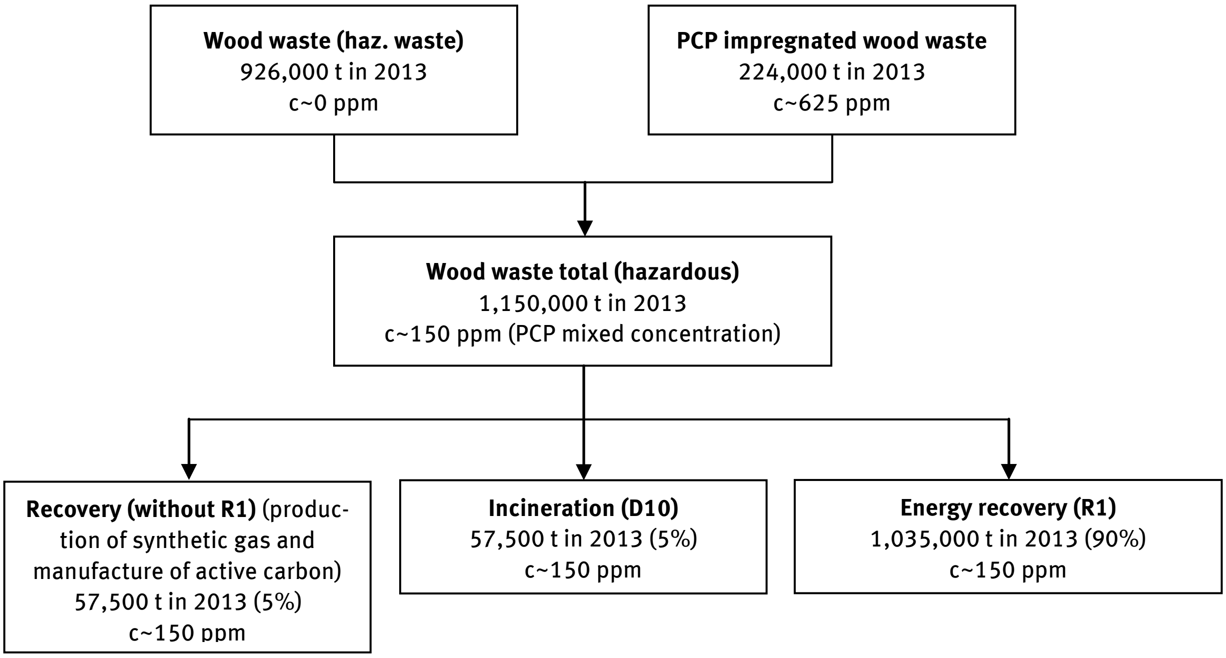


Around 90 % (126 t) of the PCP contained in impregnated wood waste in Germany is incinerated with energy recovery (R1). The remaining 10 % is incinerated without energy recovery (D10) and recovered without R1 to equal amounts (7 t respectively). Due to high process temperatures of the currently applied waste management operations, it can be considered that the PCP content in waste wood is almost completely destroyed.

3.5.6.8 Material flow

[BiPRO 2011] contains a PCP material flow diagram for the EU27. The situation in Germany is qualitatively similar. Due to better data availability, it can be further adopted for Germany that the PCP-contaminated waste stream is managed together with other hazardous waste wood (which may also contain other wood preservatives). Thus, the average PCP concentration in waste wood decreases to about 150 ppm (see Figure 44).

Figure 46: PCP material flow diagram



The management of wood waste (classified as hazardous waste) is clearly defined in Germany. In 2013, approximately 224,000 t PCP impregnated wood waste was managed, with an average PCP concentration of 625 ppm. Further, it is assumed that the PCP-containing wood waste is treated together with other wood wastes classified as hazardous (~926,000 t). The PCP contamination of the mixed waste stream decreases thereby to approximately 150 ppm. The total wood waste amounts to ~1.15 mio. Tonnes (see Figure 44). This means that around 2 % of all wood waste and around 20 % of all wood waste classified as hazardous waste contains PCP.

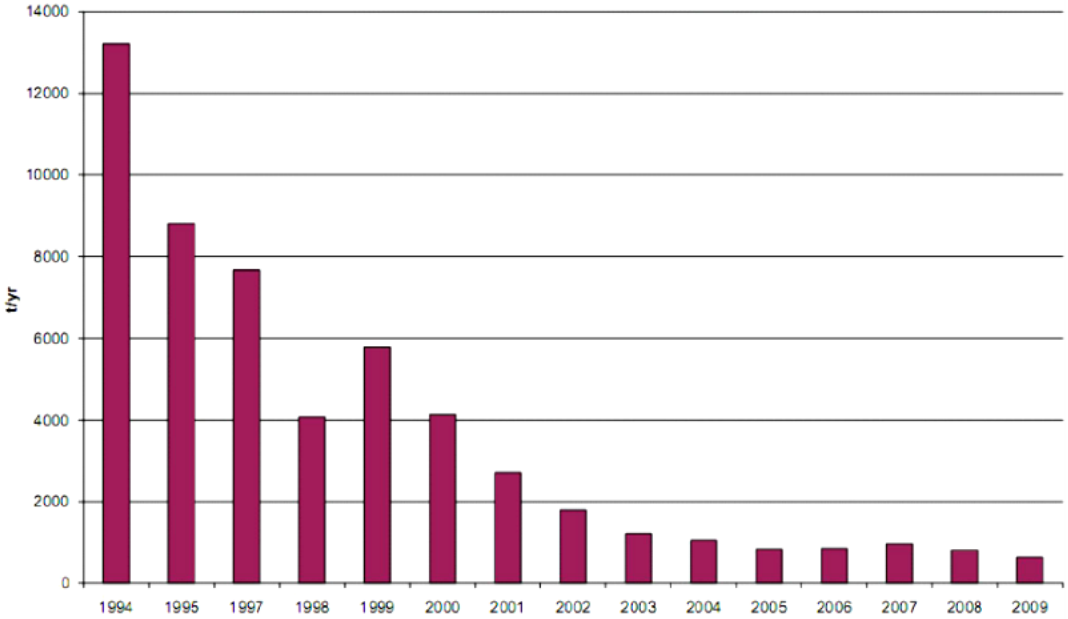
The wood waste is incinerated with and without energy recovery (~1.09 mio. t) and only around 5 % (~57.5 kt) is recovered (see Figure 44). Due to high process temperatures of the allowed recovery operations, it can be considered that the PCP content in waste wood is almost completely destroyed as during incineration of waste with and without energy recovery.

3.6 Short chain chlorinated paraffins (SCCP)

3.6.1 Manufacture and use

The manufactured and used SCCP volumes declined significantly in Germany and the entire EU during the last few years. Especially with the coming into force of EU Dir. 2002/45/EC, which banned the two most important uses of SCCP in Germany (~ 74 % of the total SCCP consumption was used in the metalworking industry and for fat liquoring of leather). The total consumption of SCCP was estimated to be around 530 t in the EU in 2010. Information on currently consumed annual amounts is not available. Figure 45 summarizes the total annual sales of SCCP in the EU from 1994 to 2009 (see [UBA 2006c], [RPA 2010]).

Figure 47: Total annual sales of SCCP in the EU [RPA 2010]



Published information on the current production and production capacities within the EU is scarce. According to [UNEP GER 2013], there are six main producers of chlorinated paraffins (CP) in the EU. It is thought that at least three or possibly four of these producers market SCCP. The main producers of SCCP in the EU in recent years are thought to be the companies Caffaro from Italy, INEOS ChlorVinyls from Great Britain, Novacke Chemické Závody from Slovakia and S.C. OLTQUINO from Romania. However, the only company which supplied a registration dossier for SCCP to ECHA is INEOS ChlorVinyls [ECHA 2013b]. Therefore, it can be assumed that only INEOS ChlorVinyls still produces SCCP in larger volumes. Given that there has been a market reduction in use in recent years, it is not quite clear whether other manufacturers still put SCCP on the market [UNEP GER 2013].

The production of SCCP ceased in Germany during the mid 90s. Before the production stopped, SCCP were manufactured by the companies Clariant, Hoechst and Huels. Important milestones of the CP production in Germany are summarizes in Table 54.

Table 58: Development of the chlorinated paraffins production in Germany

Year	Production in Germany [UBA 2006]
1990	**Production of around 20,000 – 30,000 t/y CP**
1991	Production of CP ceased in newly-formed German states
1994	Production of CP by the company Hoechst AG: 19,300 t, thereof 5,200 t SCCP (used to ~75% in metal processing)
1996	Hoechst AG stopped production of SCCP
1998	Hoechst AG ended production of all CP
1999	Leuna Tenside started production of long chain chlorinated paraffins (LCCP)

SCCP are used in a wide range of applications. Recent literature reports use of SCCP as plasticizers, binders, flame retardants in plastics, coatings and paints, rubber products, paper, textiles, joints and sealants and adhesives [GESTIS], [ECHA 2013b]. [BUND 2012] assumes that SCCP are also used in everyday products such as microwave dishes, lamps, electronic items such as cables, adapters, keyboards, memory media, photo frames, headphones, and also in detergent, etc. A recent study by the Swedish Chemicals Agency showed that more than 40 % of the investigated plastic samples from household items in Sweden contained SCCP [KEMI 2014].

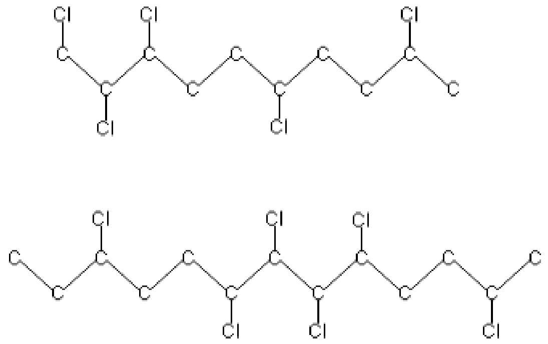
Possible imports of SCCP-containing products cannot be excluded. However, imports can only be followed, if at all, with a considerable effort. During the final workshop to this project, it was pointed out that SCCP can still occur in numerous applications and play a significant role in imports.

3.6.2 Chemical characteristics

CPs are common products of the chlorine chemistry. Chemically, CPs are saturated linear hydrocarbons with varying chlorine contents and chain lengths. CPs are divided in accordance to their chain length in short, medium and long chain CPs. Short chain CPs are saturated, linear hydrocarbons with 10-13 carbon atoms and an average degree of chlorination of 40-70 % [HDU 2007], [BAuA 2011].

Chemical formula:	$C_xH_{(2x-y+2)}Cl_y$ (x= 10-13; y=3-12)
CAS registry number:	85535-84-8
EC-number:	287-476-5

Figure 48: Chemical structure SCCP



e.g.: two SCCP compounds ($C_{10}H_{17}Cl_5$ and $C_{13}H_{22}Cl_6$)

Molecular mass: 320-500 g/mol [ERA 2000]

Table 55 summarizes the main chemical and physical properties of SCCP.

Table 59: Chemical-physical properties SCCP

Chemical-physical properties SCCP		Sources
Appearance	liquid	[POPRC 6/11], [BUWAL 2003], [ERA 2000], [ERA 2008], [GESTIS 2013]
Density	1.18-1.59 g/cm³ (20°C)	
Boiling point	›200°C	
Vapour pressure (at 100°C)	0.028-2.8 x 10^{-7} Pa; 0.0213 Pa	
Log Kow	4.48-8.69	
Solubility	150-470 µg/l	
Henry's law constant	0.7-18 Pa*m³/mol	

3.6.3 Legal background

International/EU:

Directive 2002/45/EC of 25 June 2002

Directive 2002/45/EC of the European Parliament and of the Council of 25 June 2002, amending for the twentieth time Council Directive 76/769EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (short-chain chlorinated paraffins).

In Annex I to Directive 76/769/EWG the following was added:

1. *Short-chain chlorinated paraffins may not be placed on the market for use as substance or as constituents of other substances or preparations in concentrations higher than 1 %:*

   - for metalworking;

   - for fat liquoring of leather.

The restrictions on the marketing and use are now covered by the REACH regulation.

2. *Before 1 January 2003 all remaining uses of SCCP will be reviewed by the European Commission, in cooperation with the Member States and the OSPAR Commission, in the light of any relevant new scientific data on risks posed by SCCP to health and the environment.*

(1) *Member States shall adopt and publish, not later than 6 of July 2003, the laws, regulations and provisions necessary to comply with this Directive. They shall forthwith inform the Commission thereof.*

They shall apply those measures from 6 January 2004 at the latest.

REACH Regulation (EC) No 1907/2006

Alkanes, C_{10}-C_{13}, chloro are registered under REACH [ECHA 2013b]. The relevant information (chemical properties, uses, etc.) have been submitted to ECHA in a registration dossier.

Annex XVII, Number 42

Alkanes, C_{10}-C_{13}, *chloro (short-chain chlorinated paraffins) shall not be placed on the market for use as substances or as constituents of other substances or preparations in concentrations higher than 1 % in metalworking and for fat liquoring of leather.*

SCCP have been included to the candidate list of substances of very high concern in 2008. Any producer or importer of articles shall notify ECHA about substances included in the candidate list, in case the following conditions are met [REACH 1907/2006. Art. 7(2)]:

- *the substance is present in those articles above a concentration of 0.1 % (w/w);*
- *the substance is present in those articles in quantities totalling over one tonne per producer or importer per year.*

The restriction in Annex XVII No. 42 of the REACH Regulation has been deleted by Regulation (EU) No. 126/2013. Thus, only the obligations related to Article 7 (notification) and Article 33 (communication) apply with regard to articles containing > 0.1% SCCP.

PARCOM (Convention on the Prevention ofMarine Pollution from Land-Based Sources)

PARCOM Decision 95/1 (restrictions regarding the use of short chain chlorinated paraffins) is stricter than the EU legislation and requires Contracting Parties to stepwise phase-out the use of SCCP in paints, coatings and sealants, as flame retardants in rubber, plastics and textiles; and their use in metalworking fluids [PARCOM 95/1]. The phase-out for these uses should be achieved by 31. December 1999, except for uses as plasticizer in sealants and dams and as flame retardant in conveyor belts for the exclusive use in underground mining which should be phased-out by 31 December 2004 [OSPAR 2006]. Some Member States, among them also Germany, have already introduced or plan to introduce related measures to fulfill the restrictions of the PARCOM Decision 95/1 [Dir. 2002/45/EG], [OSPAR 2006].

Stockholm Convention

SCCP are proposed as POP candidate under the Stockholm Convention. For further information related to the Stockholm Convention see section 1 (Background and Objectives).

EU POP Regulation

The annexes of the EU POP Regulation are updated in accordance to international agreements and the technical development. In February 2013, EU Member States received a draft amendment to the EU POP Regulation as regards Annexes IV and V for commenting by mid of March 2013. Regarding SCCP, the draft amendment contained a proposal for the lower POP concentration limit (LPCL) of 1,000 mg/kg and the upper POP concentration limit (UPCL) of 5,000 mg/kg. The current draft amendment from 03.12.2014 has been adjusted in this regard and proposes for both, the LPCL and UPCL, 10,000 mg/kg (corresponds to 1 %).

The EU POP Regulation restricts the placing on the market and use of SCCP as such in preparations and articles. According to Annex I, part B of the Regulation the following derogations exist for SCCP:

1. „*By way of derogation, the production, placing on the market and use of substances or preparations containing SCCP in concentrations lower than 1 % by weight shall be allowed*"

2. "By way of derogation, the production, placing on the market, and use of the following applications shall be allowed provided that Member States report to the Commission no later than 2015 and every four years thereafter on the progress made to eliminate SCCP:

a) fire retardants in rubber used in conveyor belts in the mining industry;

b) fire retardants in dam sealants.

"*As soon as new information on details of uses and safer alternative substances or technologies become available, the Commission shall review the derogations set out in point 2 so that the uses of SCCP be phased out.*" In this connection, a dossier has been submitted as a basis for discussion by the Netherlands in advance to the "*Meeting of the Competent Authorities under Regulation EC 850/2004*" in Brussels on 2 October 2013 ("*Evaluation of Possible Restrictions on Short Chain Chlorinated Paraffins*"). The contained information from the dossier confirms that there are suitable alternatives to SCCP in both areas of application by now. Several companies have already made the switch to alternatives without major implications (mostly to MCCP and LCCP). Therefore, the European Commission proposes to adjust the Annex I of the POP Regulation to the technological development and delete the derogation for the use of SCCP as flame retardant in conveyor belts and sealants from the Annex to the Regulation. Whether and at what time this will be realised is not known yet.

Further information regarding the EU POP Regulation is contained in section 1.

3.6.4 Occurrence and relevance of SCCP

SCCP are not produced in Germany since the mid 90s. Important milestones of the CP production are summarised in Table 54. Current information on SCCP imports to Germany is not readily available. In the past, imports of SCCP from non-EU countries were of minor importance. This could have changed due to increased prices for CP. [RPA 2010] confirmed, that the production of CP in China has increased significantly (from about 20,000 t in 1990 to 600,000 t in 2007). Possibly also India has increased its production of CP. Therefore, imports of SCCP and other CP cannot be generally excluded. [RPA 2010] estimates that around 1,500 t SCCP were produced, of which around 530 t were consumed within the EU27 in 2009. The remaining amount of 970 t was assumed to be exported. SCCP were not exported from Germany in 2010 [RPA 2010].

Under the assumption, that the total SCCP consumption in the EU remained constant and is proportional to the share of population, a total consumption of around 85 t SCCP can be roughly derived for Germany (share of population ~16 % of the EU28[53]).

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[53] Area and population EU28: http://wko.at/statistik/eu/europa-bevoelkerung.pdf

3.6.5 Selection of relevant products, wastes and recyclates in Germany

Leather and metalworking fluids

The use of SCCP in metal working and for fat liquoring of leather has been banned in the EU by Directive 2002/45/EC. Before the ban in 2004, around 74 % of the total SCCP consumption in Germany was used in these two areas of application. For leather processing, SCCP with low chlorine content (20-40 %) were typically applied as degreasing agents. The used SCCP were absorbed by the leather to about 95-99 %. In the metal industry, SCCP were used as extreme pressure additives in cooling lubricants, drilling and cutting oils, which were used when drilling, cutting, pulling, sawing and stamping metals. SCCP were applied in an average concentration of about 5-10% [BUWAL 2003], [UBA 2003], [UBA 2006].

It is assumed that the SCCP use has discontinued in metalworking and leather processing, after the restrictions came into force in 2004, as higher SCCP concentrations were required in those areas of application (~ 5 – 10 % in metalworking and ~ 20 % for fat liquoring of leather). The metal and leather processing fluids and also the treated leather products have relatively short product life cycles. It can therefore be assumed that the used processing fluids, as well as the treated leather products have already been disposed of and managed. Recycling of SCCP-containing metalworking and leather processing fluids as well as SCCP-containing leather products can be excluded.

Even though SCCP are not used in metalworking and for fat liquoring of leather anymore, contaminated soil (e.g. from contaminated sites of former metalworking facilities) may still be a relevant source of SCCP in Germany. This has been pointed out by a meeting participant during the final workshop to this project.

Medium chain chlorinated paraffins (MCCP), which are often used to substitute SCCP, and which may contain fractions of SCCP (≤1 %) could still be relevant. The use of MCCP as extreme pressure additive in cooling lubricants increased from 2,611 tonnes to 5,953 tonnes in Europe during the time period from 1994-1997. This is probably due to the fact that the SCCP were substituted by MCCP already by the mid/late 90s [UBA 2003].

In 1998, the production of MCCP has ended in Germany. According to lubricant manufacturers, not only the substitution of SCCP, but also the substitution of MCCP is fairly advanced in Germany. A few alternatives to CPs are available on the market. Especially organic sulphur and phosphorous compounds as well as polymer esters are used as extreme pressure additives. Therefore, MCCP are no longer used in the production of water-miscible cooling lubricants (concentrates, emulsions and solutions) in Germany. Their use in water-immiscible cooling lubricants (oils) is limited to only a few applications (e.g. in the forming of complex steel parts), [UBA 2003]. This was also confirmed by the German association of the lubricant industry [VSI 2013]. In Germany, MCCP are only used in exceptional cases as ingredients of cooling lubricant oils. The main reason for this is the costly disposal and rejection of the customers (mainly automotive industry), mostly due to health, safety and environmental reasons. There are approximately only 2-3 formulator and as many users of MCCP-containing cooling lubricants. The users are mostly smaller metalworking companies [VSI 2013].

In a Swiss campaign, the perception of the duty of self-control for a number of CP-containing raw materials, paints and coatings, adhesives and sealants, metalworking fluids and binders was checked. The campaign was conducted in order to check the compliance with applicable legal requirements in Switzerland and to raise awareness among suppliers of associated products. The study identified two metalworking fluids and one fat liquoring fluid for leather, which contained high MCCP concentrations and also increased SCCP concentrations (1.0-1.5 %). A repeated analysis of the metalworking fluid, however, showed significantly lower concentrations (<1 %). The sale of the fat liquoring fluid was immediately stopped [BAG 2011].

The uncertainty in the determination of SCCP in the Swiss study may be due to the fact that the detection of SCCP (in relatively low concentrations) in the presence of MCCP is problematic [VSI 2013]. This was also confirmed by a leading laboratory [Eurofins 2013].

Water-immiscible cooling lubricants have, in contrast to water-miscible cutting fluids, relatively long service life. Usually, only the chips or abrasive slurry must be filtered out from time to time. An exchange of lubricants due to uselessness is rarely necessary. Further, the management of used cooling lubricants is clearly defined in Germany. Generally, cooling oils must not be disposed of via the sewer system. Cooling oils are hazardous waste and must be collected separately and disposed of in hazardous waste incinerators [IBU 2013], [IPA 2012b].

Taking into account the following information (only a few formulators/user, rather low SCCP concentrations in MCCP-containing agents (<0.1 %), problems to analytically detect SCCP in MCCP-containing cooling lubricants, practiced waste management option in Germany is waste incineration) it was decided not to analyse samples of MCCP-containing cooling lubricants and associated wastes. Further, no samples of leather processing agents were taken, since this is not a major area of application for MCCP. It is believed that the use of CP has been already substituted by less hazardous alternatives.

Rubber (conveyor belts)

SCCP are used as flame retardants in rubber products. SCCP are added at concentrations between 1-10 % and also used in combination with other flame retardants. Due to their flame retardant properties, SCCP are used in conveyor belts for underground mining, sound-insulating materials in hoses as well as seals in the electrical installation and in vehicles. [RPA 2010] assumes that approximately 75-90 % of the total consumption of SCCP within the rubber industry is used for the production of flame retarded conveyor belts for the mining industry. It is preferred to use SCCP, because of their higher degree of chlorination per weight compared to MCCP and therefore higher flame retardancy [BUWAL 2003].

There are several options for reusing end of life conveyor belts (e.g. as protection against wear, squat or bounce protection, weather protection curtains, floor mats, etc.). This was also confirmed by a mining company in the course of information collection for this project. The company also stated, that the used conveyor belts from underground mining are sold to individuals and are probably also reused above ground. Two companies who are specialised in rubber recycling also confirmed that production wastes and disposed conveyor belts (also from underground mining) have been used for the production of granulates.

It was therefore decided to analyse the content of SCCP in two rubber samples (one used rubber conveyor belt and one granulate from used conveyor belts). The results of the laboratory analysis are summarised in section 5.3.

Sealants and adhesives

SCCP are used as plasticizers in sealants and adhesives to provide for the desired hardness and elasticity of products. In combination with antimony trioxide or aluminum hydroxide, they are also effective flame retardants. The areas of application include polymers such as polyacrylates, polyurethanes and polysulfides for the construction industry and automotive as well as joint seals. In these applications, SCCP are used as a substitute for PCB.

An analysis of joint seals in Switzerland showed that CP was present in one-third of the 44 samples examined. Thereby, SCCP occurred most often [BUWAL 2003]. [RPA 2010] confirmed the use of SCCP in sealants and adhesives in Germany.

In coordination with the UBA it was decided to analyse the content of SCCP in four samples of joint sealants from waste management facilities for construction and demolition waste. The results of the laboratory analyses are compiled in section 5.3.

Textiles

In the textile industry, highly chlorinated SCCP were not only used as a flame retardant, but also as water-proof and as a rot-proof agent. Traditionally, CP were used for the treatment of military tents, however, this application has probably stopped within the EU. The use of SCCP in the textile industry in the EU decreased from 183 t in 1994 to 37 t in 1995. From 2001 to 2003, the use of SCCP in textiles dropped significantly, with a further reduction in 2004 [UBA 2006].

SCCP are no longer used for the flame-retardant finishing of textiles [BfR 2002]. The Association of manufacturers of textile, paper, leather and fur additives and colorants, surfactants, chelating agents, antimicrobial agents, polymers flocculants, cosmetic and pharmaceutical raw material additives or related products (TEGEWA e.V.) confirmed that its member companies have stopped the use of SCCP during the late 90s (probably also earlier), [TEGEWA 2013]. [RPA 2010] assumes that the use of SCCP in speciality textiles has already been substituted in Germany.

In particular long-life textile products (e.g. from military remainder of stock) could still play a minor role. Therefore, it was decided to analyse the SCCP content of one speciality textile which was formerly used by military. The results of the laboratory analyses are summarised in section 5.3.

PVC and other plastics

CP serves as plasticizer and flame retardant in PVC and other plastics. They can be generally used as secondary plasticizers in order to reduce the required amount of primary plasticizers.

The flame-retardant effect occurs on the one hand due to the fact that at high temperatures the halogen compounds are dissolved and create incombustible gases which seperate the atmospheric oxygen from the seat of the fire and on the other hand by radical reactions that prevent the polymer to decompose in light to combustible molecules. It is assumed that SCCP are no longer used in PVC and other plastics [BUWAL 2003], [UBA 2006c].

Paints and varnishes

SCCP are used to around 10 % in most of the paints and varnishes. They make coatings such as paints, varnishes, etc. water-, weather- and corrosion-resistant and flame retardant. The main applications include resistant primers, paints and coatings for ships, machinery, bridges and poles, wood, swimming pool, facades and road marking paints, and flame-retardant coatings [BUWAL 2003], [ECHA 2008], [RPA 2010]. Two main materials onto which SCCP-containing paints and varnishes were applied are metal and concrete. Other materials such as plastic and wood were less often coated with SCCP-containing paints [BiPRO 2011].

The used amounts declined significantly in the EU during the last years (many manufacturers have switched to less dangerous alternatives). One of the main formulators of paints and varnishes (i.e. Akzo Nobel) confirmed that SCCP have been completely replaced in their production [ECHA 2008]. Based on previous use patterns in the EU, [BiPRO 2011] estimates the total consumption of SCCP in paints and coatings to be about 100 tonnes in 2010. More recent data is not available, however, the consumption probably continued to decline. [RPA 2010] could not confirm the use of SCCP in paints and varnishes in Germany.

Further, [BiPRO 2011] assumes that a separate treatment of contaminated waste streams is not feasible in practice. Due to the mixing of waste streams, the SCCP concentrations are likely to be very low. It was therefore decided not to analyse samples of paints and varnishes and associated SCCP-containing waste.

Speciality paper

Speciality paper from Finland contained 130 mg CP per A4-sheet. An estimated amount of 150 t CP, contained in speciality papers, was disposed of to landfills in Finland in 1991. Additional information related to the use of CP in the paper industry is not available [BUWAL 2003]. Therefore, it has been decided not to further investigate speciality papers in this study.

Secondary sources (sewage sludge)

In the European Pollutant Release and Transfer Register E-PRTR[54] 16 companies reported the release of SCCP in 2011. All reported releases were into the compartment water. The reports were in particular from the activities of municipal wastewater treatment (11 plants, IE and FR) and independently operated industrial installations (1 plant, AT). Other relevant industrial activities were mineral oil and gas refineries (1 plant, FR), manufacture of paper and paperboard (2 plants, AT) and the production of basic organic chemicals (1 plant, ES).

SCCP reach sewage sludge through waste water streams. In treatment facilities near industrial regions (in the vicinity of a metal processing plant) SCCP concentrations of 47 µg/g (in 1994) - 65 µg/g (in 1991) were measured in sewage sludge samples. However, these concentrations result, with a high probability, from the earlier use of SCCP in the metalworking industry. Sewage sludge samples from 51 municipal wastewater treatment plants were analysed in Germany between 1999 and 2000. The detected concentrations were below the limit of detection of 1 µg/g. In Hesse, sewage sludge analyses were carried out in 2003. The average SCCP concentration was around 0.382 µg/g (max. 0.537 µg/g).

Based on the average concentration of around 0.382 µg/g, it can be estimated that the total amount of sewage sludge generated in Germany in 2003 (1.89 mio. t) contained approximately 720 kg SCCP. It is likely, however, that the SCCP concentrations in sewage sludge and thus also the total load of SCCP in sewage sludge has declined significantly due to the decline in use of SCCP. The probability that SCCP are contained in sewage sludge in significant amounts is estimated to be relatively low compared to the other waste streams such as in sealants and adhesives, paints, rubber or textiles. In coordination with UBA it was therefore decided not to collect and analyse sewage sludge samples.

Relevant uses

Until the mid 90s, SCCP were used as follows in the EU: metalworking (~ 70 %), rubber products (~ 10 %), painting applications (~ 9 %), sealants (~ 5 %) and leather processing (~ 3%), [BAG 2011]. The leather processing and metalworking, with about 74 % of the total SCCP consumption, were the two most important application areas for SCCP in Germany [SCCP POPRC 6/INF/15]. This changed within the entire EU, especially with the entry into force of the EU Dir. 2002/45/EC, which restricted the use of SCCP in these two areas.

[RPA 2010] estimates the total SCCP consumption of around 530 t in the EU in 2010. More up to date information on the total consumption is not available. The estimated total tonnage is distributed in different applications as follows (see Table 56).

Table 60: Estimated consumption of SCCP in different applications in the EU [RPA 2010]

Consumption of SCCP in different application in the EU (in 2009)		
Applications	[t]	[%]
Sealants and adhesives	237	45
Paints	101	19

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[54] http://prtr.ec.europa.eu/

Rubber	162	31
Textiles	29	6
Total	~530	100

Under the assumption that the total SCCP consumption in the EU remained constant and that the consumption is proportional to the share of population, a total consumption of around 85 t SCCP can be roughly derived for Germany. Due to lack of more precise information regarding the SCCP consumption in Germany, similar consumption pattern as in the EU is used for further estimations (~45 % in sealants and adhesives, ~31 % in rubber, ~19 % in paints and ~6 % in textiles) (see Table 57).

Table 61: Estimated consumption of SCCP in different applications in Germany

Estimated consumption of SCCP in different applications in Germany		
Applications	[t][1]	[%][2]
Sealants and adhesives	~38	45
Paints	~16	19
Rubber	~26	31
Textiles	~5	6
Total	~85	100

Used assumptions for the estimation of SCCP consumption and distribution in different applications EU → DE:

[1]: share of population GER in EU28 ca. 16% (in 2013)

[2]: SCCP consumption pattern in GER similar to the one in EU27

As the use of SCCP in paints/varnishes and speciality textiles could not be reconfirmed in Germany, these areas of application are not further considered (only one random sample of speciality textiles was analysed). Further, it can be assumed that the corresponding waste streams have already been managed. Therefore, only the use of SCCP in sealants and adhesives and rubbers will be closer investigated. For further estimations a current SCCP consumption of 38 t in sealants and adhesives and 26 t in rubber applications is assumed.

Based on the past and current consumption figures for SCCP, the amount of waste which has already been managed, and the amount of waste which still need to be managed in the future can be estimated. Corresponding estimations for the EU27 are contained in [BiPRO 2011]. Specific estimations for Germany are presented in the following chapters.

3.6.6 Rubber (conveyor belts)

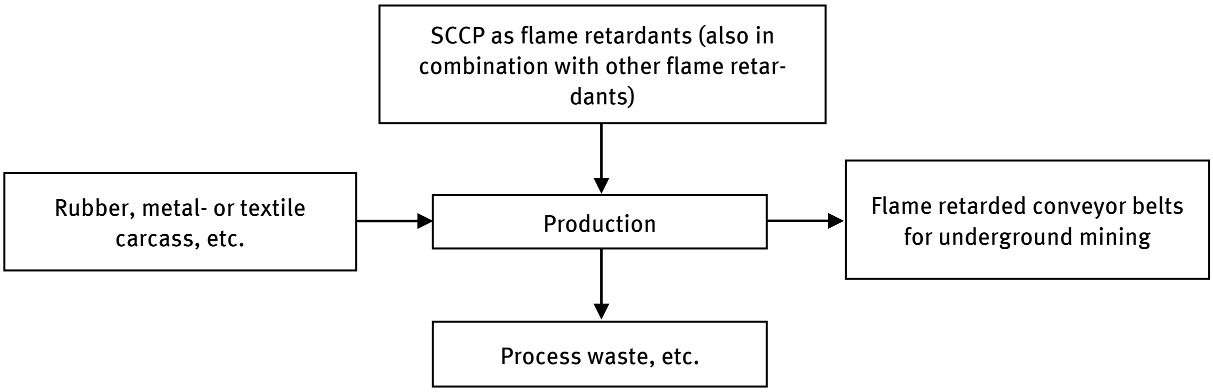
3.6.6.1 Background information

SCCP are mainly used for the manufacture of flame retarded conveyor belts for the use in underground mining (75-90 % of the total SCCP use in the rubber industry). Different rubbers can be used for this purpose (e.g. styrene, butadiene, PVC). In particular for the use in underground mining, the conveyor belts are mainly made with a textile or steel carcass [RPA 2010].

In the following, only the use of SCCP in conveyor belts for underground mining will be further elaborated. Other possible areas of applications within the rubber industry (e.g. acoustic insulation material, gasket and hoses for electrical installation and in vehicle manufacturing) are not further considered, due to their wide dispersive areas of application and the comparably low volumes used in those areas.

3.6.6.2 Processes, inputs and outputs

Figure 49: Inputs and outputs of SCCP in the production of conveyor belts



SCCP are used for the manufacture of flame retarded, high density conveyor belts for the use in underground mining. SCCP are additive flame retardants and therefore physically incorporated into the rubber matrix. SCCP can also be used in connection with other flame retardants. The carcass (mostly metal of textile carcass) is another important input to the production process. The main output streams are the flame retarded conveyor belts for the use in underground mining and different process wastes generated during the production (see Figure 47). It is assumed, that these are again recovered within the production process.

3.6.6.3 Generation factors

[BiPRO 2011] estimates losses during the entire product life time, due to wear out, to be approximately 2 %. Consequently, around 98 % of the initially used SCCP remain in waste. Due to the lack of more precise information, a factor of 0.98 is used for further estimations.

3.6.6.4 Contamination data (products, wastes and recyclates)

The SCCP content in the rubber is expected to be about 10 %, which again has a total share of around 33 % within the conveyor belt [RPA 2010]. The SCCP concentration of the total conveyor belt is therefore expected to be about 3.3 %.

Information on SCCP concentrations in wastes and recyclates is not available. It was therefore decided to analyse the SCCP content in two rubber samples (one end of life rubber conveyor belt and one granulate from used rubber conveyor belts). The results of the laboratory analysis are summarised in section 5.3.

3.6.6.5 Activity data

The use of SCCP in the production of rubber articles is currently registered under REACH. The exact tonnages, currently used in rubber products, can only be obtained from the registration dossier. However, this information has been submitted by the manufacturers/ importers to ECHA and is not publicly available. For further assessment it is therefore assumed that the derived 26 t SCCP, which are used in the rubber industry in Germany (see Table 57), are exclusively used for the production of flame retarded conveyor belts. With an average SCCP concentration of 10 % in rubber, around 260 tonnes of rubber is treated with SCCP in Germany every year.

Available information regarding the average product life time of conveyor belts varies. [ECHA 2008] estimates an average life time of conveyor belts of around 10 years. [RPA 2010] estimates it to be about 15 years. Conveyor belt manufacturers indicate a service life between 2 and 30 years. [BiPRO

2011] used a lognormal distribution with an average life time of 12.5 years and a standard deviation of 2.5 years for the estimations of the waste generation.

[BiPRO 2011] estimates that around 1,100 t SCCP was generated and managed in the EU27 in 2010. Under the assumption, that the estimated tonnage remained constant and that the waste generation is proportional to the share of population, a total consumption of around 176 t SCCP can be roughly derived for Germany (share of population ~16% of the EU28).

3.6.6.6 Waste management

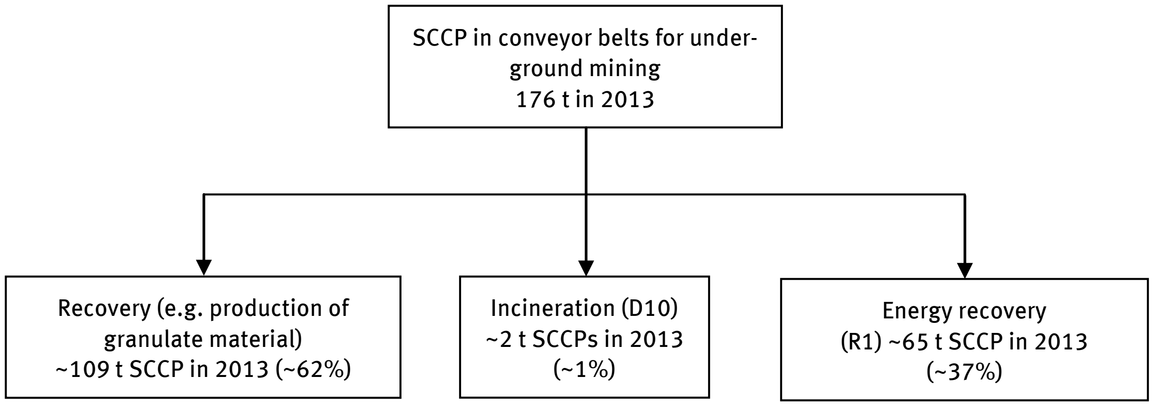
During the project, some well-known producers of conveyor belts were contacted. The willingness to provide data and information for the project was limited. From personal experience of a member of the project team (education and work in underground mines), end of life rubber conveyor belts can be used for various purposes (as wear protection, start-up or bounce protection, weather protection curtains, floor mats, etc.). This was also reconfirmed by a mining company in the course of the research work. In addition, the company stated that the used conveyor belts are also sold to individuals and may probably also be re-used. Two companies, who specialised in rubber recycling also confirmed, that production waste as well as disposed conveyor belts from underground mining are used for the production of granulates. The granulates can for instance be used to produce floors for sports fields, for the production of mats, etc. When choosing the proper recovery techniques for rubber waste, the degree of contamination of rubber is crucial. Problems may arise when rubber waste with a high content of metals is processed. The recycling is only possible if a small number of metal impurities are contained in the rubber. Larger metal parts would damage the blades of shredders and grinders [GAV 2013]. Although the steel fraction can be separated during the recycling process, the presence of steel in conveyor belts can cause problems [RPA 2010].

In the absence of more detailed information on the management of used conveyor belts from the underground mining and taking into account the information from telephone interviews with rubber recycling companies, it is assumed that the waste from conveyor belts is managed together with all the remaining rubber waste (e.g. used tires, etc.). Rubber waste from mechanical treatment of waste should be allocated to the waste category 19 12 04.

3.6.6.7 Substance flow

Around 62 % of the rubber waste was recovered (without R1), around 37 % was incinerated with energy recovery (R1) and only around 1 % was incinerated without energy recovery (D10) in Germany in 2010 [EUROSTAT 2013b]. Assuming that the quantities of treated rubber waste have remained relatively constant since 2010, and that the applied recovery and disposal management options have basically stayed the same, it is estimated that around 109 t of waste is recovered, around 65 t incinerated with energy recovery (R1) and only around 2 t incinerated without energy recovery (D10) in 2013 (see Figure 48).

Figure 50: SCCP substance flow diagram (SCCP in conveyor belts for underground mining)

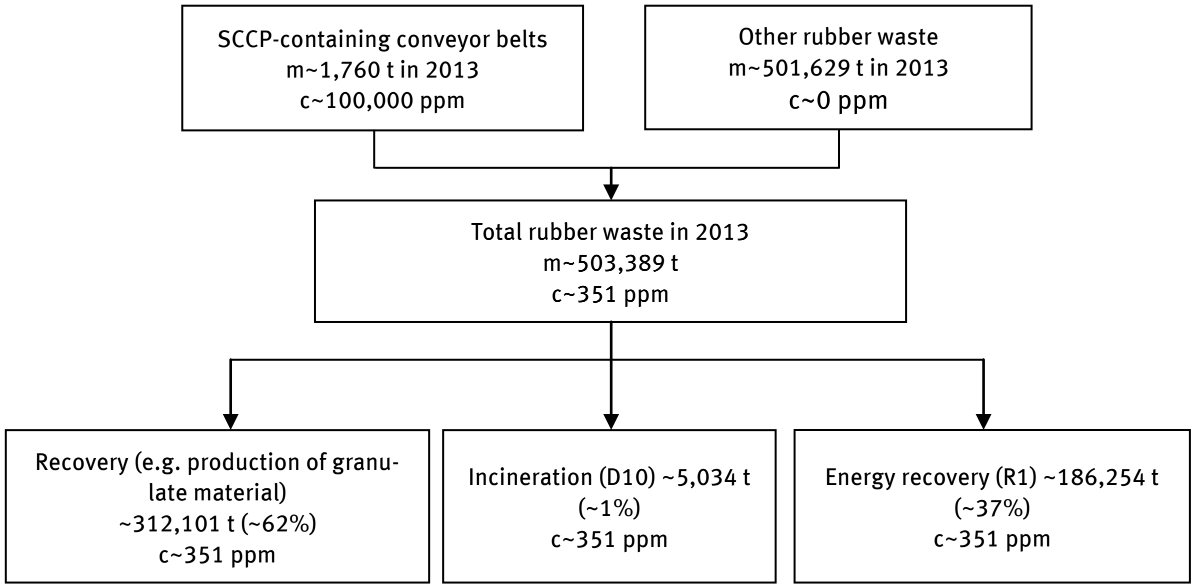


Due to the high incineration temperatures (>750 °C) during the incineration with and without energy recovery, it can be considered that the SCCP content in waste is almost completely destroyed. During the recovery (e.g. production of granulate material for further use) it cannot be completely excluded that SCCP enter recyclates (e.g. rubber floor underlay).

3.6.6.8 Material flow

Around 1,760 tonnes rubber waste from SCCP-containing conveyor belts was generated in Germany in 2013. The average SCCP concentration in the entire conveyor belts for the use in underground mining was estimated to be around 3.3 % and in the corresponding rubber about 10 % (corresponding to 100,000 ppm). When considering that the SCCP-containing rubber waste stream is managed together with all other rubber wastes, the theoretical SCCP concentration in the mixed waste stream decreases to around 351 ppm (see Figure 49).

Figure 51: SCCP material flow diagram (rubber conveyor belts)



Around 312,101 t (~62 %) of the relevant rubber waste is recovered (e.g. production of granulates for further use), around 186,254 t (~37 %) is incinerated with energy recovery and a comparably low waste amount of around 5,034 t (~1 %) is incinerated without energy recovery (see Figure 49). Due to high incineration temperatures during waste incineration with and without energy recovery, it can be considered that the SCCP content in rubber waste is almost completely destroyed. During the recovery, it cannot be excluded that SCCP enter recyclate streams.

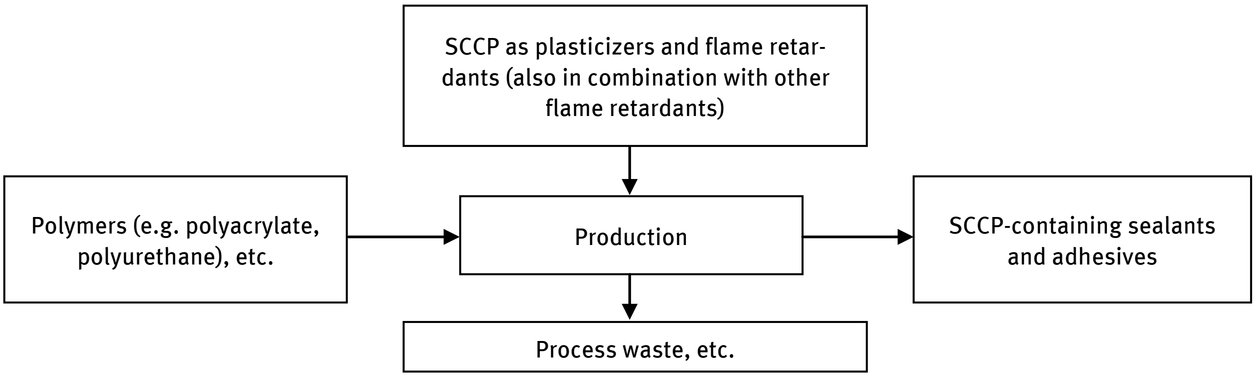
3.6.7 Sealants and adhesives

3.6.7.1 Background information

SCCP are used as plasticisers in sealants and adhesives. In combination with antimony trioxide or aluminium hydroxide, they are also effective flame retardants. The application areas include polymers such as polyacrylate, polyurethanes and polysulphides in the construction industry and the automotive sector as well as joint sealing. In this field, SCCP are used as a substitute for PCB. [RPA 2010] could confirm the use of SCCP in sealants and adhesives in Germany.

3.6.7.2 Processes, inputs and outputs

Figure 52: Inputs and outputs in the production of SCCP-containing sealants and adhesives



SCCP are used for the production of sealants and adhesives, especially for the construction sector. SCCP can be also applied as flame retardants in combination with antimony trioxide or aluminum hydroxide. The polymer (e.g. polyacrylate, polyurethanes) is a further input variable to the production process. The main outputs are the SCCP-containing sealants and adhesives and process wastes, which may arise during production (see Figure 50).

3.6.7.3 Generation factors

[BiPRO 2011] estimates losses during product life time, due to wear out, to be approximately 8 %. Consequently, around 92 % of the initially used SCCP remain in waste. Due to the lack of more precise information, a factor of 0.92 is used for further estimations.

3.6.7.4 Contamination data (products, wastes and recyclates)

SCCP are used in a concentration of approximately 5-14 % in sealants and adhesives. However, the concentrations may also be higher. [ECHA 2008] reported SCCP concentrations in products of 20 % (200,000 ppm) and higher. [BiPRO 2011] considers an average SCCP concentration of 20 % for the estimation of the relevant waste streams in the EU. This concentration is also used for the estimation of related waste amounts in Germany.

3.6.7.5 Activity data

The use of SCCP in the production of sealants and adhesives is currently registered under REACH. The exact tonnages can only be obtained from the registration dossier. However, this information has been submitted by the manufacturers/importers to ECHA and is not publicly available. For further estimations it is assumed that the derived 38 t SCCP (see Table 57) are used for the production of sealants and adhesives in Germany. Further, it is assumed that the sealants and adhesives are mainly used in the construction sector. With an average SCCP concentration of 20 %, around 190 t of sealants and adhesives are treated with SCCP.

[BiPRO 2011] assumes an average product life cycle time of 17 years for the estimation of corresponding waste amounts in the EU. The amount of waste in the EU27 was estimated to be approximately 412 t in 2010. Assuming that the estimated tonnage has remained constant in recent years and that the amount of waste is approximately proportional to the size of the population (Germany about 16% of the EU28) a waste amount of 66 t can be roughly estimated for Germany.

3.6.7.6 Waste management

In the absence of more precise information regarding the waste management of sealants and adhesives waste, and also considering their properties, it must be assumed that a significant proportion of sealants and adhesives used in the construction sector adheres to the surface of building materials (especially on concrete, tiles, bricks and ceramics). In practice, it is therefore not expected that the sealants and adhesives can be completely separated and treated separately from other waste streams. It is assumed that about 2/3 of the sealants and adhesives are managed together with other construction wastes. SCCP -containing sealants and adhesives may arise in various types of waste in the construction sector (for waste codes and explanations see Table 8).

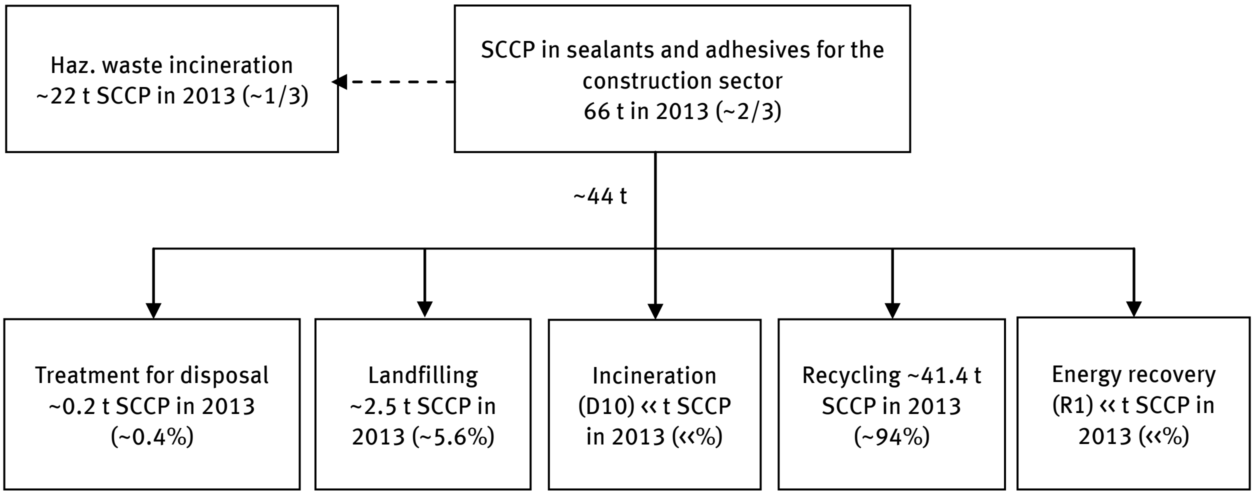
Approximately 54 million tonnes of concrete, tile, brick and ceramic waste was managed in Germany in 2011. A total of about 3 million tonnes was disposed of (landfilled and incinerated) and about 51 million tonnes were recovered (energy and material recovery). Of the 3 million tonnes disposed waste, only about 2,000 tonnes were incinerated, while the remaining waste was landfilled. Of the 51 million tonnes of recovered waste, only around 3,000 tonnes were incinerated with energy recovery, while the remaining waste was recycled [DESTATIS 2013].

If the sealants and adhesives can be successfully separated, it is assumed that this waste will be subsequently incinerated (e.g. in cases of suspected PCB-containing joint sealants which must be separately collected and disposed of in incinerators for hazardous waste). Therefore, it is assumed that the rest of SCCP-containing sealants and adhesives (approximately one third) can be collected separately and disposed of in hazardous waste incinerators.

3.6.7.7 Substance flow

Assuming that the amount of the treated concrete, tile, brick and ceramic waste has remained constant in Germany since 2011 and that the applied waste management operations have not changed, it can be estimated that around 41.4 t SCCP are recycled, approximately 2.5 t landfilled, about 0.2 t treated for disposal and only minor waste incinerated (<2 kg) and incinerated with energy recovery (<3 kg). Besides, the successfully separated SCCP-containing waste stream is disposed of in hazardous waste incinerators (~ 22 t) (see Figure 51).

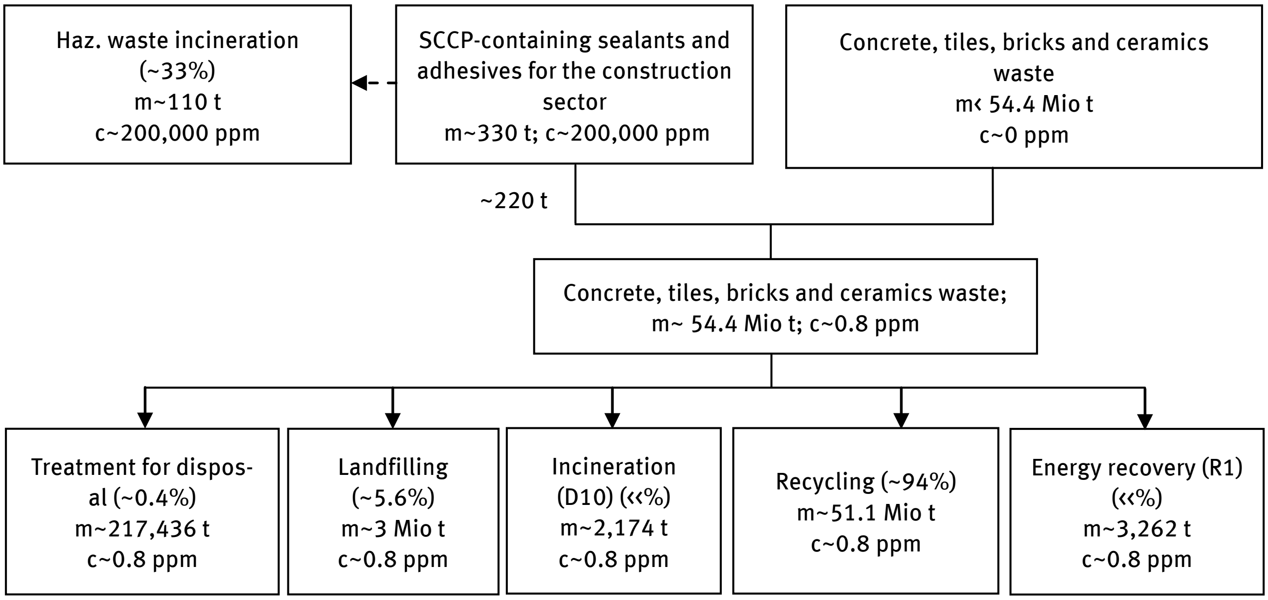
Figure 53: Substance flow diagram of SCCP in sealants and adhesives for the construction industry



3.6.7.8 Material flow

Around 330 tonnes waste from SCCP-containing sealants and adhesives was generated in Germany in 2013. The average SCCP concentration in the waste was estimated to be 200,000 ppm. When considering that around two thirds of the SCCP-containing waste is managed together with the waste from concrete, tiles, bricks and ceramics (ca. 54 mio. t), the theoretical SCCP concentration in the mixed waste stream decreases considerably (~0.8 ppm) (see Figure 52).

Figure 54: Material flow diagram of SCCP-containing sealants and adhesives



For the separately managed waste fraction (~110 t) it can be considered that, due to high incineration temperatures (>1,000 °C) during hazardous waste incineration, the high SCCP content in waste (~200,000 ppm) is almost completely destroyed. This also applies for the mixed waste stream which is incinerated with and without energy recovery.

With regard to the recycling and landfilling, it cannot be completely excluded that SCCP enter recyclate streams or are released to the environment. The theoretically concerned waste amount would be significant (>54 mio. t), while the SCCP concentration within the mixed waste stream rather low (~0.8 ppm) (see Figure 52).

4 Sample procurement

4.1 Sample schedule

In coordination with the UBA sample procurement and measurement schedules were developed. For each single POP particular regard was paid to:

- selection of relevant source sectors
- first evaluation of relevance (amount) in products, wastes and recyclates (i.e. relevant because still used, potential accumulation in recycled products)
- Decision on sample procurement (Number of products, wastes and recyclates)
- Contacts/ideas for sample procurement (i.e. processors, producers, plant operators)

The discussion with the UBA proceeded in a structured way on the basis of an Excel file. The conclusions of the discussion were documented and a clearly arranged sample schedule was developed. For some of the samples there was doubt about the possibility to procure samples. Therefore it was decided to increase the number of samples for all substances to have reserve samples on hand if necessary. The adjusted sample overview was used as basis for the sample procurement.

4.2 Sample overview

From July until September 2013 the sample procurement was conducted. Altogether 38 samples from different source sectors for overall 45 laboratory tests were procured. They can be allocated to the single substances/substance groups as presented in Table 58:

Table 62: Distribution of the samples on different substances/substance groups

Substance/substance group	HBCD	HCBD	PCN	PCP	SCCP	Total
Number of analyses	11	10	9	7	8	45

Table 59 gives a detailed overview of the procured samples. Further information on the individual samples and the corresponding pictures can be obtained from the annex.

Table 63: Overview of the samples

Substance	Sector of origin	Sample No.	Sample	Analyses per sample	Description
HBCD	**EPS/XPS construction sector**				**PS-E insulation material and/or PS-E-contaminated waste fractions and recyclates from PS-E insulation material (from construction waste processing facilities)**
		1	1	1	Containing PS-E insulation material (grinded XPS from insulation materials from the construction sector, which is used for the production of recyclates)
		2	1	1	Waste from construction waste processing facility, containing PS-E insulation material (grinded EPS from insulation materials from the construction sector)
		5	1	1	Recyclate from PS-E insulation material (granules from recycled PS)
HBCD	**EPS/XPS other**				**PS-E packaging waste and recyclates (recyclate from PS-E packaging material)**
		8	1	1	PS-E packaging waste (EPS-mixed fraction; packaging waste)
		9	1	1	PS-E packaging waste (grinded packaging material)
		10	1	1	Recyclate from PS-E packaging and insulation material (granules from recycled PS)
		11	1	1	PS-E packaging waste (packaging chips)
		12	1	1	Recyclate from PS-E packaging and insulation material (granules from recycled PS)
		12 b	1	1	Recyclate from PS-E packaging
HBCD	**WEEE (HIPS)**				**Brominated waste stream from waste electrical and electronic equipment (WEEE)**
		13	1	1	Brominated waste from WEEE
		13 b	1	1	PS recyclate from WEEE
HCBD	**Chlorine chemistry**				**Incineration residues (slag) from production facilities TRI, TETRA or PER**
		14	1	1	Slag facility A batch 1
		15	1	1	Slag facility A batch 2
HCBD	**Waste water treatment**				**Sewage sludge (from randomly selected municipal waste water treatment plant)**
		16	1	1	Sewage sludge (municipal waste water treatment)
HCBD/PCN	**Incineration of mu-**				**Waste from municipal waste incineration MWI (slag, boiler ash, filter ash, solid resi-**

Substance	Sector of origin	Sample No.	Sample	Analyses per sample	Description
	nicipal waste				**dues from flue gas scrubbing)**
		18	1	2	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)
		19	1	2	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)
		20	1	2	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)
		21	1	2	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)
		22	1	2	Filter ash MWI, facility B (mixed sample from 4 vessels over the time period of the 3rd Quarter 2013)
HCBD/PCN	**Incineration of hazardous waste**				**Filter ash (hazardous waste incineration HWI)**
		23	1	2	Filter dust HWI facility 1
		24	1	2	Filter dust HWI facility 2
PCN	**Production of secondary Al**				**Filter dust and salt slag (production of secondary aluminium)**
		26	1	1	Filter dust sec. Al facility A
		28	1	1	Salt slag sec. Al facility A
PCP	**Wood impregnation**				**Waste wood and recycled chipboard**
		31	1	1	Impregnated waste wood (waste wood category IV, shredded, mostly railway sleepers)
		32	1	1	Impregnated waste wood (wood from exterior use; fence type "Jägerzaun", ca. 35 years)
		33	1	1	Recycled chipboard (large chipboard, produced in Germany)
		34c	1	1	Chipboard (from waste wood processing facility)
		35	1	1	Impregnated waste wood (wood poles from exterior use, probably in contact with soil)
PCP	**Textiles**				**Special textiles (water- and weather-resistant)**
		36	1	1	Special textile A (military poncho from mid/late 80s)

Substance	Sector of origin	Sample No.	Sample	Analyses per sample	Description
		37	1	1	Special textile B (textile covered military air mattress from mid/late 80s)
SCCP	**Rubber industry**				**Used rubber conveyor belt from mining industry and granules from used conveyor belts**
		44	1	1	Used rubber conveyor belt from mining industry
		47b	1	1	Granules from used conveyor belts
SCCP	**Sealants and adhesives**				**Joint sealants (C&D wastes)**
		48	1	1	Joint sealant A
		49	1	1	Joint sealant B
		50	1	1	Joint sealant C
		51	1	1	Joint sealant D
SCCP	**Textiles**				**Special textiles (flame retarded)**
		53	1	1	Special textile A (pilot's cap from mid/late 80s)
		54	1	1	Special textile B (military poncho from mid/late 80s)
Altogether	**Altogether**		**38**	**45**	

5 Chemical analyses

The chemical analyses aim to fill knowledge gaps concerning typical concentrations of the relevant substances/substance groups in products, wastes and recyclates. Measurements are also particularly required in those cases where corresponding data is lacking or not reliable or where a particularly large input into the environment has to be expected.

Between October and March 2013 the gathered samples were analysed. In total 45 analytical measurements were carried out in order to analyse and quantify the presence of the relevant substances/substance groups in products, waste and recyclates.

The chemical analyses were performed by Eurofins Lab Service GmbH. Eurofins Lab Service GmbH possesses all the equipment required for sample preparation and homogenisation, such as various types of mills, freeze-dryers and cooling units. Subsequently to the professional inventory of the delivered sample material and primary processing steps such as homogenisation, splitting, drying, sieving or grinding, the Incoming Samples Department provides samples ready for analysis for all subsequent departments.

The applied analytical methods and parameters, including detection limits etc., are specified in the following.

5.1 Available analytical methods

Analysis costs and detection limits depend on the individual matrix which is examined, as well as on the expenditures invested in the analysis. For the evaluation, not the minimum detection limit of an analytical method is used, but, as far as available, the detection limit in the usual waste matrices under usual effort. Analysis costs include costs for typical sample preparation. Costs up to €500 per individual measurement are regarded as economically available. The actual costs partly range significantly below this value and differ distinctly depending on the substance/substance group. PCP analyses cause costs of nearly 100 to 200€ per individual measurement, whereas the costs for SCCP analyses can double this value (see Table 60). The detection limits of analytical methods depend on the matrix, in which a substance is analysed. The detection limit should take into account the typical spectrum of relevant waste matrices. Typical achievable detection limits of adequate methods range between 10 and 100 µg/kg for all substances/substance groups for samples with minor contents of the analysed substances. However, the detection limits can be lower depending on method and matrix or higher for samples with significantly high contents of the analysed substances due to lower required initial weights or higher dilution. The corresponding detection limits to the analysed samples are indicated in Table 61.

Table 64: Typically achievable detection limits and usual costs for chemical analyses depending on the sample matrix

Substance	Sample No.	Matrix	Achievable detection limit (in µg/kg)	Analysis costs (in € per analysis)
HBCD	1, 2, 5, 8, 9, 11, 12b	Expanded polystyrene	10 – 100	170 – 340
	10, 12, 13b	Polystyrene	10 – 100	
	13	Plastics from WEEE	10 – 100	
HCBD	14, 15	Incineration residues (slag)	10 – 100	130 – 270

Substance	Sample No.	Matrix	Achievable detection limit (in µg/kg)	Analysis costs (in € per analysis)
	16	Sewage sludge	10 – 100	
	18, 19	Incineration residues (slag)	10 – 100	
	20, 21, 22, 23, 24	Incineration residues (ash)	10 – 100	
PCN	18, 19	Incineration residues (slag)	10 – 100	170 – 345
	20, 21, 22, 23, 24, 26	Incineration residues (ash)	10 – 100	
	28	Salt slag	10 – 100	
PCP	31, 32, 33, 34c, 35	Wood/wooden materials	10 – 100	90 – 190
	36, 37	Special textiles	10 – 100	
SCCP	44, 47 b	Rubber	10 – 100	190 – 380
	48, 49, 50, 51	Sealants	10 – 100	
	53, 54	Special textiles	10 – 100	

* Detection limit per congener; analysed congeners: 1,2,3,4-TetraCN, 1,2,3,5,7-PentaCN, 1,2,3,4,6,7-HexaCN, 1,2,3,5,6,7-HexaCN, 1,2,3,5,7,8-HexaCN, 1,2,3,4,5,6,7-HeptaCN, OctaCN

5.1.1 HBCD

On the basis of extensive literature search concerning standardised analytical methods, [BiPRO 2011] concludes that both LC/MS and LC-MS/MS techniques are state-of-the-art in the field of HBCD analysis. Analytical methods for simultaneous determination of several brominated flame retardants covering polybrominated diphenyl ethers (PBDE) besides HBCD have been developed as well. Different extraction and clean-up procedures are both available and suitable for analysing a broad spectrum of matrices. From this perspective, the available techniques are suitable to allow analytical control of limit values.

Due to the inhomogeneity of the waste matrix, it seems to be very challenging to develop one standard method for HBCD analysis in all types of waste. In view of the big differences between the identified relevant waste matrices, different extraction procedures have to be used. As extraction in most cases is the most sensitive part of an analytical method, it has to be taken into account that quality criteria like detection limits or recovery rates might be different for different waste matrices. This has to be taken into account when defining a suitable detection limit for analytical methods to determine the HBCD content (content of brominated flame retardants) in waste as a basis for establishing concentration limit values.

According to [BiPRO 2011], brominated flame retardants can be detected in very low concentrations through analytical methods for HBCD contents in matrices with properties comparable to relevant waste matrices. In soils and sediments for instance, concentrations of a few µg/kg can be quantified. In post-consumer plastic waste from WEEE, the detection limit for flame retardants lies in the range of 0.01 – 1 mg/kg. As a conclusion, [BiPRO 2011] states that a detection limit of 10 mg/kg would be realistically achievable with common laboratory equipment and usual effort. The chemical analyses for HBCD in the present project were measured via GC/MS (detection limit 10 to 100 µg/kg; for details see section 5.2.1).

So contents of 1 mg/kg HBCD can be detected with existing state-of-the-art methods in the relevant matrices.

5.1.2 HCBD

According to [BiPRO 2011], on the basis of extensive literature search, GC/MS and GC-ECD techniques were identified as state-of-the-art in the field of HCBD analysis. Performance criteria of the known methods are comparable. Different extraction and clean-up procedures are available and suitable for analysing a broad spectrum of matrices. Extraction and clean-up procedures have to be adapted to the relevant types of waste (matrices). Against this background, achievable limits of detection for waste matrices might be higher than for matrices like water or biological samples, which are taken into account when defining a detection limit for sludge or ash. However, the available techniques are suitable to allow analytical control of limit values.

The methods listed in literature are designed to detect HCBD at very low levels in the corresponding matrices. However, it has to be emphasised that the achievable levels can vary and strongly depend on the individual matrix to be analysed, especially if waste matrices are analysed for their HCBD content. Although standard methods have not been identified, there are analytical methods available to determine the HCBD concentration in environmental samples which define critical performance criteria like detection limits or recovery rates.

Available state-of-the-art methods are able to detect HCBD in the low µg/kg range, depending on analytical effort and sample matrix (see [BiPRO 2011]). Common detection limits reported in scientific literature are about 0.05 µg/l in water, 0.1 µg/kg in fat matrices and 0.5 µg/kg (dry weight) for soil samples. [BiPRO 2011] draws the conclusion that a detection limit of 50 µg/kg could be achieved using the common GC/MS methods. In the scope of this research project, GC/MS methods were used for the chemical analyses for HCBD. The detection limit for this method is indicated as 10 to 100 µg/kg. In the examined matrices, detection limits of 0.54 µg/kg (for sewage sludge) and 8.87 to 9.87 µg/kg were achieved (for details on the applied methods see section 5.2).

So contents of 0.1 mg/kg HCBD can be detected with existing state-of-the-art methods in the relevant matrices.

5.1.3 PCN

According to [BiPRO 2011], the methods listed in scientific literature allow the detection of very low PCN concentrations in corresponding matrices. However, it has to be emphasised that the achievable levels can vary and strongly depend on the individual matrix to be analysed, especially in the analysis of wastes, which can present completely different sample matrices. Although standard methods have only been identified for water analyses, there are analytical methods available to determine the PCN concentration in environmental samples which define critical performance criteria like detection limits or recovery rates.

[BiPRO 2011] states that GC/MS techniques represent the state-of-the-art in the field of PCN analysis. Performance criteria are comparable and different extraction and clean-up procedures are available and suitable for analysing a broad spectrum of matrices. Extraction and clean-up procedures have to be adapted to the relevant types of waste (matrices). Co-eluation of PCBs can influence the GC/MS analysis. Achievable detection limits for waste matrices might be higher than for matrices like water or biological samples. However, the waste matrices relevant for PCN analyses seem to show comparable characteristics as environmental samples such as sediment or soils. From this point of view, the available techniques are suitable to allow analytical control of limit values.

The detection limits reported in scientific literature show that GC/MS techniques in combination with adequate extraction and clean-up methods are suitable to detect low ng/kg PCN concentrations in sediment or sludge (see [BiPRO 2011]). However, the achievable detection limits for PCN in waste matrices can be higher. In [BiPRO 2011], it is concluded that a detection limit of 0.1 mg/kg would be realistically achievable with common state-of-the-art methods.

In the scope of this research project, GC/MS methods were used for the chemical analyses for specific PCN congeners. The detection limit for this method is indicated as 10 to 100 µg/kg. In the examined matrices, detection limits of 4.64 – 4.94 µg/kg (for ash) and 5.03 µg/kg (for salt slag) were achieved for each congener (for details on the applied method see section 5.2).

So contents of 0.1 mg/kg of each PCN congener can be detected with existing state-of-the-art methods in the relevant matrices.

5.1.4 PCP

According to [BiPRO 2011], GC/MS and GC-ECD techniques can be cited as state-of-the-art techniques in the field of PCP analysis. Performance criteria are comparable and different extraction and clean-up procedures are available and suitable for analysing a broad spectrum of matrices. Extraction and clean-up procedures have been adapted to the relevant types of waste (matrices). From this point of view, the available techniques are suitable to allow analytical control of limit values. Due to the inhomogeneity of the waste matrices, it seems to be very challenging to develop one standard method for PCP analysis in all types of waste. Standardised methods are available for most of the waste matrices which have been identified to be relevant.

Depending on the analytical effort, it is generally possible to detect PCP in different waste matrices in the low µg/kg range. Those detection limits are achievable for common waste matrices like wood, paper and textiles with standard methods and standard laboratory equipment. In [BiPRO 2011], it is concluded that, with usual effort for the analysis of PCP in waste woods, a detection limit of 0.1 mg/kg would be realistically achievable. In the scope of this research project, GC/MS methods were used for the chemical analyses for PCP. The detection limit for this method is indicated as 10 to 100 µg/kg (for details on the applied method see section 5.2).

So contents of 0.1 mg/kg PCP can be detected with existing state-of-the-art methods in the relevant matrices.

5.1.5 SCCP

According to [BiPRO 2011], GC/MS techniques are state-of-the-art in the field of SCCP analysis. Performance criteria depend on the kind of the matrix which is analysed. Soxhlet extraction followed by clean-up using column chromatography is suitable for analysing a broad spectrum of matrices. This approach of extraction followed by clean-up seems to be suitable for most of the relevant matrices and can also be applied to rubber or plastic samples. Against this background, taking into account that extraction procedures are the most critical step in the analysis of contaminants, achievable detection limits for different waste matrices seem to be in the same range as for other matrices like environmental samples or PUR foams.

However, compared to environmental samples like sediment or soil, relevant waste matrices may show different properties during SCCP analysis regarding sample extraction. The available techniques are suitable to allow analytical control of limit values in a low ppm range.

In [BiPRO 2011], it is concluded that, with usual effort for SCCP analysis, a detection limit of 10 mg/kg would be realistically achievable in relevant waste matrices.

In the scope of this research project, GC/MS methods were used for the chemical analyses for SCCP. The detection limit for this method is indicated as 10 to 100 µg/kg (for details on the applied method see section 5.2).

It can be assumed that contents of 1 mg/kg SCCP can be detected with existing state-of-the-art methods in the relevant matrices.

5.2 Applied analytical methods

The frame conditions for the analyses performed in the scope of this research project are described in the following for the relevant substances/substance groups:

5.2.1 HBCD

The basic analysis steps for all matrices are the following:

- Extraction of the sample material through Soxhlet, ASE or liquid/liquid extraction (depending on the matrix)
- Addition of $^{13}C_{12}$-labeled internal standards ($^{13}C_{12}$-α-HBCD and $^{13}C_{12}$-γ-HBCD)
- Clean-up of the extract through column chromatography with adequate adsorbents
- Analysis via capillary gas chromatography in combination with mass spectrometry (GC/MS)
- Identification through molecular or fragment ions
- Quantification of summarised native HBCD isomers through ^{13}C-labeled internal standards (isotope dilution method)

Analytical parameters:

▸ α-HBCD	CAS 134237-50-6
▸ β-HBCD	CAS 134237-51-7
▸ γ-HBCD	CAS 134237-52-8
▸ Sum α-, β-, γ-HBCD	

For the detection of the above mentioned HBCD compounds, a GC/MS analysis is performed.

Detection limits range between 10 and 100 µg/kg for HBCD free samples, whereas for samples with significantly high contents, the detection limit can be higher due to lower required initial weights or higher dilution.

5.2.2 HCBD

The basic analysis steps for all matrices are the following:

- Extraction of the sample material through Soxhlet, ASE or liquid/liquid extraction (depending on the matrix)
- Addition of an adequate ^{13}C-labeled internal standard ($^{13}C_4$-HCBD)
- Clean-up of the extract through column chromatography with adequate adsorbents
- Analysis via capillary gas chromatography in combination with mass spectrometry (GC/MS)
- Identification through molecular or fragment ions
- Quantification of native HCBD through ^{13}C-labeled internal standard

Analytical parameter:

▸ HCBD	CAS 87-68-3

For the detection of HCBD, a GC/MS analysis is performed

Detection limits range between 10 and 100 µg/kg for HCBD free samples, whereas for samples with significantly high contents, the detection limit can be higher due to lower required initial weights or higher dilution.

5.2.3 PCN

The basic analysis steps for all matrices are the following:

- Extraction of the sample material through Soxhlet, ASE or liquid/liquid extraction (depending on the matrix)
- Addition of adequate ^{13}C-labeled internal standards
- Clean-up of the extract through column chromatography with adequate adsorbents
- Analysis via capillary gas chromatography in combination with mass spectrometry (GC/MS)
- Identification through molecular or fragment ions
- Quantification of the summarised native PCN isomers through ^{13}C-labeled internal standards (isotope dilution method)

Analytical parameters:

1,2,3,4-TetraCN	(CN 27)	CAS 20020-02-4
1,2,3,5,7-PentaCN	(CN 52)	CAS 53555–65–0
1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	(CN 66/67)	CAS 103426–96–6/103426–97–7
1,2,3,5,7,8-HexaCN	(CN 69)	CAS 103426–94–4
1,2,3,4,5,6,7-HeptaCN	(CN 73)	CAS 58863–14–2
OctaCN	(CN 75)	CAS 2234–13–1

For the detection of the above mentioned PCN compounds, a GC/MS analysis is performed.

Detection limits range between 10 and 100 µg/kg for PCN- free samples, whereas for samples with significantly high contents, the detection limit can be higher due to lower required initial weights or higher dilution.

5.2.4 PCP

The basic analysis steps for all matrices are the following:

- Soxhlet or liquid/liquid extraction of the sample material (depending on the matrix)
- Addition of a $^{13}C_6$-labeled internal PCP standard ($^{13}C_6$-PCP)
- Clean-up of the extract through column chromatography with adequate adsorbents
- Analysis via capillary gas chromatography in combination with mass spectrometry (GC/MS)
- Identification through molecular or fragment ions
- Quantification of native PCP through ^{13}C-labeled internal standard (isotope dilution method)

Analytical parameter:

Pentachlorophenol (PCP)	CAS 87-86-5

For the detection of PCP, a GC/MS analysis is performed.

Detection limits range between 10 and 100 µg/kg for PCP free samples, whereas for samples with significantly high contents, the detection limit can be higher due to lower required initial weights or higher dilution.

5.2.5 SCCP

The basic analysis steps for all matrices are the following:

- Extraction of homogenised sample material using toluene
- Addition of an internal standard (cis-chlordane)
- Clean-up via sulphuric acid treatment and column chromatography
- Addition of a recovery standard (trans-chlordane)
- Analysis via gas chromatography in combination with mass spectrometry (GC/MS-NCI)
- Quantification of native chlorinated paraffins using the internal standard method

Analytical parameter:

- SCCP as total sum of C10 to C13

For the detection of the above mentioned SCCP compounds, a GC/MS analysis is performed.

Detection limits range between 10 and 100 µg/kg for SCCP-free samples, whereas for samples with significantly high contents, the detection limit can be higher due to lower required initial weights or higher dilution.

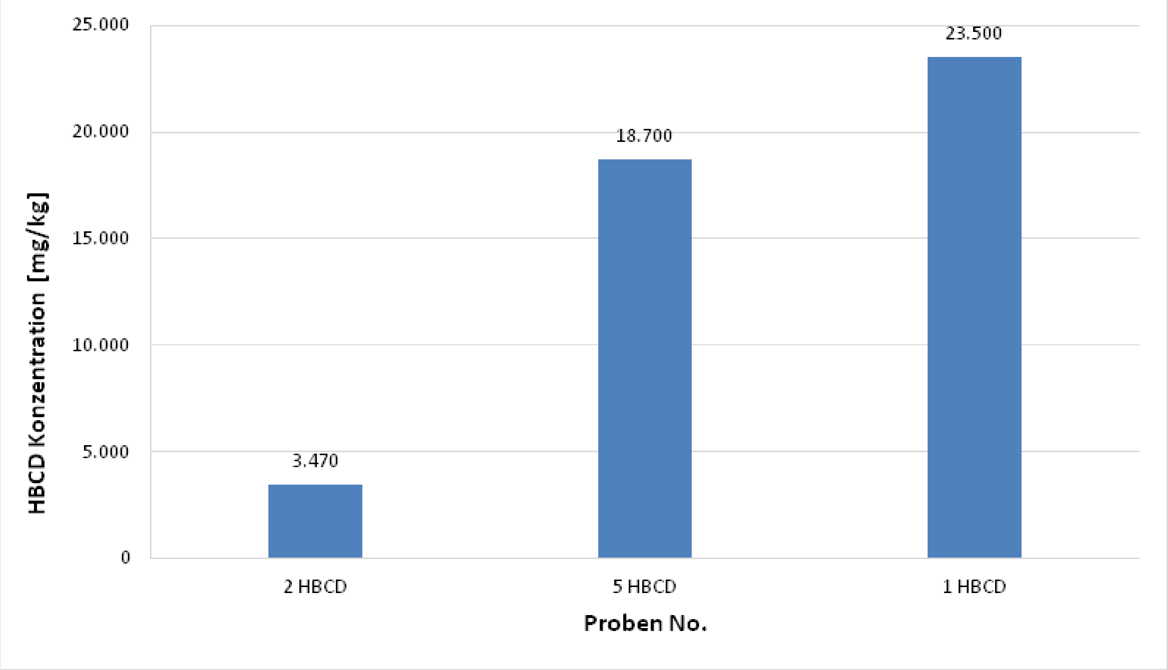
5.3 Results of the laboratory analyses

Within the framework of the research project, 38 samples were obtained from different sectors of origin for a total number of 45 analytical measurements. The results of these laboratory analyses are discussed in the following section and are summarised in Table 61. Additional details concerning the outcomes of the analyses (pictures of the samples, detailed measurement results of specific congeners and isomers, detection limits, etc.) can be obtained from the annex.

5.3.1 Discussion of the laboratory analyses results (HBCD)

EPS/XPS construction sector

Figure 55: Results of the laboratory analyses EPS/XPS construction sector

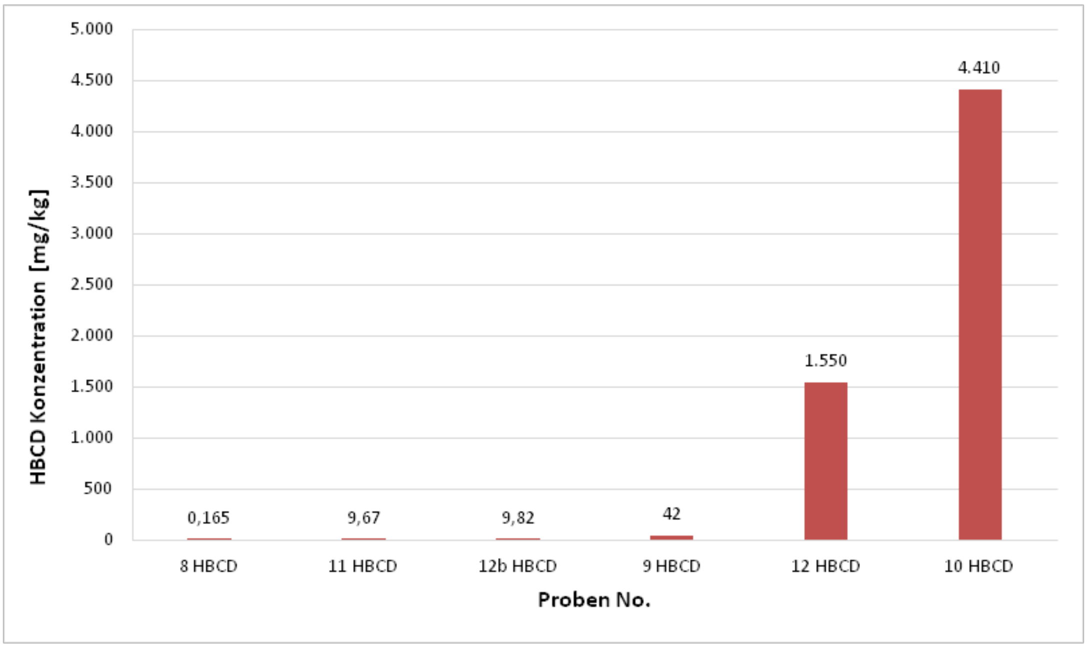


Due to the high relevance of PS foams from the construction sector within the context of the project, it was decided in consultation with the UBA to analyse EPS and XPS wastes and recyclates from the construction industry concerning their HBCD content. Therefore, samples from construction waste processing plants and/or recycling companies were obtained which were analysed within the course of the project (No 1 HBCD: XPS samples from insulation materials from the construction sector; No 2 HBCD: grinded EPS insulation materials from the construction sector; No 5 HBCD: recyclate of PS-E insulation material). The samples come from recyclers and are used to produce recyclates or are recyclates. The initial intention to obtain EPS/XPS wastes directly from construction waste processing plants proved to be difficult as these kinds of waste are available only in exceptional cases, according to several operators. However, the concentrations in EPS and XPS products are sufficiently well known and within the context of the project it seemed to be more relevant to sample the waste streams that are actually utilised for the production of recyclates or the recyclates themselves.

The analyses of the aforementioned samples from the construction sector revealed HBCD concentrations of 0.34 % (sample No 2 HBCD), 1.87 % (sample No 5 HBCD) and 2.35 % (sample No 1 HBCD); see Figure 53 and Table 61. As expected, the concentrations are in ranges that are typical for the application of HBCD in insulation materials (0.7 to 3 %; see Table 30) or, as in the case of the grinded EPS, below the common concentrations of 0.7 %. Potentially, the grinded EPS also contains portions of slightly or unpolluted EPS materials, such as packaging materials. The results of the chemical analyses confirmed the main assumptions of the research. For the calculation of material flows in the construction sector, concentrations of 0.7 % for EPS insulation materials and 1.5 % for XPS insulation materials are assumed.

EPS/XPS Others (EPS packaging)

Figure 56: Results of the laboratory analyses EPS/XPS others (EPS packaging)



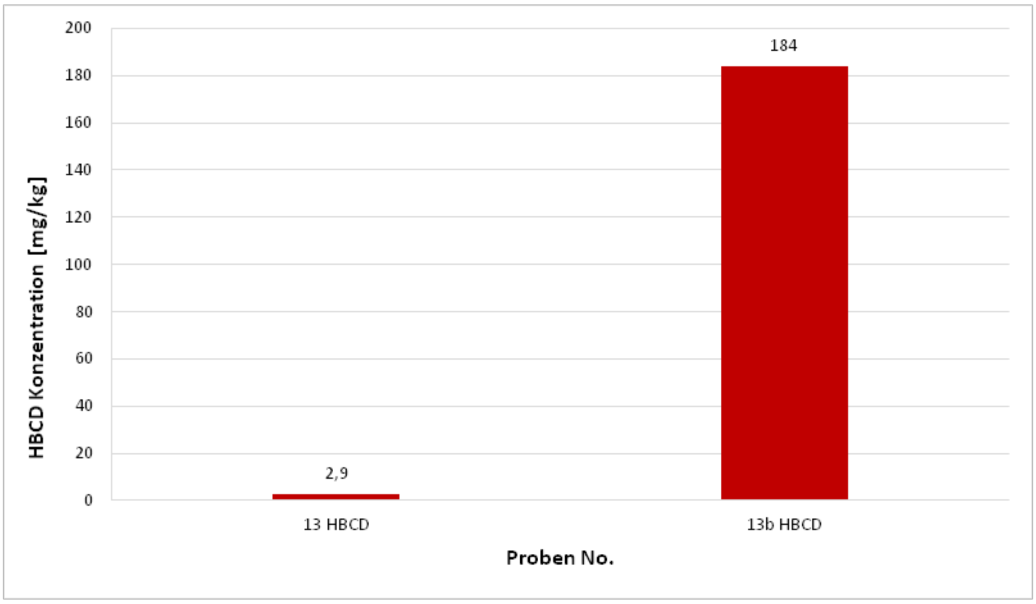
For other EPS and XPS relevant applications, which are dominated by the packaging sector, HBCD is no longer utilised in Germany. Due to the short product lifetimes in this sector HBCD might enter German waste streams via imports. In order to detect potential HBCD contents in the packaging sector, it has been decided in consultation with the UBA to conduct chemical analyses in this field. For this purpose, samples from recycling companies were procured and analysed (No 8 HBCD: EPS mixed fraction packaging waste; No 9 HBCD: grinded PS-E packaging; No 10 HBCD: recyclates of PS-E packaging/insulation materials; No 12 HBCD: recyclates of PS-E packaging/insulation materials; No 12b HBCD: recyclates of PS-E packaging).

The analyses of the aforementioned samples from the packaging sector revealed differing results, see Figure 54. To some extent, the concentrations are relatively low, which may be explained e.g. by contaminations of imports, old packaging, cross contamination from the construction sector or the use of HBCD-contaminated recyclates during the production of packaging. The measured HBCD concentrations are 0.165 mg/kg (sample No 8 HBCD), 9.760 mg/kg (sample No 11 HBCD), 9.820 mg/kg (sample No 12b HBCD) and 42 mg/kg (sample No 9 HBCD); see Table 61. The analyses confirmed that waste fractions of EPS packaging usually contain HBCD but levels of contamination are comparatively low. The results of the samples No 8/9/11/12b HBCD suggest that the average HBCD contamination of packaging waste may be about 10 mg/kg. This assertion is based on the outcomes of 4 random samples and could be verified with additional measurements, if applicable.

Two samples are striking due to their high HBCD contents of 1,550 mg/kg (sample No 12 HBCD) and 4,410 mg/kg (sample No 10 HBCD) (see Table 61). Closer consideration of the origin of the sample reveals that the samples were obtained from a recycling process in which a mixed fraction was created from packaging material and scrap pieces of new products of the insulation material field and processed into PS granulate. According to the recycler, flame retardants in input materials are destroyed during the recycling process (based on information by the plant manufacturer). Within this research project it was not possible to ascertain more detailed information on the process. However, the analysis results reveal that the destruction does not take place (or perhaps only partially). The recycler was informed about the analysis results and is in contact with the plant manufacturer. The high contaminations of the sample can be explained by the mixing of wastes from the construction sector with packaging wastes. It is to be expected that the high levels of contamination have their origin in the input of insulation materials into the mixture. If a reliable destruction of the HBCD content during the recycling process cannot be ensured, thermal recovery of the PS-E insulating material wastes is to be recommended. The partially practiced mixing of PS-E packaging wastes with PS-E insulation material wastes should be prevented under all circumstances. Otherwise, the recyclability of the uncontaminated waste streams would have to be questioned.

HIPS in the electronics sector

Figure 57: Results of the laboratory analyses (HIPS from waste electrical and electronic equipment)



No concrete information is available on whether HBCD is still being used in the electronics sector (although the current use cannot be excluded). In the waste sector, HBCD-containing HIPS from waste electronic equipment can be found due to former use and imports. In order to detect potential HBCD contents, it was decided in consultation with the UBA to conduct chemical analyses in this field. Samples for the analyses were obtained from recycling companies and subsequently analysed (No 13 HBCD: brominated waste from WEEE; No 13b HBCD: PS recyclate from WEEE).

The analyses of the HIPS samples from the electronics sector revealed different results, see Figure 55. The brominated waste from waste electrical equipment (sample No 13 HBCD) shows very low HBCD concentrations with 2.9 mg/kg (see Table 61). The result of this random sample is in accordance with the existing available values (see Table 37) and implies that brominated plastics from waste electrical equipment may be slightly contaminated on average. This can be explained by the fact that (potentially HBCD-containing) HIPS only make up a small share of this plastics fraction. The assertion is based on one random sample and an already available value and could be verified with additional measurements.

The PS recyclate from waste electrical equipment (sample No 13bHBCD) is made from polystyrene, which was recycled from HIPS from waste electrical equipment. Within that process, solely waste electrical equipment is utilised. The HBCD concentration within the recyclate is 184 mg/kg (see Table 61). This concentration lies significantly below the usual application concentrations of HBCD in HIPS in the electronics sector (1 to 7 %; see Table 30). This analysis result lying well below the application concentrations can be due to the fact that (1) only a small share of HIPS in waste electrical equipment contains HBCD, (2) other non HBCD-containing polystyrenes from waste electrical equipment enter the recyclate and (3) the contained HBCD is possibly partially destroyed during the process. As only one random sample was analysed it is to be questioned whether the sample has its origin in a representative batch. The HBCD concentrations in HIPS from waste electrical equipment could be verified through further analyses.

In principle, there are commitments according to Directive 2012/19/EU for the separation of plastics containing brominated flame retardants when treating waste electronics. If relevant concentrations are detected in the HIPS recyclate, this indicates that against the requirements, not all plastics that contain brominated flame retardants are separated. A strict implementation of the requirements would minimise the input of HBCD (and of other brominated flame retardants) into plastics recyclates from waste electrical equipment.

5.3.2 Discussion of the laboratory analyses results (HCBD)

HCBD was not found above the respective detection limits in the samples.

Production of chlorinated solvents

Relevant chlorinated solvents are produced at two sites in Germany. The production residues are incinerated on the site of production. No ashes are produced during the process as they are fed back into the incineration.

Whether relevant amounts of HCBD arise in the waste is thus not clear. In consultation with UBA it was agreed on sampling the slag created during the process in order to allow an estimation of the input of HCBD through ashes/slag from the production process of chlorinated organic compounds. Two slag samples were collected and analysed concerning the content of HCBD (samples 14 and 15 HCBD). HCBD was not found above the detection limits in the samples (detection limits 8.87 µg/kg and 9.24 µg/kg respectively; see Table 61). The results of the analyses imply that HCBD does not occur in the incineration residues from incinerating the production residues of chlorinated solvents in Germany in relevant amounts (on the basis of two random samples).

Incineration processes

In order to clarify the potential relevance of waste incineration processes, samples (ashes and slag) from plants for the incineration of municipal wastes (two plants) and hazardous waste (two plants) were obtained (samples No 18 to 22 HCBD/PCN). One of the plants for the incineration of municipal waste also incinerates hospital waste in a separate furnace. The waste gases of the municipal waste and hospital waste incineration are combined for cleaning, thus leading to mixed incineration residues.

The collected samples were analysed regarding their HCBD content in order to estimate the potential relevance of waste incineration processes[55]. HCBD was not found above the detection limits (detection limits 9.87 µg/kg, 9.82 µg/kg, 9.62 µg/kg, 9.40 µg/kg and 8.92 µg/kg, respectively; see Table 61). These analytical results suggest that HCBD does not occur or at least not in relevant amounts in incineration residues of the incineration of municipal wastes in Germany (on the basis of five random samples).

Sewage sludge

No data on the content of HCBD in sewage sludge in Germany is available. Due to the large quantities of sewage sludge that arise in Germany and in order to improve the information basis, a sewage sludge sample was obtained from a large German municipal sewage treatment plant. The sample was analysed regarding the content of HCBD. HCBD was not found above the detection limits (detection limits 0.54 µg/kg; see Table 61). This analytical result indicates that HCBD does not occur in relevant amounts in municipal sewage sludge in Germany. On the assumption that the HCBD content is usually below 0.54 µg/kg in Germany, it can be assumed that the total load in sewage sludge in Germany is below 1 kg per year.

5.3.3 Discussion of the laboratory analyses results (PCN)

The samples were analysed regarding their content of specific PCN congeners[56]. The analysed PCN congeners were not found above the respective detection limits in the samples.

Waste incineration processes

In order to clarify the possible relevance of waste incineration processes, samples (ashes and slag) from plants for the incineration of municipal wastes (two plants; samples 18 to 22HCBD/PCN) and of hazardous wastes (two plants; samples 23 and 24 HCBD/PCN) were obtained.

The collected samples were analysed regarding their PCN content in order to estimate the potential relevance of waste incineration processes[57]. The analysed congeners were not found above the detection limits in the samples obtained from municipal waste incineration (detection limits 4.94 µg/kg, 4.91 µg/kg, 4.81 µg/kg, 4.70 µg/kg and 4.46 µg/kg; see Table 61). The analysed congeners were neither found above the detection limits in samples from hazardous waste incineration (detection limits 4.69 µg/kg and 4.92 µg/kg; see Table 61). These analytical results suggest that PCN do not occur or at least not in relevant amounts in incineration residues of the incineration of wastes in Germany (on the basis of seven random samples).

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[55] The same samples were also analysed regarding the PCNs content

[56] Analysed congeneres: 1,2,3,4-TetraCN, 1,2,3,5,7-PentaCN, 1,2,3,4,6,7-HexaCN, 1,2,3,5,6,7-HexaCN, 1,2,3,5,7,8-HexaCN, 1,2,3,4,5,6,7-HeptaCN, OctaCN

[57] The same samples were also analysed regarding their HCBD content

Production of secondary copper

As no samples could be obtained from the production of secondary copper, no statement can be made regarding the relevance of this sector. In order to assess the relevance of the production of secondary copper in Germany regarding the occurrence of PCN, a chemical analysis of corresponding samples would be required.

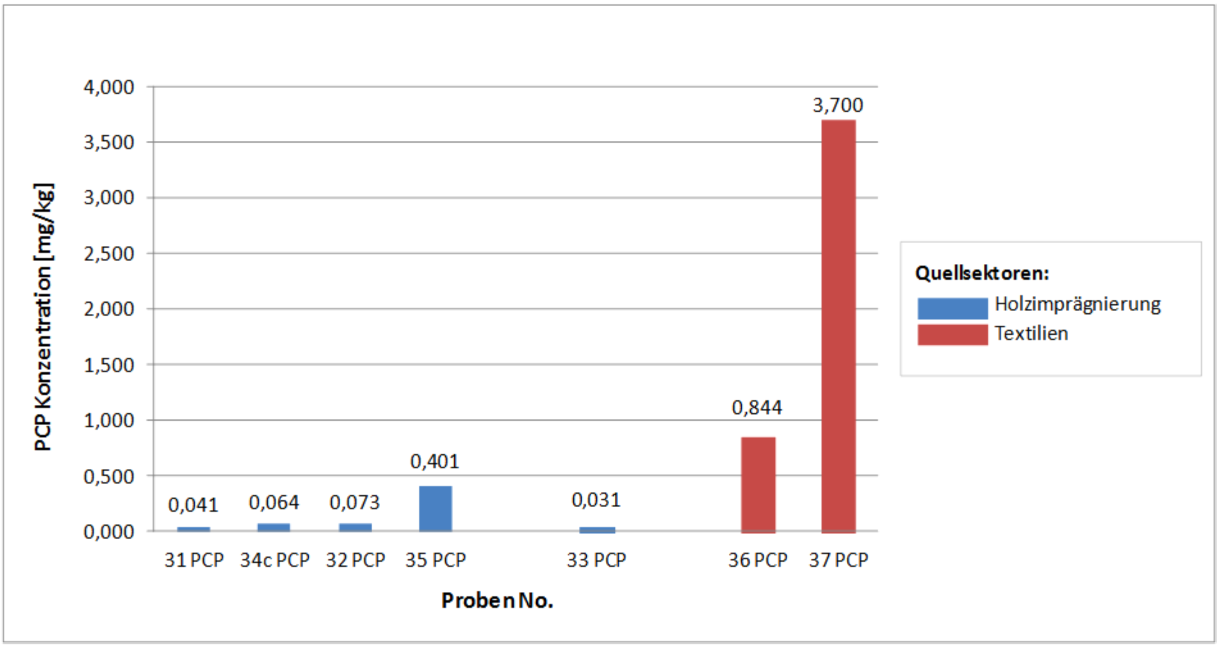
Production of secondary aluminium

Through the German Aluminium Industry Association (original title in German: Gesamtverband der Aluminiumindustrie) two samples (filter dust and salt slag) from a plant for the production of secondary aluminium were provided. The samples were analysed regarding their PCN content, in order to estimate the possible relevance of the production of secondary aluminium. The analysed congeners were not found above the detection limits in the samples (detection limits 4.71 µg/kg and. 5.03 µg/kg; see Table 61). These analytical results suggest that PCN do not occur in relevant amounts in filter dust and salt slag from the production of secondary aluminium (on the basis of two random samples). This indicates that PCN should not play a relevant role in wastes from the secondary aluminium industry.

5.3.4 Discussion of the laboratory analyses results (PCP)

In the course of the research project seven material samples in total were analysed regarding their PCP content (see Table 61). PCP could be detected in all samples in relatively small concentrations. The measured PCP contaminations of some of the individual samples scattered strongly. The highest PCP contents were measured in old special textiles (samples 36 and 37 PCP). In all cases, the PCP contents of waste wood range significantly below the concentration threshold defined for PCP in AltholzV (3 mg/kg).

Figure 58: Results of the laboratory analyses (PCP)



Key to colours: samples of impregnated wood displayed in blue, textiles in red

Wood

PCP is currently neither produced nor used in Germany. PCP was primarily used for the preservation of wood and buildings. Owing to the long lifetime of impregnated wooden products especially in the construction sector, it has to be assumed that PCP impregnated woods will continue to arise as waste and will have to be treated/disposed of in the future. In Germany, PCP still poses problems in connection with the recycling of construction wastes and has been identified sporadically over the recent years in the scope of documentation and verification. Regarding contaminated waste streams several analytical results can be obtained from the analyses database ABANDA. ABANDA confirms that the contamination in wastes can be several 1,000 mg/kg. However, it cannot be excluded that those are relatively old analytical results (e.g. early 90s), as ABANDA does not indicate the years in which individual analyses were performed. In consultation with the UBA it was therefore decided to analyse a total of five samples of waste wood and chipboard regarding PCP (samples 31, 32, 33, 34c and 35 PCP).

AltholzV defines a limit value of 3 mg PCP/kg dry matter for wood chips and shavings for the production of wooden materials. Operators of waste wood processing plants are obliged to comply with this limit value. An important application field for wood chips and shavings is the production of chipboard. Although the limit value for PCP is clearly defined, it cannot generally be excluded that PCP might also occur in higher concentrations in recycled timber products. In consultation with the UBA it was therefore decided to investigate this matter on the basis of a random sample (large chipboard with waste wood fraction).

The detected PCP concentrations in waste wood lie in the range of ~0.04 – 0.4 mg/kg (see Figure 56, samples 31, 32, 35 and 34c PCP), therefore ranging significantly below the assumed average concentration of 625 mg/kg for impregnated and air-dried wood. In the analysed chipboard a PCP concentration of ~0.03 mg/kg was detected (sample 33 PCP). In all cases, the PCP contamination lies significantly below the concentration threshold defined for PCP in AltholzV (3 mg/kg).

Special textiles

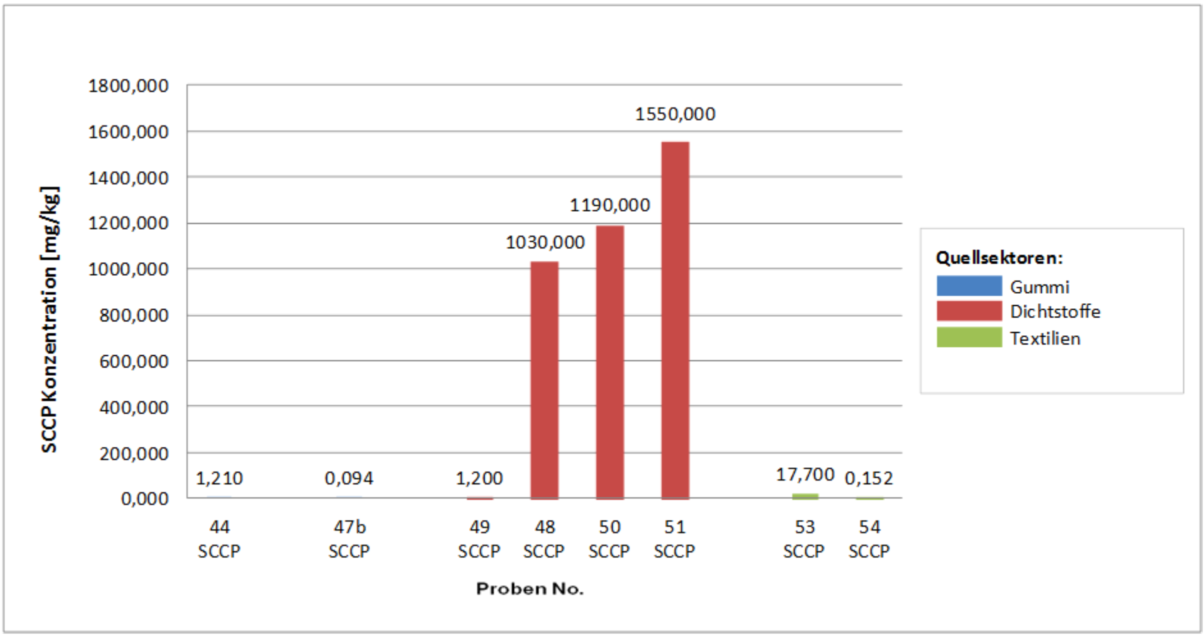
PCPL was used in textile industry for the treatment of special textiles. In 2000, PCPL production ceased in the entire EU. However, PCPL was imported into the EU for two more years after the production stop and used mainly in Great Britain and France. In contrast to the European situation, due to an early regulation of PCP and PCPL in Germany, it can be assumed that no considerable waste amounts are affected nowadays. Relevant waste amounts rather have to be expected in countries where PCPL were permissible to be used until 2008 (Spain, Portugal, France and Great Britain). In Germany, especially durable textile products could still play a role. In consultation with the UBA it was therefore decided to analyse two random samples of special textiles for military purposes regarding PCP.

The highest PCP content amounts to 3.7 mg/kg (sample 37 PCP) and was detected in a special textile (military air mattress from mid/late 80s). In a further special textile designed for military purposes (military poncho from mid/late 80s), the second largest PCP contamination of 0.844 mg/kg (sample 36 PCP) was detected. Yet a targeted use of PCP can be largely excluded for both special textiles, since significantly higher PCP concentrations would be required in order to be effective (~2.5 %). Moreover, no large amounts of textiles remaining from the military have to be expected in Germany. The Military Science Institute for Materials and Supplies (original designation in German: Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe), which is responsible for the textiles of the Military of Germany, confirmed that currently no PCP-containing textiles exist in the stocks of the Military. Those textiles were sorted out directly after the ban on PCP.

5.3.5 Discussion of the laboratory analyses results (SCCP)

In the course of the research project, a total of eight samples from three sources of origin (rubber, sealants and special textiles) were analysed regarding their SCCP content. The highest SCCP concentrations were detected in joint sealants from C&D waste (samples 48, 50 and 51 SCCP).

Figure 59: Results of the laboratory analyses (SCCP)



Key to colours: rubber samples displayed in blue, sealants in red, textiles in green

Rubber conveyor belts

Due to their flame retardant properties, SCCP are especially used in rubber conveyor belts for underground mining. To this end, they are incorporated as additive flame retardant into the rubber mixture in a proportion of about 10%. In 2013, an estimated 1,760 t rubber waste arose in Germany from SCCP-containing conveyor belts. Specific information concerning the processing and disposal of used conveyor belts from underground mining is not available. Taking into consideration the information gathered in telephone calls with rubber recycling companies, it is assumed that the rubber fraction of used conveyor belts is treated/disposed of together with other rubber waste in Germany. A large share of the rubber waste is directed to material recovery (e.g. production or granules) in Germany. During the recovery it cannot generally be excluded that SCCP are transferred into recyclates. In consultation with the UBA it was therefore decided to analyse two rubber samples (used rubber conveyor belt and granules from used conveyor belts) regarding SCCP.

The small SCCP concentration of the analysed rubber conveyor belt (sample 44SCCP) indicates that the random sample was not obtained from an SCCP-containing conveyor belt. As to the analysed granules from used rubber conveyor belts (sample 47b SCCP), it can be excluded as well that SCCP-containing rubber was recovered in the production of the granules. In the course of the project, several well-known producers of conveyor belts, mining companies and rubber recycling companies were contacted. There was little willingness to contribute information and samples for the project. As the use of SCCP for the treatment of rubber conveyor belts is still permissible and as relevant waste amounts arise annually in Germany and have to be treated/disposed of, it cannot generally be excluded that SCCP might be transferred into recyclates. Since no further relevant samples could be gathered, no final statement can be made concerning the relevance of this sector. In order to assess the relevance of this sector in Germany regarding the occurrence of SCCP, samples from rubber conveyor belts for the use in underground mining or corresponding granules would have to be analysed.

Sealants and adhesives

SCCP are used as softeners, in order to impart to the product the necessary hardness and elasticity. Moreover, they are efficient flame retardants. The application fields are polymers as polyacrylates, polyurethanes and polysulfide sealants in construction industry and car manufacturing as well as joint sealants. SCCP are used in this field as substitute for PCB. SCCP are used in proportions of about 5-14% in sealants and adhesives. However, higher concentrations are possible as well (>20%). In order to estimate the relevant waste arisings, an average SCCP concentration of 20% was assumed. An examination of joint sealants in Switzerland revealed that one third of a total of 44 analysed samples contained chlorinated paraffins. SCCP were the most common [BUWAL 2003]. In consultation with the UBA it was therefore decided to analyse four samples of joint sealants from construction waste processing facilities regarding SCCP.

Three of the four analysed joint sealants have SCCP contents above 1,000 ppm (samples 48, 50 and 51 SCCP). In one joint sealant a significantly lower SCCP concentration of 1.2 ppm was detected (sample 49 SCCP). As partly relatively high concentrations of MCCP were detected in the samples (as compared with SCCP), influences of MCCP cannot be excluded (see also [BUWAL 2003]). The analysed samples could also be MCCP-containing sealants, which have an SCCP share of about 0.5-1%. In case the joint sealants were treated with SCCP exclusively, the concentrations should be significantly higher (at least 5%).

Textiles

In the textile industry, highly chlorinated SCCP did not only serve as flame retardants, but also for the manufacture of water-repellent and rot-proof products. Chlorinated paraffins were traditionally used in the treatment of military tents. In Germany, SCCP are no longer used for flame resistant textiles. [TEGEWA 2013] confirms that their members have stopped the use of SCCP since the end of the 90s, probably even earlier. In Germany, especially durable textile products (e.g. from military remaining stocks) could still play a role. It was therefore decided to analyse two special textiles from military purposes regarding SCCP.

In a special textile designed for military purposes (pilot's cap from mid/late 80s), an SCCP concentration of 17.7 ppm (sample 53 SCCP) and in the military poncho which had also been analysed on PCP an SCCP concentration of 0.152 ppm was detected (sample 54 SCCP). A targeted use of SCCP can be largely excluded for both special textiles, since significantly higher SCCP concentrations would be required in order to be effective (~20 %).

Table 65: Results of the laboratory analyses

Substance	Sector of origin	Sample No.	Description	Content [mg/kg]	Detection limit
HBCD	**EPS/XPS construction sector**		**PS-E insulation material and/or PS-E-contaminated waste fractions and recyclates from PS-E insulation material (from construction waste processing facilities)**		
		1	Containing PS-E insulation material (grinded XPS from insulation materials from the construction sector, which is used for the production of recyclates)	23,500.000	15 mg/kg
		2	Waste from construction waste processing facility, containing PS-E insulation material (grinded EPS from insulation materials from the construction sector)	3,470.000	1.5 mg/kg
		5	Recyclate from PS-E insulation material (granules from recycled PS)	18,700.000	15 mg/kg
HBCD	**EPS/XPS other**		**PS-E packaging waste and recyclates (recyclate from PS-E packaging material)**		
		8	PS-E packaging waste (EPS-mixed fraction; packaging waste)	0.165	0.00015 mg/kg
		9	PS-E packaging waste (grinded packaging material)	42.000	1.5 mg/kg
		10	Recyclate from PS-E packaging and insulation material (granules from recycled PS)	4,410.000	1.5 mg/kg
		11	PS-E packaging waste (packaging chips)	9.670	1.7 mg/kg
		12	Recyclate from PS-E packaging and insulation material (granules from recycled PS)	1,550.000	1.5 mg/kg
		12 b	Recyclate from PS-E packaging	9.820	0.00015 mg/kg
HBCD	**WEEE (HIPS)**		**Brominated waste stream from waste electrical and electronic equipment (WEEE)**		
		13	Brominated waste from WEEE	2.900	0.00015 mg/kg
		13 b	PS recyclate from WEEE	184.000	1.5 mg/kg
HCBD	**Chlorine chemistry**		**Incineration residues (slag) from production facilities TRI, TETRA or PER**		
		14	Slag facility A batch 1	< 0.00887	n.r.
		15	Slag facility A batch 2	< 0.00924	n.r.
HCBD	**Waste water treatment**		**Sewage sludge (from randomly selected municipal waste water treatment plant)**		
		16	Sewage sludge (municipal waste water treatment)	< 0.00054	n.r.

Substance	Sector of origin	Sample No.	Description	Content [mg/kg]	Detection limit
HCBD/ PCN	**Incineration of municipal waste**		**Waste from municipal waste incineration MWI (slag, boiler ash, filter ash, solid residues from flue gas scrubbing)**		
HCBD		18	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	< 0.00987	n.r.
PCN		18	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	< 0.00494	n.r.
HCBD		19	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	< 0.00982	n.r.
PCN		19	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	< 0.00491	n.r.
HCBD		20	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	< 0.00962	n.r.
PCN		20	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	< 0.00481	n.r.
HCBD		21	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	< 0.0094	n.r.
PCN		21	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	< 0.0047	n.r.
HCBD		22	Filter ash MWI, facility B (mixed sample from 4 vessels over the time period of the 3rd Quarter 2013)	< 0.00892	n.r.
PCN		22	Filter ash MWI, facility B (mixed sample from 4 vessels over the time period of the 3rd Quarter 2013)	< 0.00446	n.r.
HCBD/ PCN	**Incineration of hazardous waste**		**Filter ash (hazardous waste incineration HWI)**		
HCBD		23	Filter dust HWI facility 1	< 0.00937	n.r.
PCN		23	Filter dust HWI facility 1	< 0.00469	n.r.
HCBD		24	Filter dust HWI facility 2	< 0.00983	n.r.
PCN		24	Filter dust HWI facility 2	< 0.00492	n.r.
PCN	**Production of secondary Al**		**Filter dust and salt slag (production of secondary aluminium)**		
		26	Filter dust sec. Al facility	< 0.00471	n.r.
		28	Salt slag sec. Al facility	< 0.00503	n.r.
PCP	**Wood impregnation**		**Waste wood and recycled chipboard**		
		31	Impregnated waste wood (waste wood category IV, shredded, mostly railway sleepers)	0.041	1 µg/kg
		32	Impregnated waste wood (wood from exterior use; fence type "Jägerzaun", ca. 35 years)	0.073	1 µg/kg
		33	Recycled chipboard (large chipboard, produced in Germany)	0.031	1 µg/kg

Substance	Sector of origin	Sample No.	Description	Content [mg/kg]	Detection limit
		34c	Chipboard (from waste wood processing facility)	0.064	1 µg/kg
		35	Impregnated waste wood (wood poles from exterior use, probably in contact with soil)	0.401	1 µg/kg
PCP	**Textiles**		**Special textiles (water- and weather-resistant)**		
		36	Special textile A (military poncho from mid/late 80s)	0.844	1 µg/kg
		37	Special textile B (textile covered military air mattress from mid/late 80s)	3.700	100 µg/kg
SCCP	**Rubber industry**		**Used rubber conveyor belt from mining industry and granules from used conveyor belts**		
		44	Used rubber conveyor belt from mining industry	1.210	250 µg/kg
		47b	Granules from used conveyor belts	0.094	25 µg/kg
SCCP	**Sealants and adhesives**		**Joint sealants (C&D wastes)**		
		48	Joint sealant A	1,030.000	250,000 µg/kg
		49	Joint sealant B	1.200	250 µg/kg
		50	Joint sealant C	1,190.000	250,000 µg/kg
		51	Joint sealant D	1,550.000	250,000 µg/kg
SCCP	**Textiles**		**Special textiles (flame retarded)**		
		53	Special textile A (pilot’s cap from mid/late 80s)	17.700	2,500 µg/kg
		54	Special textile B (military poncho from mid/late 80s)	0.152	25 µg/kg

6 Risk assessment

6.1 Overview of relevant sectors

Based on the substance and mass flows as well as additional information concerning the occurrence in products and waste, Table 62 demonstrates in which sectors the substances/substance groups typically occur and may cause relevant risks.

Table 66: Overview of POPs, relevant sectors and corresponding amounts in products, waste and emissions (in Germany in 2012); highlighted sectors are considered in the risk assessment

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
Expanded Polystyrene (EPS) for construction	HBCD	Until 2015 high relevance in products and in the future for many decades in waste due to long lifetimes (ca. 161 t HBCD/y in 2012; ca. 960 t HBCD/y around 2050)	n.r.	1,708	161
Extruded Polystyrene (XPS) for construction	HBCD	Until 2015 high relevance in products and in the future for many decades in waste due to long lifetimes (ca. 41 t HBCD/y in 2012; ca. 460 t HBCD/y around 2050)	n.r.	979	41
EPS/XPS other than construction	HBCD	At present no longer relevant in products; also in waste no longer relevant due to limited lifetime of products (used mostly in packaging) with continuously decreasing relevance (ca. 0.4 t HBCD/y in 2012)	n.r.	0	0.4
High Impact Polystyrene (HIPS) for electrical and electronic devices	HBCD	At present no longer relevant in products; former use in electronic devices; in comparison to EPS/XPS minor relevance in waste (ca. 70 t/y in 2012 with continuously decreasing relevance). Imports might play a certain role for waste.	n.r.	0	70
Polymer dispersions for textiles	HBCD	Since 2007 no longer relevant in products; until then use in the institutional sector (venues) and automotive sector; due to lifetime and amounts of consumption in Germany minor relevance in waste (ca. 290 t/y in 2012 with continuously decreasing relevance)	n.r.	0	290
Sewage sludge	HBCD	Not relevant	n.r.	n.r.	0.1

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
Incineration residues waste incineration	HBCD	Not relevant	n.r.	n.r.	0.01
Products from historical applications	HCBD	Not relevant	n.r.	n.r.	n.r.
Unintentional production – Production of chlorinated solvents	HCBD	Not relevant; analytical results indicate that in Germany HCBD does not occur in relevant amounts in incineration residues from incineration of the production residues of chlorinated solvents	n.r.	n.r.	n.r.
Unintentional production – Incineration processes waste	HCBD	Not relevant; analytical results indicate that in Germany HCBD does not occur in relevant amounts in incineration residues from incineration of municipal waste	n.r.	n.r.	n.r.
Unintentional production – Production of plastics	HCBD	Not relevant	n.r.	n.r.	n.r.
Sewage sludge	HCBD	Not relevant; analytical results indicate that in Germany HCBD does not occur in relevant amounts in municipal sludge	n.r.	n.r.	n.r.
Former use in various sectors	PCN	Not relevant	n.r.	n.r.	n.r.
Electronics industry	PCN	Not relevant; occurrence in former PCB applications possible; not relevant in quantity	n.r.	n.r.	n.r.
Waste incineration	PCN	Not relevant; confirmed by analytical results	n.r.	n.r.	n.r.
Secondary copper production	PCN	Possibly relevant; Samples for investigation on estimation could not be obtained			
Secondary aluminium production	PCN	Not relevant; analytical results indicate that PCN play no relevant role in waste of secondary aluminium industry	n.r.	n.r.	n.r.
Chlor-alkali electrolysis	PCN	Not relevant	n.r.	n.r.	n.r.
Wood impregnation	PCP	Relevant in waste and possibly also in recyclates	n.r.	n.r.	140
Textile industry	PCP	In comparison to wood impregnation of minor relevance (durable textile products for military purposes might still play a role)	n.r.	n.r.	‹‹
Substances from metal and leather treatment	SCCP	Not relevant	n.r.	n.r.	n.r.

Potential sector of origin	Substance	Estimated relevance in the project context	Emission (t/y)	Product (t/y)	Waste (t/y)
Rubber industry	SCCP	Relevant in products, waste and possibly also in recyclates	n.r.	26	176
Sealants and adhesives	SCCP	Relevant in products and waste	n.r.	38	66
Paints and lacquers	SCCP	Not relevant	n.r.	n.r.	n.r.
Textile industry	SCCP	Durable textile products for military purposes might still play a role	n.r.	n.r.	‹‹
Leather industry	SCCP	Not relevant	n.r.	n.r.	n.r.
PVC and other polymeric materials	SCCP	Not relevant	n.r.	n.r.	n.r.
Special papers	SCCP	Not relevant	n.r.	n.r.	n.r.
Secondary source (sewage sludge)	SCCP	Not relevant	n.r.	n.r.	n.r.

6.2 Risk assessment

In the risk assessment, especially the following questions are considered:

- Are disposal and recovery operations (D9, D10, R1, R4), permitted according to Annex V, part 1, appropriate to destroy or irreversibly transform the relevant substances/substance groups?
- Can the corresponding processes lead to an unintended generation of new POPs?
- Can disposal or recovery cause a risk to human health or the environment (i.e. a relevant exposure of humans or the environment)? The emission of significant amounts of POPs into the environment is generally considered a risk.

Further information on the methodology and environmental and health impacts is provided in sections 2.4.3.6 and 7.3.2.2.

Table 67: Overview of POPs, relevant sectors and possible risks

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
HBCD	EPS and XPS insulation panels	‹ 2.6 t/a (‹ 2.1 t/a EPS; ‹0.5 t/a XPS)	Recycling	In general, insulation panels from construction waste are not recycled, according to information from the insulation material industry. A comparatively small amount of HBCD is recycled in EPS/XPS insulation materials, which are not separated from the rest of the building rubble (max. 2.6 t, but possibly significantly less), together with other polymeric materials. POPs are usually neither destroyed nor generated in the recycling processes. Presumably small HBCD concentrations are preserved in the recyclates for long periods and involve the risk of a further transfer of the HBCD content into various plastic products, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected. The risk can be minimised by separating EPS/XPS insulation materials to the largest extent possible in construction and destruction and by treating them in an appropriate way. During construction and destruction works, where EPS/XPS insulation panels are handled, dust generation should be avoided. It might be reasonable to apply personal protection measures, in order to avoid potential inhalation of HBCD-containing dust. Apparently in practice, cutting losses of insulation materials are also mixed and recycled with packaging waste. Thus, waste which is not contaminated or contains only minor amounts of HBCD (PS-E packaging waste), is mixed with HBCD-containing waste (PS-E insulation material waste) and severely contaminated recycled PS granules are generated in the consequence. The relevance of such mixtures in practice is unknown. This practice entails the risk of a further transfer of the HBCD content into various plastic products, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. A specific health or environmental risk due to the exceeding of critical environmental con-

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				centrations ((P)NEC) or exposure limits (TDI) is not expected. The risk can be minimised through separate treatment of EPS/XPS insulation materials and EPS packaging waste.
		~ 200 t/a	Energy recovery	In general, EPS/XPS insulation materials are recovered in waste incineration plants which allow the recovery of their energy content.
			Incineration	A maximum share of 2% EPS and XPS insulation panels in a mixture with other waste can be appropriately treated in state-of-the-art waste incineration plants. The incineration process largely destroys HBCD (destruction rate for incineration in incineration plants ›99.99%) and does not contribute to the generation of other POPs. Crucial for a professional incineration is the expert mixture in the bunker of the plant. For a share of 1 percent by weight (corresponding to about 15 percent by volume) the customary insulation panels can be handled without any problems in the incineration process. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected. During the product lifetime, nearly 100% of the HBCD content remains in the insulation panels. During construction and demolition works, where EPS/XPS insulation panels are handled as well as during the handling of the boards for recovery and disposal, dust could be generated and cause an exposure via inhalation. In order to minimise environmental and especially health risks, dust generation should be avoided and it might be reasonable to apply personal protection measures (breathing masks), in order to avoid potential inhalation of HBCD-containing dust.
		‹ 0.4 t/a	Landfill	Landfilling happens unintentionally and in small amounts (max. 0.4 t/a) through adhesions in mineral building rubble. HBCD is preserved, a generation of other POPs does not occur. Specific health or environmental risks are not expected due to small HBCD concentrations. Separation of impurities from the mineral fraction to the largest extent possible can minimise the effect of transfer and global distribution.
		Not relevant	Temporary storage	n.r.

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
HBCD	HIPS electronic devices	ca. 0.13 t/a	Recycling	The typical HIPS products usually arise in WEEE, with a share of 7.5% being recycled. For the waste treatment, the plastics from WEEE are usually dismantled by hand or treated mechanically in shredders. The shredding process is performed by large metal shredders or in specific shredders for the treatment of individual WEEE categories. In the manual disassembly, individual plastic components can be detached by hand. Shredding processes are often combined with automatic sorting processes. In individual cases, HIPS from WEEE treatment are used in order to produce PS recyclates. The analytical results for a PS recyclate from WEEE confirm a considerable HBCD content of 184 mg/kg in the recyclate. During those processes, POPs are usually neither destroyed nor generated. Contained HBCD is preserved and entails the risk of a further transfer of the HBCD content into various plastic products, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is possible in case the shredding processes lead to the emission of HBCD-containing dust into the environment or to the exposure of workers via inhalation. This assumption is also supported by a current study of the Austrian Federal Environment Agency (see [UBA AT 2014]): „HBCDD is recommended for restriction under RoHS as a risk for the environment is expected from both shredding of WEEE and recycling of HBCDD-containing HIPS from WEEE “and „Workers are expected to be at risk in facilities where HBCDD-containing plastic parts from WEEE are recycled.“ The risk can be minimised by separating brominated plastics from WEEE to the largest extent possible, as already stipulated in Directive 2012/19/EU. As not all brominated plastics are separated in practice, it has to be assumed that HBCD is transferred into recyclates. A relevant part of the used electronic equipment is exported from Germany. Adequate disposal or recovery leading to the destruction of the POP content is not necessarily ensured in the countries of destination. The disposal of WEEE in the recipient countries and the global distribution cause risks to human health and the environment. Those risks can be minimised by a restriction of corresponding exports to countries, where appropriate recov-

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				ery and disposal of WEEE are ensured.
		ca. 1.57 t/a	Energy recovery Incineration	The bulk of the plastics from WEEE (ca. 90%) are directed to energy recovery. It can be assumed that HBCD-containing waste can be incinerated in state-of-the-art waste incineration plants in such a way, that the HBCD content is largely destroyed and that the risk of other POPs being generated in relevant amounts is kept at a minimum (see [BiPRO 2011], section 9.7 and [PlasticsEurope 2014]). A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		ca. 0.043 t/a	Landfill	A minor share (ca. 2.5%) of the plastics from WEEE is landfilled. HBCD is preserved, a generation of other POPs does not occur. Specific health or environmental risks cannot be excluded and are represented in the long run especially due to the risk of uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised through the separation of HBCD-containing plastics to the largest extent possible and through their appropriate disposal.
		n.r.	Temporary storage	n.r.
	Textiles	‹ 75 t/a	Recycling	A considerable share of ca. 26% of the flame retarded textiles (especially in the recovery of end-of-life vehicles) is recycled. During those processes, POPs are normally neither destroyed nor generated. Contained HBCD is preserved and entails the risk of a further transfer of the HBCD content, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		› 215 t/a	Energy recov-	The bulk of the flame retarded textiles (ca. 74%) is directed to energy recovery.

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
			ery	It can be assumed that HBCD-containing waste can be incinerated in state-of-the-art waste incineration plants in such a way, that the HBCD content is largely destroyed and that the risk of other POPs being generated in relevant amounts is kept at a minimum (see [BiPRO 2011], section 9.7 and [PlasticsEurope 2014]). A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		ca. 0.7 t/a	Landfill	A minor share (ca. 0.25%) of the flame retarded textiles is landfilled. HBCD is preserved, a generation of other POPs does not occur. Specific health or environmental risks cannot be excluded and are represented in the long run especially due to the risk of uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised through the separation of HBCD-containing textiles to the largest extent possible and through their appropriate disposal.
HCBD		n.r.	Recycling	n.r.
		n.r.	Energy recovery	State-of-the-art incineration reaches destruction rates of more than 99.9% (see BiPRO 2011])
		n.r.	Incineration	
		n.r.	Landfill	n.r.
		n.r.	Temporary storage	n.r.
PCN		n.r.	Recycling	n.r.
		n.r.	Energy recovery	State-of-the-art incineration reaches destruction rates between 99.32 and 99.96% (see [BiPRO 2011])
		n.r.	Incineration	
		n.r.	Landfill	n.r.

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
		n.r.	Temporary storage	n.r.
PCP	Wood impregnation (impregnated waste wood)	Small amount	Recycling	In Germany, waste wood is assigned to the waste wood categories AI-AIV according to AltholzV, depending on their contamination with pollutants. Waste wood treated with wood conserving agents is assigned to waste wood category AIV and has to be treated/disposed of in a corresponding way. The recovery of waste wood classified as waste wood of category AIV as wood chips and shavings for the production of wood based materials is not permitted in Germany, according to AltholzV. However in practice, parts of impregnated wood can be disseminated into other waste wood categories and submitted to material recovery. AltholzV determines that wood chips and shavings processed for the production of wood based materials may not exceed the limit values for specific elements/compounds which are listed in Annex II. A limit value of 3 mg PCP/kg dry matter was determined for PCP. In order to ensure the compliance with those values, the operator of the waste wood processing plant is obliged by AltholzV to procure and analytically examine regular samples. In the following, wood chips or shavings may only be supplied to the production of wood based materials if the tests and examinations do not indicate contamination with creosote or exceeding of the limit values listed in Annex II of AltholzV (3 mg/kg). If these tests and examinations reveal a contamination or the exceeding of one of the limit values, the sampled batch has to be assigned to waste wood category AIV. In the course of this research project, a sample (large chipboard with waste wood fraction) was analytically examined on PCP. In this chipboard, a PCP concentration of ~0.03 mg/kg was measured. Hence the contamination lies significantly below the concentration threshold of 3 mg/kg determined in AltholzV. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		126.0	Energy recovery	Only waste wood of categories AI and AII is permissible for the incineration in small firing installations which do not require licensing pursuant to the Federal Immission Control Act

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
		7.0	Incineration	(original title in German: Bundesimmisionsschutzgesetz), with waste wood assigned to waste wood category AII only being permissible for firing installations with a nominal heat output of 30 kW or more and only in companies of the wood processing industry. Waste wood treated with wood preservatives and waste wood with coatings which contain halogenated organic compounds or heavy metals, may only be treated in installations meeting the requirements defined in the Seventeenth Ordinance for the Implementation of the German Federal Immission Control Act (17.BImSchV). Due to high incineration temperatures in energy recovery/incineration (›800°C) it can be assumed that the PCP content in waste wood is almost completely destroyed. Hence, in order to guarantee a high destruction rate, the incineration temperature should reach at least 800 °C. Destruction rates of ›99.9% are reported for those temperatures (see [BiPRO 2011]). Under controlled incineration conditions, the generation of new POPs can be excluded [BiPRO 2011]. A minor environmental and health risk remains, in case PCP-containing waste wood has to be broken down mechanically before energy recovery/incineration, as dust can be generated in the handling of contaminated waste wood. In order to minimise environmental and especially health risks, dust generation should be avoided and it might be reasonable to apply personal protection measures (breathing masks), in order to avoid potential inhalation of PCP-containing dust.
		-	Landfill	The AltholzV restricts waste wood disposal on thermal disposal. Landfilling of waste wood is not permitted in Germany.
		7.0	Recovery (without energy recovery)	A comparatively small amount of PCP-containing waste wood is recovered (without energy recovery). The recovery operations permitted in Germany for waste wood of waste wood category IV are the production of synthesis gas for further chemical purposes as well as the production of activated carbon/industrial charcoal (installations licensed pursuant to §4 of the German Federal Immission Control Act/BImSchG). The corresponding processes reach similar process temperatures as energy recovery/incineration. Therefore, it can be assumed that the PCP content in the waste wood is

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				destroyed. However corresponding destruction rates are not known. There is also no information available on potential generation of new POPs resulting from the above mentioned processes. A potential health or environmental risk has to be expected in case PCP-containing waste wood has to be broken down mechanically (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.
SCCP	Rubber (rubber conveyor belts for the use in underground mining)	109.0	Recycling	In Germany, rubber from used rubber conveyor belts is directed to material recovery (e.g. production of granules for further purposes). In this context, it cannot generally be excluded that SCCP might also be released into recyclates (e.g. rubber floorings for halls, playgrounds etc.). In the absence of specific information on the disposal and processing of used rubber conveyor belts from underground mining, and under consideration of the information gathered in telephone calls with rubber recycling companies, it is assumed that the relevant rubber waste from used conveyor belts is treated/disposed of together with other rubber waste in Germany. A large share of the rubber waste is directed to material recovery (~62%) in Germany. During those recycling processes, POPs are usually neither destroyed nor generated. Therefore there is a specific risk that SCCP might be released into recyclates (e.g. floorings for halls, playgrounds etc.). Relatively small concentrations of the SCCP are preserved in the recyclates, respectively in various rubber products, for long periods, resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised through separation of SCCP-containing conveyor belts from underground mining as far as possible and through the choice of appropriate treatment operations. Moreover, a further environmental and health risk before the actual recovery cannot be excluded. The recovery is only possible for minor amounts of non-dangerous, small metal impurities. Larger metal components would damage the shredders and mills. Hence, the

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				metal fraction of the conveyor belt has to be separated from the rubber fraction as far as possible. This can result in dust generation and therefore presents a potential environmental and health risk. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.
		65.0	Energy recovery	SCCP are thermally decomposed at only 200 °C [BiPRO 2011]. Due to high incineration temperatures in energy recovery/incineration (›800°C), it can be assumed that the SCCP content in used rubber conveyor belts is almost completely destroyed. However, exact destruction rates for SCCP have not been identified. There is also no information available on potential generation of new POPs resulting from energy recovery/incineration processes. A potential health or environmental risk has to be expected in case SCCP-containing rubber waste has to be broken down mechanically prior to energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.
		2.0	Incineration	
		-	Landfill	n.r.
SCCP	sealants (for the use in the construction sector)	41.4	Recycling	In the absence of exact information on treatment/disposal of sealants and due to their properties it is assumed, that a considerable share of the sealants and adhesives applied in the construction sector adheres to the surface of the construction materials (especially on concrete, tiles, bricks and ceramics) and is treated together with those types of waste. Hence in practice, it is not expected that the sealants can be separated completely and treated separately. It is assumed that about 2/3 of the SCCP-containing waste stream are treated/disposed of together with other construction waste. 1/3 of the relevant waste stream is separated successfully and is subsequently disposed of in hazardous waste incineration plants. About 54 million tonnes of concrete, tiles, bricks and ceramic wastes were treated/disposed of in Germany in 2011, ca. 51 million tonnes of which being directed to material recovery.

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				During those recycling processes, POPs are usually neither destroyed nor generated. Therefore there is a specific risk that SCCP might be released into recyclates and therefore into various products. Relatively small SCCP concentrations are preserved for long periods in various products used in the construction industry, resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. However, due to the mixture, the expected SCCP concentration in the products would be negligible. The risk can be minimised through separation of SCCP-containing sealants as far as possible. However, complete separation is not feasible in practice, especially due to their properties. In case the sealants and adhesives can be separated successfully, it can be assumed that they are disposed of thermally (e.g. suspected PCB-containing joint sealants have to be collected separately and directed to hazardous waste incineration).
		Small amounts	Energy recovery	Out of the 2/3 of the SCCP-containing waste stream, which is treated/disposed of together with other construction waste, only a very small share is submitted to energy recovery and/or is incinerated. Due to high incineration temperatures (>800°C) it can be assumed that the SCCP content of the waste is almost completely destroyed, as SCCP are decomposed at only 200°C. However, the exact destruction rates have not been identified. There is also no information available on potential generation of new POPs resulting from energy recovery/incineration processes. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		Small amounts	Incineration	
		22.0	Hazardous waste incineration	In practice, it is not expected that SCCP-containing sealants can be separated completely and treated separately (due to adhesion to the surface of the construction materials). Hence it is assumed that about 1/3 of the SCCP-containing waste stream can be separated successfully and can subsequently be disposed of in hazardous waste incineration plants. Due to high incineration temperatures (>1,000°C) it can be assumed that the SCCP content in the waste is almost completely destroyed. However, the exact destruction rates for SCCP

POPs	Sector	Amount of substance (in t/a or qualitatively)	Treatment operation	Possible risks regarding the POP content
				have not been identified. There is also no information available on potential generation of new POPs resulting from energy recovery/incineration processes. A specific health or environmental risk due to the exceeding of critical environmental concentrations ((P)NEC) or exposure limits (TDI) is not expected.
		0.2	Treatment for disposal	It is not completely clear, which disposal operations are applied in Germany. The release of SCCP into the environment cannot be excluded in general. Moreover, health risks cannot be excluded. In order to minimise the risks, dust generation in the treatment processes should be minimised as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.
		2.5	Landfill	In general, landfilling involves the risk that the persistent substance could be released from the landfill site into the environment. Under the presumption that the SCCP-containing waste stream is treated together with concrete, tiles, bricks and ceramic waste, the mixed waste stream would be relatively extensive, while the theoretical SCCP concentration would be negligible. SCCP are preserved, a generation of new POPs does not occur. Due to the minor SCCP concentration no specific environmental or health risks have to be expected. Separation to the largest extent possible can minimise the effect of transfer and global distribution.

Table 64 explains the different sectors/activities identified in the scope of the risk analysis, which can possibly give rise to risks concerning the relevant substances/substance groups:

Table 68: Overview of possible risks

Sector	Possible risk	Potential risk minimisation
EPS/XPS construction	General risk due to the high amounts of HBCD in EPS/XPS insulation materials as well as high amounts of waste; Mixing of insulation materials and packaging waste in combination with recycling → risk of transfer and uncontrolled global distribution.	Separate treatment of EPS/XPS insulation materials and EPS packaging waste.
EPS/XPS construction	In construction and demolition works as well as in the handling of EPS/XPS insulation panels for recovery and disposal, dust could be generated and lead to exposure via inhalation.	Avoid dust generation, possibly personal protection measures in order to avoid inhalation.
EPS/XPS construction	Unintentional landfilling of small amounts adhering to mineral construction waste → risk of transfer and uncontrolled global distribution.	Separation of impurities from the mineral fraction of the construction waste as far as possible.
HIPS electronic devices	Recycling of HIPS from WEEE→ risk of transfer and uncontrolled global distribution; Shredding of WEEE → possible emission of HBCD-containing dust into the environment or exposure of workers via inhalation cannot be excluded.	Separation of brominated plastics from WEEE as far as possible as stipulated in Regulation 2012/19/EU
HIPS electronic devices	Export of old electronic devices → possible risks in other countries.	Restriction of corresponding exports to countries where adequate recovery and disposal are ensured.
PCN in the production of secondary copper	Production residues might possibly contain PCN (unclear) → risks.	n.a.
PCP in waste wood	Environmental or health risks may arise if PCP-containing waste wood is broken down mechanically (dust generation → exposure via inhalation).	Avoid dust generation, possibly personal protection measures in order to avoid inhalation.
SCCP in rubber conveyor belts (underground mining)	Recycling of rubber from rubber conveyor belts for underground mining → Risk of SCCP being released into recyclates (e.g. floorings for halls, playgrounds etc.) → SCCP are preserved in recyclates or in various rubber products, resulting in uncontrolled global distribution. Environmental and health risk before the actual recovery → recovery is only possible for minor amounts of small, non-dangerous metal impuri-	Separation of SCCP-containing conveyor belts from underground mining as far as possible and choice of appropriate treatment operations. Avoid dust generation as far as possible. Avoid inhalation of contaminated dust through the use of breathing masks.

	ties (larger metal components would damage the shredders and mills). Hence, the metal fraction of the conveyor belt has to be separated from the rubber fraction as far as possible (dust generation → exposure via inhalation)	
SCCP in sealants (construction industry)	There is a risk that SCCP might be released into recyclates and therefore into various products → SCCP are preserved in various products used in the construction industry, resulting in uncontrolled global distribution (due to the mixture, the expected SCCP concentration would be negligible). Landfilling of SCCP-containing sealants → Persistent substance will be released from the landfill site into the environment in the long run (however, due to the mixture, the expected SCCP concentration would be negligible).	Separation to the largest extent possible can minimise the effect of transfer and global distribution (complete separation is not feasible in practice). When removing sealants from buildings, fast running machines should not be used in order to avoid heat generation.

7 Scenarios, prognoses and evaluation of the limitation criteria

7.1 Scenarios for realistic limit values and their effects on treatment operations

7.1.1 Scenarios for HBCD

Using typical HBCD concentrations of the relevant waste fractions and product categories (see Table 30) as well as the waste amounts which arose within the individual applications during the reference year 2012 (cf. material flows in section 0), different scenarios of the concerned waste amounts for possible low POP concentration limits can be derived.

Under the presumption that flame retarded textiles from the automotive sector are disposed of and recovered together with the total shredder light fraction arising in Germany, a possible limit value of 364 ppm is the consequence. For a limit value of less than 364 ppm, consequently the entire shredder light fraction (~400 kt/a) would be affected, as well as > 95% of the EPS and XPS waste amounts each (21.9 kt/a and 2.6 kt/a respectively), which were separated (total: 424.5 kt/a).

Assuming that the waste amounts arising from the product category HIPS are disposed of and recovered along with the total plastic waste fraction from the electronics sector, a further possible limit value of 290 ppm can be derived. Below this limit value, consequently the entire plastic waste fraction from the electronics sector would be concerned (241 kt/a) in addition to the aforementioned 424.5 kt/a, resulting in a theoretically concerned waste amount of 665.6 kt/a in total.

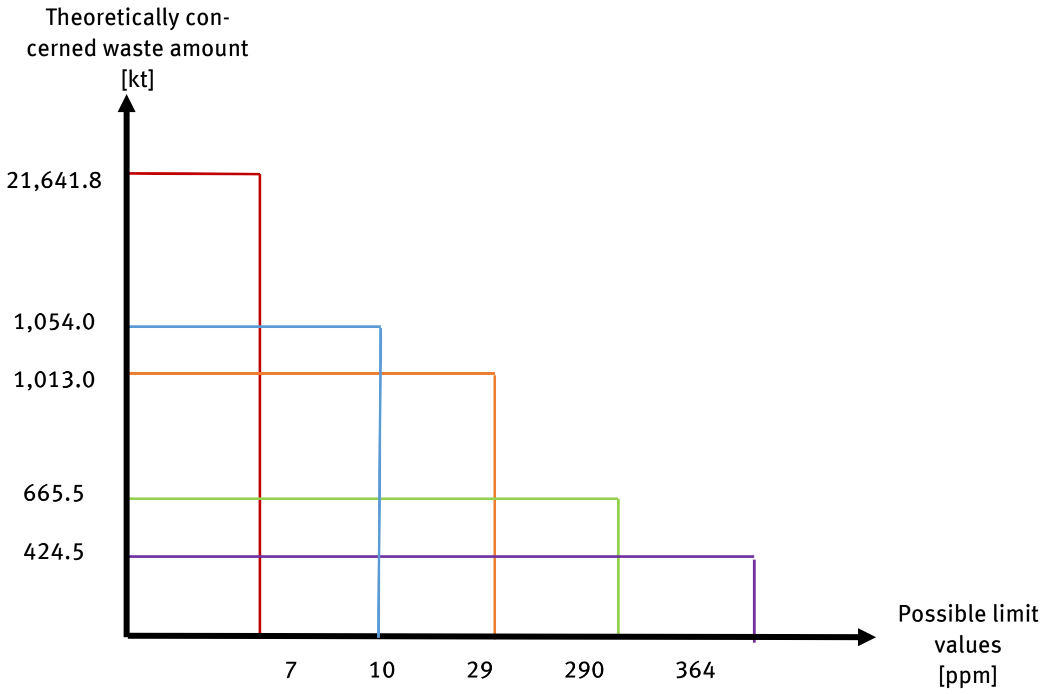
With the premise that a share of the EPS and XPS waste from the construction sector (< 5%) are disposed of and recovered together with the other plastic waste from the construction sector, a further possible limit value of 29 ppm can be derived. Below this limit value, the total plastic waste arising from the construction sector (372.0 kt/a) and the waste amounts of the total plastic waste fraction from the electronics sector (241 kt/a) as well as the total shredder light fraction arising in Germany (400.0 kt/a) would be affected (total: 1,013.0 kt/a).

As illustrated in section 3.2.8.3, it is assumed that at present, HBCD is used exclusively in the construction sector and that therefore no relevant waste amounts arise in other sectors. However, the analysis results indicate that the average HBCD contamination of packaging waste might amount to about 10 mg/kg. Assuming that the arising amount of packaging waste is approximately equivalent to the produced amount (41 kt in 2011), these quantities have to be considered in a further scenario. Hence, for a possible limit value of 10 ppm, an additional 41 kt/a of waste would be concerned in addition to the aforementioned 1,103.0 kt/a (total: 1,054.0 kt/a).

Another possible limit value of 7 ppm results supposing that flame retarded textiles from the institutional sector are disposed of and recovered along with the total amount of bulky waste and mixed municipal waste arisen in Germany (20,587.8 kt). For this limit value, a theoretically concerned waste amount of 21,641.8 kt/a in total would be the consequence.

Figure 58 graphically illustrates the theoretically concerned waste amounts within each of the different scenarios.

Figure 60: Scenarios for realistic low POP concentration limits (HBCD)



Possible low POP concentration limits also entrain modifications in the waste treatment. Thus, where applicable, waste exceeding a possible low POP concentration limit has to be directed to an alternative treatment operation. For instance, certain wastes can no longer be recycled or landfilled, but have to be directed exclusively to thermal recovery/disposal.

Table 65 represents in detail the concerned waste streams for different possible low POP concentration limits explained in the text above. Moreover, it lists the HBCD-containing waste streams which theoretically would have to be directed to alternative treatment operations.

Table 69: Possible low POP concentration limits and their effects on the present treatment operations (HBCD)

Possible low POP concentration limits [ppm]	7	10	29	290	364
Concerned waste streams for different low POP concentration limits					
EPS construction [kt/a]	372.0	372.0	372.0	21.9	21.9
XPS construction [kt/a]				2.6	2.6
EPS/XPS apart from construction	41.0	41.0	-	-	-
HIPS [kt/a]	241.0	241.0	241.0	241.0	-
PD [kt/a]	20,987.8	400.0	400.0	400.0	400.0
Total [kt/a]	**21,641.8**	**1054.0**	**1013.0**	**665.5**	**424.5**
Concerned waste streams which theoretically would have to be treated alternatively for different low POP concentration limits					
EPS construction [kt/a]	103.6	103.6	103.6	0	0
XPS construction [kt/a]				0	0
EPS/XPS apart from construction	17.3	17.3	-	-	-

HIPS [kt/a]	24.1	24.1	24.1	24.1	-
PD [kt/a]	2,228.0	169.2	169.2	169.2	169.2
Total [kt/a]	**2372.9**	**314.2**	**296.9**	**193.3**	**169.2**

At a possible low POP concentration limit of 364 ppm, in total 169.2 kt/a would have to be treated alternatively. This amount results from the large proportion directed to material recovery (42.3%) regarding the total shredder light fraction arisen in Germany. Thus, a possible low POP concentration limit of 364 ppm would mean that 169.2 kt/a would have to be thermally recovered/disposed, instead of being recycled as hitherto.

A possible low POP concentration limit of 290 ppm would affect a waste amount of 193.3 kt/a in total, which would then have to be treated alternatively. Besides the 169.2 kt/a of flame retarded textiles from the automotive sector (shredder light fraction), an additional 10% of the waste amounts of the total plastic waste fraction from the electronics sector (24.1 kt) would have to be directed to thermal recovery/disposal.

For a possible low POP concentration limit of 29 ppm, an additional 103.6 kt/a of EPS and XPS construction waste would have to be treated alternatively, which at present is recycled or landfilled as assumed (total: 296.9 kt/a).

A possible low POP concentration limit of 10 ppm would mean that a total of 314.2 kt/a would have to be directed to an alternative waste management operation. In addition to the aforementioned 296.9 kt/a, a further 17.3 kt/a EPS packaging waste would have to be treated alternatively, which hitherto has been directed to substance and material recovery or which has been landfilled.

The highest waste amount to be treated alternatively and amounting to 2,372.9 kt/a would result from a possible low POP limit value of 7 ppm. This enormous increase in volume results on the condition that flame retarded textiles from the institutional sector are disposed of and recovered along with the total amount of bulky waste and mixed municipal waste.

7.1.2 Scenarios for HCBD

As outlined in section 3.3, there is no specific information indicating relevant HCBD concentrations in certain waste fractions or products in Germany. On that account, scenarios of the concerned waste amounts for possible low POP concentration limits cannot be elaborated. In all probability, an LPCL would not concern any relevant waste fractions or recyclates.

7.1.3 Scenarios for PCN

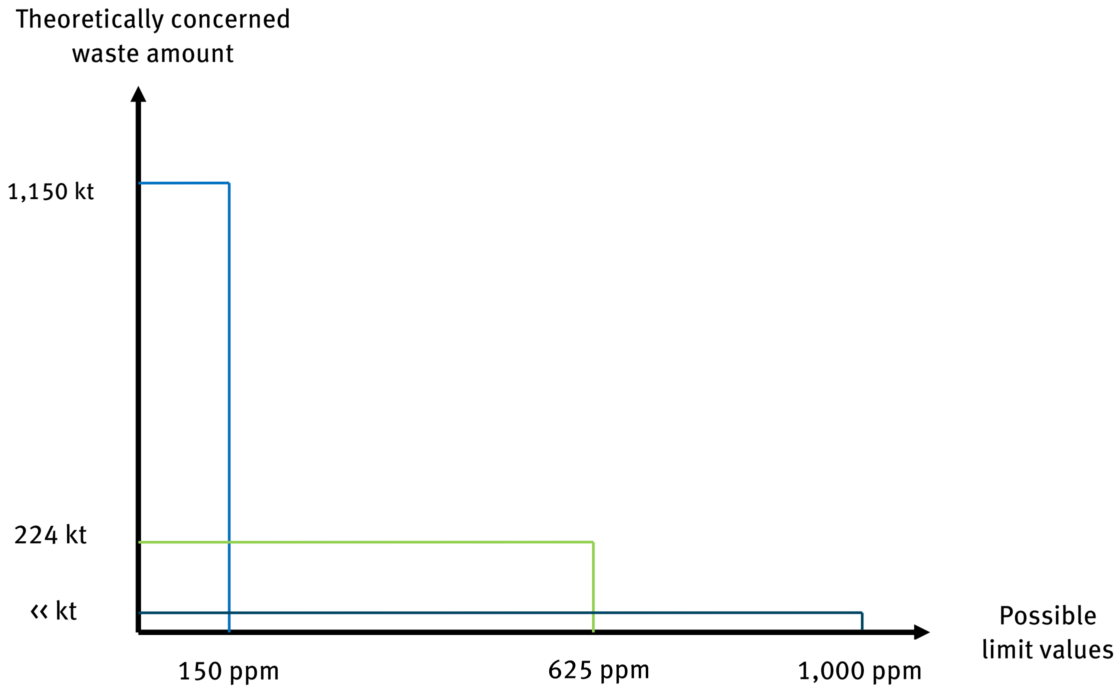
As outlined in section 3.4, there is no specific information indicating relevant PCN concentrations in certain waste fractions or products in Germany. On that account, scenarios of the concerned waste amounts for possible low POP concentration limits cannot be elaborated. In all probability, an LPCL would not concern any relevant waste fractions or recyclates.

However it cannot be entirely excluded that waste from the production of secondary copper might contain relevant amounts of PCN (see section 3.4.7).

7.1.4 Scenarios for PCP

The uppermost wood layers can contain PCP-contents of several 1,000 ppm. [BiPRO 2011] estimates that the average PCP concentration in impregnated and air-dried woods amounts to 625 ppm. Assuming that the PCP-containing waste stream is treated along with other hazardous waste wood, the PCP contamination of the mixed waste stream diminishes to approximately 150 ppm. Hence, at a possible POP limit value of 1,000 ppm, only a minor amount of waste wood would be concerned (maximum concentrations in the 1,000 ppm range). At a limit value below 625 ppm, theoretically about 224 kt of waste wood would be affected. In case the low POP concentration limit is set below 150 ppm, a considerably larger waste amount would be concerned (total amount of the waste wood categorised as hazardous in Germany: 1,150 kt) (see Figure 59).

Figure 61: Scenarios for realistic low POP concentration limits (PCP)



For all treatment operations currently used in Germany, an environmental hazard can be largely excluded. Approximately 95% of the relevant waste stream are already recovered and/or disposed of thermally. A low POP concentration limit of 150 ppm or less would exclusively affect a relatively small waste stream, which is recovered at present (ca. 5%). However, relevant PCP emissions can also be largely excluded in the recovery operations permissible in Germany (production of synthesis gas for further use and production of activated carbon). At limit values above 150 ppm, theoretically no waste would have to be treated alternatively (see Table 66).

Table 70: Possible low POP concentration limits and their effects on the present treatment operations (PCP)

Possible low POP concentration limits	150 ppm	625 ppm	1,000 ppm
Concerned waste streams for different low POP concentration limits			
Hazardous waste wood (except PCP impregnated waste wood); [kt/a]	926	0	0
PCP impregnated waste wood [kt/a]	224	224*	‹‹
Total [kt/a]	1,150	224	‹‹
Concerned waste streams which theoretically would have to be treated alternatively for different low POP concentration limits			
Total [kt/a]	57.7	0	0

* PCP-contaminated waste stream successfully separated and treated separately (rather unlikely in practice)

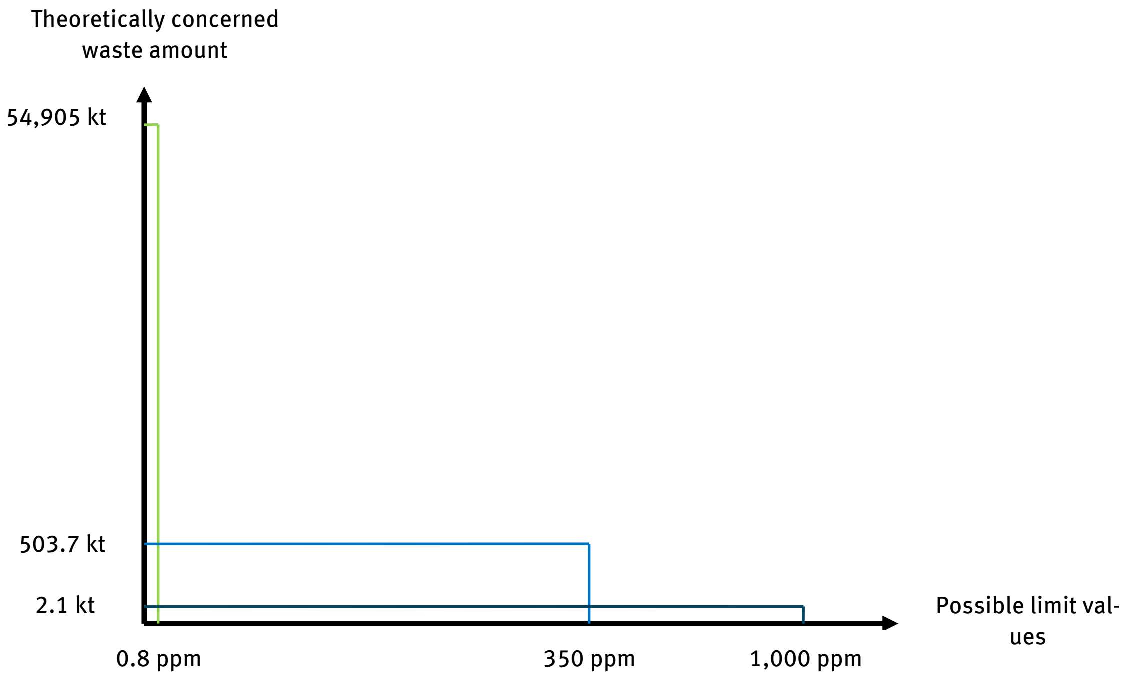
7.1.5 Scenarios for SCCP

The average SCCP concentration in rubber conveyor belts for the use in underground mining amounts to 3.3%, and to ca. 10% (100,000 ppm) in the corresponding rubber fraction of the conveyor belts. In the absence of more precise information concerning the processing and disposal of used rubber conveyor belts and under consideration of the information gathered in telephone calls with rubber recyclers, it is assumed that the rubber fraction of the conveyor belts is treated/disposed of together with other rubber wastes. Under this presumption, the theoretical SCCP concentration of the total waste stream decreases significantly to ca. 350 ppm.

The average SCCP concentration in joint sealants for the construction sector amounts to 20% (200,000 ppm). It is assumed that especially due to their properties, a major proportion of the applied sealants adheres to the surface of the construction materials (e.g. on concrete, tiles, bricks and ceramics) and is treated together with this waste. In the absence of more precise information, it is assumed that about 2/3 (~220 t) of the SCCP-containing waste stream is treated along with the other construction and demolition waste and that ca. 1/3 (~110 t) of the relevant waste stream is disposed of separately in hazardous waste incineration plants. For the separately treated waste it can be assumed that the considerable SCCP content (200,000 ppm) is almost completely destroyed due to high incineration temperatures (>1,000°C).

At a possible low POP concentration limit of 1,000 ppm theoretically only the SCCP-contaminated waste streams would be concerned (~1,760 t rubber waste and ~330 t joint sealants). At a low POP concentration limit <350 ppm theoretically the total rubber waste in Germany would be affected (~503.4 kt). At a low POP concentration limit <0.8 ppm theoretically the total construction and demolition waste in Germany would be concerned (~54,905 kt) (see Figure 60).

Figure 62: Scenarios for realistic low POP concentration limits (SCCP)



A possible POP concentration limit <1,000 ppm would have no impact on the current waste treatment. Only at a low POP concentration limit of <350 ppm theoretically about 312 t SCCP-containing rubber waste would have to be treated alternatively. At a low POP concentration limit <0.8 ppm a considerably larger waste amount of 54.6 million t would be concerned (see Table 67).

Table 71: Possible low POP concentration limits and their effects on the present treatment operations (SCCP)

Possible low POP concentration limits	0.8 ppm	350 ppm	1,000 ppm
Concerned waste streams for different low POP concentration limits			
SCCP-containing rubber waste [kt/a]	1.8	1.8	1.8
SCCP-containing sealants and adhesives [kt/a]	0.3	0.3	0.3
Rubber waste [kt/a]	503.4*	503.4*	-
Concrete, tiles, bricks and ceramic waste [kt/a]	54,400*	-	-
Total [kt/a]	**54,905**	**503.7**	**2.1**
Concerned waste streams which theoretically would have to be treated alternatively for different low POP concentration limits			
Rubber waste (incl. SCCP-containing rubber waste) [kt/a]	312.1	312.1	0
Concrete, tiles, bricks and ceramic waste [kt/a]	54,317		0
Total [kt/a]	**54,629**	**312.1**	**0**

*SCCP-containing waste already included in the waste stream

7.2 Prognosis on future development

The prognoses are essentially based on the currently and historically applied amounts of the relevant substances/substance groups and on typical concentrations in relevant products and waste. The time span covered in the prognosis depends on the predictable time of use of the substances and on the relevant product life cycle time.

7.2.1 Prognosis for HBCD

For the prognosis on the future development of HBCD-containing waste amounts, historically applied HBCD amounts and amounts currently circulating in the economic cycle as well as the average product lifetimes and typical concentrations were taken into account (see Table 29). The results for all relevant application fields are outlined in the following and are presented in Table 68 below.

EPS/XPS products from the construction sector usually turn into waste only 25 to 75 years (lifetime 50 +/-25) after their use. As a result from the substitution of HBCD in EPS/XPS products in the construction sector, which started in early 2013, and due to the legal situation, the use is already declining and it can be expected that it will cease until autumn 2015. In the scope of the prognosis it was assumed, that by the year 2016, HBCD will no longer be used in EPS/XPS products in the construction sector in Germany. Moreover, available data on amounts of use according to [Dämmstoffindustrie 2013a] and [Dämmstoffindustrie 2013b] were taken into account for the calculations from the year 1966 onwards. About 660 t/a HBCD in EPS waste and 352 t/a in XPS waste from the construction sector will still arise in the year 2064. Clearly, the bulk of the HBCD-containing waste will arise in the future, resulting from applications in the construction sector with comparatively large amounts of use and very long product lifetimes. As a consequence, it is estimated that the annually arising HBCD amounts in EPS waste from the construction sector will increase until the year 2050 (960 t/a), before decreasing waste amounts will eventually result from the substitution already in process. Regarding HBCD in XPS waste from the construction sector, the waste amount in the prognosis reaches its peak in 2052 (468 t/a). The corresponding waste amount (EPS and XPS) is about 168 kt in total.

This corresponds to a 0.7% share of the currently available total capacity provided by plants for thermal waste treatment in Germany.

No specific information is available on the use of HBCD in HIPS for electronic equipment. However, it can be assumed that HBCD is no longer used in Germany for this purpose, although current use cannot be entirely excluded. Also imports of HIPS in electronic equipment cannot be excluded. However, in the absence of more detailed information on this issue, the quantitative prognosis is elaborated on the basis of former amounts of use in Germany for an average lifetime of 9 (+/-5) years. The result indicates that no relevant HBCD amounts in waste electronic equipment have to be expected after the year 2027.

HBCD has no longer been used in the textile industry since 2007. Based on previous amounts of use and a lifetime of 10 (+/-3) years, no relevant HBCD amounts in PD for textiles are expected to arise after the year 2022.

Application fields which are not related to the construction sector are regarded irrelevant, both currently and in the future. Those fields are mainly influenced by the packaging sector. It is assumed that this sector is of minor relevance for the input of HBCD into waste streams and that it will no longer be relevant in future waste streams. This assumption is made under the prerequisite that waste streams deriving from the packaging sector and the construction sector are kept separate, in order to avoid cross-contaminations from the construction sector.

Table 72: Estimated future annual arisings of HBCD in the relevant application fields (in tonnes)

Year	EPS for construction	XPS for construction	HIPS for electronic equipment	Polymer dispersions for textiles
2014	195	51	73.9	220.4
2015	213	57	75.2	171.0
2016	232	63	75.1	120.5
2017	252	70	73.1	75.9
2018	272	77	68.5	42.2
2019	294	85	60.8	20.4
2020	316	93	50.5	8.4
2021	339	101	38.6	2.8
2022	363	110	26.7	0.7
2023	388	120	16.6	
2024	413	130	9.2	
2025	439	141	4.5	
2026	465	153	1.9	
2027	492	165	0.7	
2028	519	177		
2029	547	190		
2030	575	204		
2031	603	218		
2032	631	232		
2033	658	247		

Year	EPS for construction	XPS for construction	HIPS for electronic equipment	Polymer dispersions for textiles
2034	686	262		
2035	713	277		
2036	740	293		
2037	766	308		
2038	792	324		
2039	816	339		
2040	839	355		
2041	861	369		
2042	881	384		
2043	899	397		
2044	915	410		
2045	929	422		
2046	941	433		
2047	950	443		
2048	957	451		
2049	960	457		
2050	960	463		
2051	958	466		
2052	952	468		
2053	943	467		
2054	931	465		
2055	915	461		
2056	897	456		
2057	875	448		
2058	851	439		
2059	824	427		
2060	795	415		
2061	764	401		
2062	731	385		
2063	696	369		
2064	660	352		

7.2.2 Prognosis for HCBD

As outlined in section 3.3, there is no specific information indicating relevant HCBD concentrations in certain waste fractions or products in Germany. Against the backdrop of the legal situation – also due to the expected inclusion of HCBD in the Stockholm Convention in addition to the EU POP Regulation – it is assumed that also in the future, HCBD will not occur in relevant amounts in waste and products in Germany.

7.2.3 Prognosis for PCN

As outlined in section 3.4, there is no specific information indicating relevant PCN concentrations in certain waste fractions or products in Germany. Against the backdrop of the legal situation – also due to the expected inclusion of PCN in the Stockholm Convention in addition to the EU POP Regulation – it is assumed that also in the future, PCN will not occur in relevant amounts in waste and products in Germany.

However, it cannot be entirely excluded that waste from the production of secondary copper might contain relevant amounts of PCN (see section 3.4.7).

7.2.4 Prognosis for PCP

At present, PCP is neither produced nor used in Germany. However, owing to the long lifetime of impregnated wooden products especially in the construction sector, it has to be assumed that PCP treated woods will continue to arise as waste and will have to be treated over the next years. For instance, PCP still poses problems in connection with the recycling of construction wastes. Furthermore, it was confirmed that PCP has occurred sporadically over the recent years in the scope of documentation and verification in Germany. Moreover, PCP was detected analytically in low concentrations in waste wood samples (~0.04 – 0.4 mg/kg) in the course of this research project.

The PCP amount in impregnated waste wood arisen in 2013 was estimated to ca. 140 t. This corresponds to a waste stream of approximately 224 kt. Since no new PCP inputs into the economic cycle have occurred in Germany for a long time, it is to be expected that the annual amounts of PCP arising will decrease continuously in the years to come. According to [BiPRO 2011], relevant waste amounts are theoretically to be expected in the EU until 2030. The same is assumed for Germany.

7.2.5 Prognosis for SCCP

SCCP production in Germany ceased in the mid-90s. Assuming that the estimated total SCCP consumption in the EU has remained constant and that the consumption is roughly proportional to the size of the population, the current SCCP consumption in Germany was roughly estimated to about 85 t. SCCP are used as flame retardants in rubber products. In 2013, an estimated 1,760 t of rubber arose as waste from SCCP-containing rubber conveyor belts. A second important application field of SCCP is in sealants for the construction industry. SCCP are used as softeners here, in order to impart to the product the necessary hardness and elasticity. In 2013, an estimated 330 t of SCCP-containing sealants turned into waste in Germany.

SCCP-containing rubber conveyor belts and sealants are permitted to be produced, placed on the market and used according to Annex I to the POP Regulation. However, the EU Commission proposes to adapt Annex I of the POP Regulation to technical progress, i.e. to delete the use of SCCP as flame retardant for rubber used in conveyor belts in the mining industry and the use as flame retardant in sealants from the Annex of the Regulation. Whether and how this will be realised is not certain yet. Thus, it is not possible to elaborate a prognosis on the future development of SCCP. In general it is expected that the annual amounts of contaminated waste will decrease continuously. A Dutch study („Evaluation of Possible Restrictions on Short Chain Chlorinated Paraffins“) which was submitted prior to the meeting of the competent authorities on 2 October 2013 in Brussels “Meeting of the Competent Authorities under Regulation EC 850/2004” shows that there are already appropriate alternatives available for both uses. Some companies have already managed to substitute SCCP successfully in their applications by alternative substances (mostly MCCP and LCCP).

7.3 Evaluation of lower and upper limitation criteria

7.3.1 Evaluation of the lower limitation criteria

7.3.1.1 (A) Analytical potential

The LPCL should be above the detection limit of analytical methods available at reasonable economic conditions (i.e. costs per analysis < 500€). The detection limits of analytical methods available at reasonable economic conditions are summarised in Table 69, based on the information presented in section 5.1.

Table 73: Detection limits of analytical methods available at reasonable economic conditions

Substance/substance group	Detection limits of analytical methods available at reasonable economic conditions (in mg/kg)
HBCD	1.0
HCBD	0.1
PCN	0.1
PCP	0.1
SCCP	1.0

7.3.1.2 (H) Background contamination

As outlined in the explanations on the methodology in section 2.4.3.2, limit values should be above existing environmental background contamination, in order to exclude the risk that excavated soil with a usual background contamination might enter into the POP waste regime. The derivation of limit values was carried out pursuing the following scheme:

Highest background contamination x uncertainty factor (10) = result for the limitation criterion “background contamination”.

The next higher decimal value of the highest background contamination reported serves as a basis for the background contamination. The LPCL should not fall short of this value.

HBCD

According to [BiPRO 2011], the existing background contamination level of HBCD in sediments in Europe lies below 0.01 mg/kg. However, in areas which are exposed to increased contaminations, due to their vicinity to point sources for instance, values of up to 0.071 mg/kg can be detected as well (Netherlands). Data on existing background contaminations in soils are lacking for Europe. In Asia, concentrations between 0.0017 and 0.0056 mg/kg were determined in soils. Specific values for sediments and soils in Germany are not available. For the evaluation of the lower limitation criteria, an initial value below 0.01 mg/kg is assumed for the background contamination of HBCD and an uncertainty factor of 10 is applied. This results in the value of 0.1 mg/kg.

For detailed information on existing background contaminations, including the consulted references, please refer to [BiPRO 2011, Tab. 6-68].

HCBD

According to [BiPRO 2011], most of the data on existing background contamination in sediments and soils exist for Canada and the United States, but also for Europe. The HCBD contamination in sediments amounts to about 0.001 mg/kg. The highest background contamination reported is indicated as 0.55 mg/kg, detected in the Great Lakes area in Canada. Different studies focusing on Germany identified concentrations of up to 0.005 mg/kg. For the evaluation of the lower limitation criteria, an initial value below 0.01 mg/kg is assumed for the background contamination of HCBD and an uncertainty factor of 10 is applied. This results in the value of 0.1 mg/kg.

For detailed information on existing background contaminations including the consulted references, please refer to [BiPRO 2011, Tab. 6-84].

PCN

The existing background contaminations in soils in Germany range up to 0.015 mg/kg, according to [BiPRO 2011]. The highest background contamination reported on an international level is a value of 8.64 mg/kg (Great Britain). For the evaluation of the lower limitation criteria, an initial value below 0.1 mg/kg is assumed for the background contamination of PCN and an uncertainty factor of 10 is applied. This results in the value of 1.0 mg/kg.

For detailed information on existing background contaminations including the consulted references, please refer to [BiPRO 2011, Tab. 6-93].

PCP

The background contamination levels for PCP presented in [BiPRO 2011] are mostly based on sediment monitoring in the North Sea and of rivers which flow into the North Sea. Accordingly, the background contamination ranges between 0.005 mg/kg and 0.03 mg/kg. The highest background contamination level reported for sediments in Germany is 0.042 mg/kg. In soils, levels of 0.0005 mg/kg (Germany) and of up to 4 mg/kg (Finland) can be detected [see BiPRO 2011, Tab. 6-78 and Tab. 6-79].

For the evaluation of the lower limitation criteria, an initial value of 0.1 mg/kg is assumed for the background contamination of PCP and an uncertainty factor of 10 is applied. This results in the value of 1.0 mg/kg.

SCCP

As outlined in [BiPRO 2011], the existing SCCP background contamination in sediments ranges from the detection limit to a maximum reported concentration level of 0.484 mg/kg (Japan). In Germany, concentrations reaching 0.083 mg/kg were measured [see BiPRO 2011, Tab. 6-47 and Tab. 6-48].

For the evaluation of the lower limitation criteria, an initial value of 0.1 mg/kg is assumed for the background contamination of SCCP and an uncertainty factor of 10 is applied. This results in the value of 1.0 mg/kg.

Table 70 presents a summary of the results elaborated for the criterion “background contamination”:

Table 74: Overview of the results for limitation criterion H

Substance	Highest reported background contamination in Germany (if available) [mg/kg]	Background contamination [mg/kg]	Uncertainty factor	Result [mg/kg]
HBCD	‹0.01[58]	‹0.01	10	0.1
HCBD	0.005[59]	‹0.01	10	0.1
PCN	0.015[60]	‹0.1	10	1.0

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[58] Typical existing background contamination in sediments in Europe

[59] Highest international background contamination reported: 0.55 mg/kg (Canada)

[60] Highest international background contamination reported: 8.64 mg/kg (Great Britain)

PCP	0.042[61]	<0.1	10	1.0
SCCP	0.083[62]	<0.1	10	1.0

7.3.1.3 (BV) Disposal and recovery capacities

The criterion „disposal and recovery capacities" assesses whether (new) required capacities for recovery and disposal are realistically available for different possible low POP concentration limits (cf. section 2.4.3.3). Possible low POP concentration limits might implicate considerable changes in waste treatment, as some wastes will not be permissible for recycling or landfilling anymore, but will inevitably have to be directed to energy recovery/thermal disposal facilities. This proceeding guarantees that the POP content is destroyed or irreversibly transformed without undue delay. Based on those scenarios and the elaborated material flows (cf. section 3) it is subsequently assessed whether sufficient treatment capacities are available for changed waste treatment operations.

According to the BMU[63], 95% of the capacity of municipal waste incineration plants was utilised in Germany in 2009. In 2010, 87.7% of the total capacity of the German waste incineration plants and hazardous waste incineration plants were utilised[64]. Thus, for the derivation of a proposed limit value, an additional increase of up to 5% of the currently required capacities of the relevant thermal waste treatment sites is considered justifiable.

The required capacities in relation to every substance/substance group are calculated via a comparison of the changes in the required thermal treatment capacities resulting from different possible low POP concentration limits with the total treatment capacities available in Germany (change in % = quantity change of the current state for possible low POP concentration limit/total capacity).

The following Table 71 initially gives an overview of the capacities of thermal waste treatment plants available in Germany according to [DESTATIS 2013b]. Only those incineration plants are presented which are considered relevant for the types of waste taken into account in the scope of this project.

Table 75: Overview of the capacities available in Germany for the thermal treatment of relevant wastes in 2010[65] (Source: [DESTATIS 2013b])

Type of facility	Number	Total input [million t/a]	Total nominal load [million t/a]
Waste incineration plants	94	20.56	23.07
Hazardous waste incineration plants	35	1.40	1.97

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[61] Highest international background contamination reported: 4 mg/kg (Finland)

[62] Highest international background contamination reported: 0.484 mg/kg (Japan)

[63] The BMU (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit) is the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

[64] Calculation based on [DESTATIS 2013b]

[65] Sewage sludge incineration plants (nominal load 2.05 million t/a) and other plants for thermal treatment (nominal load 0.44million t/a) are not taken into account

HBCD

In order to assess the potential consequences of different low POP concentration limits on existing or possibly required additional capacities, the current treatment paths for all relevant application fields were taken into account. Referring to the material flows as presented in section 0, the following total amounts for recovery and disposal of the considered HBCD-containing wastes can be derived:

Thermal treatment (D10 or R1)	19,268.9 kt/a (~89%),
Landfill	123 kt/a (~0.6%),
Recycling (including mechanical and feedstock recycling)	2,249.9 kt/a (~10.4%).

Table 72 shows the composition of the indicated amounts (total: 21,641.8 kt/a) for the assumed current treatment:

Table 76: Overview of the composition of the total amounts for current recovery and disposal operations of HBCD-containing waste

Waste identification	Amount (t/a)	HBCD concentration (mg/kg)
Thermal treatment (D10 or R1)		
separated EPS waste	21,899.6	7,000
separated XPS waste	2,608.4	15,000
EPS and XPS waste treated together with total plastic waste fraction from the construction sector	243,939	29
EPS/XPS waste from sectors other than construction (in general EPS packaging)	23,698	10
HIPS treated together with total plastic waste fraction from the electronics sector	216,900	290
HBCD flame retarded textiles from the automotive sector treated together with the total shredder light fraction arisen in Germany	230,800	364
flame retarded textiles from the institutional sector treated together with the total amount of bulky waste and mixed municipal waste arisen in Germany	18,529,020	7
Landfilling		
EPS and XPS waste treated together with total plastic waste fraction from the construction sector	13,900	29
EPS/XPS waste from sectors other than construction (in general EPS packaging)	164	10
HIPS treated together with total plastic waste fraction from the electronics sector	6,025	290
flame retarded textiles from the institutional sector treated together with the total amount of bulky waste and mixed municipal waste arisen in Germany	102,939	7
Recycling		
EPS and XPS waste treated together with total plastic waste fraction from the construction sector	89,653	29
EPS/XPS waste from sectors other than construction (in general EPS packaging)	17,138	10

Waste identification	Amount (t/a)	HBCD concentration (mg/kg)
HIPS treated together with total plastic waste fraction from the electronics sector	18,075	290
HBCD flame retarded textiles from the automotive sector treated together with the total shredder light fraction arisen in Germany	169,200	364
flame retarded textiles from the institutional sector treated together with the total amount of bulky waste and mixed municipal waste arisen in Germany	1,955,841	7

In Table 73 following further below in the report, this current state of the waste treatment is regarded as a starting point and compared with the state at specific low POP concentration limits, with the resulting changes being calculated (in kt and as a percentage, referring to the current total amounts for thermal treatment, landfilling and recycling).

At a possible low POP concentration limit below 364 ppm, a total of 169.2 kt/a of HBCD-containing waste would be concerned, requiring additional thermal treatment capacities. This amount results from the HBCD flame retarded textiles recycled so far, derived from the automotive sector, which are treated along with the total shredder light fraction arising in Germany. The required treatment capacities for the recycling of those wastes would diminish accordingly.

A possible low POP concentration limit below 290 ppm would give rise to the requirement of additional thermal treatment capacities for 24.1 kt/a HBCD-containing HIPS (18.1 kt/a of which have been recycled and 6 kt/a of which have been landfilled so far) treated together with the total plastic waste fraction from the electronics sector, in addition to the above mentioned 169.2 kt/a.

At a possible low POP concentration limit of 29 ppm, changed treatment paths as compared to the current state would be the consequence for EPS and XPS wastes, which are currently treated together with the total waste fraction from the construction sector as assumed. Along with the aforementioned affected amounts the required thermal capacity would increase and the required capacities for recycling and landfilling would decrease accordingly.

At a possible low POP concentration limit below 10 ppm only slight changes would result in comparison to the limit value of 29 ppm, caused by modified treatment paths for EPS/XPS wastes from sectors other than the construction sector (EPS packaging waste). A slightly increased required thermal capacity will then be compensated by the reduced required capacities for landfilling and recycling.

The most significant changes, compared to the current situation, would result from a possible low POP concentration limit of less than 7 ppm. At this limit value, waste of all relevant application areas would have to be exclusively directed to thermal treatment. Therefore, the required thermal capacity would rise to 21,641.8 kt/a. Both, for landfilling and recycling no capacities whatsoever would be needed at this limit value.

Table 77: Overview of quantitative changes in recovery and treatment operations, depending on possible low POP concentration limits (HBCD)

HBCD	Current state [kt/a]	State at specific POP concentration limit [kt/a]	Change in [kt]	Change in [%]
		364 ppm		
Thermal treatment (D10 or R1)	19,268.9	19,438.1	+ 169.2	+ 0.9

Landfilling	123.0	123.0	0	0
Recycling	2,249.9	2,080.7	- 169.2	- 7.5
290 ppm				
Thermal treatment (D10 or R1)	19,268.9	19,462.2	+ 193.3	+ 1.0
Landfilling	123.0	117.0	- 6,0	- 4.9
Recycling	2,249.9	2,062.6	- 187.3	- 8.3
29 ppm				
Thermal treatment (D10 or R1)	19,268.9	19,565.7	+ 296.9	+ 1.5
Landfilling	123.0	103.1	- 19.9	- 16.2
Recycling	2,249.9	1,973.0	- 276.9	- 12.3
10 ppm				
Thermal treatment (D10 or R1)	19,268.9	19,583.0	+ 314.2	+ 1.6
Landfilling	123.0	102.9	- 20.1	- 16.3
Recycling	2,249.9	1,955.8	- 294.1	- 13.1
7 ppm				
Thermal treatment (D10 or R1)	19,268.9	21,641.8	+ 2,372.9	+ 12.3
Landfilling	123.0	0	- 123.0	- 100.0
Recycling	2,249.9	0	- 2,249.9	- 100.0

The derivation of a proposed limit value is performed via a comparison of the total capacity of the relevant waste treatment plants available in Germany (25,033 kt/a, cf. Table 71) with the changes in thermally treated waste amounts presented in Table 73, which vary with the low POP concentration limit. Table 74 presents the results and shows the percentage changes resulting for each possible low POP concentration limit, based on the total capacities.

Table 78: Changes as compared with the total capacity of the relevant thermal waste treatment plants in Germany, depending on possible LPCL for HBCD

Possible low POP concentration limit [ppm]	Additionally required thermal capacities [kt]	Change as compared with existing total capacity of relevant thermal waste treatment plants in Germany [%]
364	+ 169.2	+ 0.68
290	+ 193.3	+ 0.77
29	+ 296.9	+ 1.19
10	+ 314.2	+ 1.25
7	+ 2,372.9	+ 9.48

As an additional increase of up to 5% of the currently required thermal treatment capacities is considered feasible, the concentration limit for HBCD should, in any case, lie above 7 ppm. It is proposed to set a concentration limit of 10 ppm.

HCBD

Due to the information based on performed research and analysis results and presented in section 3.3, it can be assumed that HCBD does not occur in relevant amounts in products, waste and recyclates in Germany. Thus possible LPCL will have no relevant effects on disposal and recovery capacities. Therefore, the LPCL can be set arbitrarily low regarding these capacities.

PCN

Due to the information based on performed research and analysis results and presented in section 3.4, it can be assumed that PCN do not occur in relevant amounts in products, waste and recyclates in Germany. Thus possible LPCL will have no relevant effects on disposal and recovery capacities. Therefore, the LPCL can be set arbitrarily low regarding these capacities.

However, it cannot be excluded that waste from the production of secondary copper might contain relevant amounts of PCN. Until this issue is clarified, effects of possible LPCL on recovery and disposal capacities cannot be conclusively assessed.

PCP

AltholzV regulates the recovery and disposal of waste wood in Germany. Waste wood is classified in different waste wood categories, depending on the content of contaminants, and has to be treated accordingly. It is assumed that PCP-contaminated waste wood is recovered/disposed of together with other waste wood classified as hazardous (PCP mixed concentration of the waste stream ~ 150 ppm). Approximately 95% of the waste woods classified as hazardous are currently recovered/disposed of thermally in Germany. The remaining 5% are used for the production of synthesis gas and activated carbon.

At limit values above 150 ppm theoretically no waste would have to be treated alternatively. At a low POP concentration limit of 150 ppm, approximately 57.5 kt/a of waste wood, which is currently used for the production of synthesis gas and activated carbon, would have to be directed to incineration and/or energy recovery (see Table 75).

As it is assumed that the PCP content in the waste is almost completely destroyed during the recovery operations (similarly high process temperatures as during thermal disposal/recovery), an alternative treatment of the concerned waste stream may not be required. However, if the waste is to be recovered/disposed of thermally nevertheless, sufficient incineration capacities are available in Germany. The concerned 57.7 kt correspond to approximately 0.23% of the nominal load of the waste incineration plants and hazardous waste incineration plants available in Germany. Therefore, the LPCL can be set arbitrarily low.

Table 79: Changes in treatment operations at specific POP limit values (PCP)

PCP	Current state [kt/a]	State at specific POP concentration limit [kt/a]	Change in [kt]	Change in [%]
150 ppm				
Incineration (D10)	57.5	>57.5	+57.5	5
Energy recovery (R1)	1,035	>1,035		
Recovery (Production of synthesis gas and activated carbon)	57.5	0	-57.5	-100

SCCP

The waste streams relevant in Germany are SCCP-containing rubber wastes from conveyor belts for the use in underground mining and SCCP-containing sealants from construction and demolition wastes. Assuming that the SCCP-containing rubber waste is disposed of/recovered together with other rubber waste, the SCCP concentration of the total waste stream decreases to about 350 ppm. In Germany, approximately 62% (312.1 kt/a) of this waste is currently directed to material recovery facilities (production of granulates for further use), about 186.2 kt/a (~37%) to energy recovery and a comparably low waste amount is currently incinerated (~5 kt/a; 1%). It can be assumed that the SCCP content in the rubber is almost completely destroyed during energy recovery and incineration processes. During material recovery processes, it cannot be excluded that SCCP might be released into recyclates. At a low POP concentration limit of 350 ppm, theoretically ~312.1 kt/a of rubber waste, which is recovered at present, would have to be incinerated additionally and/or would have to be directed to energy recovery (see Table 76). Those 312.1 kt/a correspond to ~1.25% of the nominal load (waste incineration plants and hazardous waste incineration plants) available in Germany and therefore should not pose any capacity problems.

Currently an estimated 0.33 kt/a SCCP-containing sealants and adhesives turn into waste in Germany. It is assumed that around 1/3 of the waste (~0.11 kt/a) can be separated successfully and disposed of separately in hazardous waste incineration plants. The remaining 2/3 of the waste stream (~0.22 t/a) are assumed to adhere to construction and demolition waste (e.g. concrete, tiles, bricks and ceramics) owing to their properties and to be recovered and disposed of together with those wastes. Due to the large amounts of construction and demolition waste arising each year (ca. 54 million tonnes), the SCCP concentration in the mixed waste stream declines to about 0.8 ppm. It can be assumed that the high SCCP content of the separated waste fraction is almost completely destroyed due to high incineration temperatures (>1,000 °C). This is also the case for the waste fraction which undergoes energy recovery or incineration together with other construction and demolition waste. However, in the scope of material recovery and landfilling of the waste it cannot be excluded that SCCP might be released into recyclates and into the environment. The theoretically concerned waste amount, which would have to be treated alternatively at a possible concentration limit of 0.8 ppm, would be considerable (>54 million t) (see Table 76). In order to avoid required alternative treatment for a major share of the arising construction and demolition wastes, the limit value should be set above 0.8 ppm.

Table 80: Changes in treatment operations at specific POP limit values (SCCP)

SCCP	Current state [kt/a]	State at specific POP concentration limit [kt/a]	Change in [kt]	Change in [%]
		350 ppm		
Landfilling	3,000	3,000	0	0
Underground disposal	0	0	0	0
Hazardous waste incineration	0.11	0.11	0	0
Incineration (D10)	7.21	508.94	+312.1	+58.6
Energy recovery (R1)	189.52			
Material recovery	51,412	51,100	-312.1	-0.6
		0.8 ppm		
Landfilling	3,000	0	-3,000	-100

Hazardous waste incineration	0.11	0.11	0	0
Underground disposal	0	54,609	+54,412	››
Incineration (D10)	7.21			
Energy recovery (R1)	189.52			
Material recovery	51,412	0	-51,412	-100

Table 77 gives an overview on the evaluation of the disposal and recovery operations.

Table 81: Overview of the results for limitation criterion E

Substance	Result of the evaluation for criterion E [mg/kg]	Comment
HBCD	10	The limit value should lie above 7 mg/kg
HCBD	0.1	The limit value can be set arbitrarily low
PCN	0.1	The limit value can be set arbitrarily low
PCP	0.1	The limit value can be set arbitrarily low (max. concerned waste amount which would have to be treated alternatively arises for limit values below 150 mg/kg)
SCCP	1	The limit value should lie above 0.8 mg/kg

7.3.1.4 (W) Economic feasibility

Criterion W assesses the economic impacts of changed treatment costs which accompany possible low POP concentration limits. Based on an analysis of the possible treatment options, the changes in costs for future modified disposal and recovery paths were estimated (e.g. changes in costs when a certain type of waste may no longer be landfilled but has to be incinerated). Table 6 from section 2.4.3.4 serves as a starting point for the calculation of changes in costs.

The objective in the choice of a possible limit value was to ensure economically reasonable disposal costs.

HBCD

In order to assess the changes in treatment costs for HBCD-containing waste, at first current waste treatment costs were elaborated based on the results of Table 6 (treatment costs per tonne of waste) and Table 73 (quantitative changes in recovery and treatment operations). Based on the current treatment costs, besides total costs at possible low POP concentration limits also additional costs arising (changes as compared with the current state) were calculated. Table 78 gives an overview of the results:

Table 82: Economic impacts at possible LPCL (HBCD)

HBCD	Current costs [million €/a]	Costs at a specific POP concentration limit [million €/a]	Change [million €/a]
364 ppm			
Thermal treatment	3,257.7	3,304.5	+ 28.8
Landfilling	17.2	17.2	0
Recycling	90.0	83.2	- 6.8

Total	3,382.9	3,404.9	+ 22.0
290 ppm			
Thermal treatment	3,257.7	3,308.6	+ 32.9
Landfilling	17.2	16.4	- 0.8
Recycling	90.0	82.5	- 7.5
Total	3,382.9	3,407.5	+ 24.5
29 ppm			
Thermal treatment	3,257.7	3,326.2	50.5
Landfilling	17.2	14.4	- 2.8
Recycling	90.0	78.9	- 11.1
Total	3,382.9	3,419.5	+ 36.6
10 ppm			
Thermal treatment	3,257.7	3,329.1	+ 53.4
Landfilling	17.2	14.4	- 2.8
Recycling	90.0	78.2	- 11.8
Total	3,382.9	3,421.8	+ 38.8
7 ppm			
Thermal treatment	3,257.7	3,679.1	+ 403.4
Landfilling	17.2	0	- 17.2
Recycling	90.0	0	- 90.0
Total	3,382.9	3,679.1	+ 296.2

At a possible LPCL of below 364 ppm, theoretically additional treatment costs of about 22 million Euros per year would arise in total. This steep increase in costs is ascribable to flame retarded textiles from the automotive sector (169.2 kt/a) which have been recycled together with the total shredder light fraction arisen in Germany so far. At this limit value, the total shredder light fraction would have to be incinerated. Setting off additional thermal treatment costs of 28.8 million Euros per year against the declining recycling costs of 6.8 million Euros per year, the above mentioned additional costs amount to 22 million Euros (see Table 78).

At a possible LPCL of 290 ppm, theoretically additional treatment costs of 24.5 million Euros per year would arise in total. The increase in costs of a further 2.5 million Euros per year as compared with a possible LPCL of 364 ppm results from the additional thermal treatment of HBCD-containing HIPS (24.1 kt/a) which are treated together with the total plastic waste fraction from the electronics sector and which have been recycled/landfilled so far. At this possible limit value, the total waste fraction from the electronics sector would have to be incinerated (see Table 78).

Corresponding additional costs would also arise at further possible LPCLs of 29 ppm, 10 ppm and 7 ppm. At a possible LPCL of 29 ppm, further additional costs of 12.1 million Euros arise per year (total costs: 36.6 million Euros per year). This is due to changed treatment operations for EPS and XPS waste (exclusive thermal treatment of wastes which have been landfilled/recycled so far), which is treated together with the total plastic waste fraction from the construction sector. A possible LPCL of 10 ppm would theoretically result in a further increase by 2.2 million Euros to total costs of 38.8 million Euros per year – pursuing the principle outlined above. This would be ascribable to changed treatment operations for EPS/XPS waste from sectors other than the construction sector (EPS packaging waste). The highest additional costs by far would result from an LPCL of 7 ppm, as in this case, also the total amount of bulky waste and mixed municipal waste in Germany would exclusively have to be treated thermally. The resulting additional costs of 257.4 million Euros per year would cause total costs for waste treatment of 296.2 million Euros overall (see Table 78).

Discussion

HBCD

At a possible LPCL above 364 ppm, no economic impacts on waste management would have to be expected.

If a possible LPCL ranges below 364 ppm, additional costs of 22 million Euros per year would arise. In case HBCD flame retarded textiles from the automotive sector (1,820 t/a, c~80,000 ppm) were separated and treated separately before entering the shredder light fraction (398,180 t/a, c~0 ppm), a significantly lower LCPL could be proposed. The HBCD contamination of about 364 mg/kg in the total shredder light fraction would fall to a negligibly small concentration. This would imply that treatment operations for the shredder light fraction could remain unchanged and that recycling of this waste stream remains possible. Separation would only be required for the period in which considerable HBCD amounts from the automotive sector have to be expected (ca. 5 years). For flame retardance of textiles within the automotive sector, HBCD was used especially for seat covers, door trim panels as well as for rugs in fond, bunk and engine compartments until about 2007.

At a possible LPCL of 290 ppm, estimated 2.5 million Euros additional costs per year would arise due to thermal treatment of HBCD-containing HIPS. This situation is also comparable to the treatment of flame retarded textiles at 364 ppm explained above. In case the HBCD-containing HIPS (1,746.8 t/a, c~40,000 ppm) were separated and treated separately before entering the total plastic waste fraction from the electronics sector (239,253.2 t/a, c~0 ppm), a significantly lower LPCL could be proposed. As described in section 3.2.9.2, plastics containing brominated flame retardants have to be removed from separately collected waste electrical and electronic equipment. This obligation inter alia applies to plastics (e.g. HIPS) containing HBCD as brominated flame retardant. If the entire HBCD plastics were effectively separated in practice, as mentioned above, a lower LPCL could be proposed.

A possible LPCL of 29 ppm would cause estimated additional costs of 12.1 million Euros per year due to the thermal treatment of EPS and XPS waste, which is treated together with the total plastic waste fraction from the construction sector. Under the assumption that this EPS/XPS waste (<5% of the 2012 waste amount each) cannot be separated at present, the possible LPCL should, in any case, lie above 29 ppm. Possible LPCLs of 10 ppm and 7 ppm are therefore beyond dispute.

Based on the discussion above, the following proposals are made:

Option 1: 1,000 ppm: no economic impact on waste management, a reduction of the limitation criterion to 100 ppm after ca. 5 years would be possible.

Option 2: 100 ppm: provided that HBCD flame retarded textiles from the automotive sector as well as HIPS from waste electronic and electrical equipment are separated and treated separately, and do not enter the total waste amounts of the shredder light fraction and the plastics waste fraction from the electronics sector.

HCBD

The data basis indicates that HCBD-containing waste is not relevant in Germany. Therefore, LPCLs have no relevant economic impacts and can be set arbitrarily low. In reference to the other lower limitation criteria a value of 0.1 mg/kg is proposed.

PCN

The data basis indicates that PCN-containing waste is not relevant in Germany. Therefore, LPCLs have no relevant economic impacts and can be set arbitrarily low. In reference to the other lower limitation criteria a value of 0.1 mg/kg is proposed.

PCP

PCP-contaminated waste wood is recovered/disposed of along with other waste wood classified as hazardous. Approximately 95% of the waste wood classified as hazardous in Germany is already energy recovered/disposed of thermally. The remaining 5% are used for the production of synthesis gas and activated carbon.

At limit values above 150 ppm, theoretically no waste would have to be treated alternatively, which would avoid changes in the current costs for waste management. At a low POP concentration limit of 150 ppm, theoretically 57.5 kt/a waste wood, which is currently used for the production of synthesis gas and activated carbon, would have to be directed to incineration and/or energy recovery. This would cause an increase in costs of ~7.5 million Euros per year (see Table 79). The costs are regarded justifiable for Germany. Hence the limit value can be set arbitrarily (also <150 ppm).

Table 83: Economic impacts at possible LPCL (PCP)

PCP	Current costs [million €/a]	Costs at a specific POP concentration limit [million €/a]	Changes [million €/a]
	150 ppm		
Incineration (D10)	9.78	195.5	+9.8
Energy recovery (R1)	175.9		
Recovery (Production of synthesis gas and activated carbon)	2.3	0	-2.30
Total	188.0	195.5	~7.5

SCCP

At a possible limit values above 350 ppm, theoretically no waste would have to be treated alternatively, which would avoid an increase in costs for waste management.

It is assumed that the SCCP-containing rubber waste is disposed of/recovered together with other rubber waste. At a low POP concentration limit of 350 ppm, theoretically ~312.1 kt/a rubber waste, which is currently recovered, would have to be incinerated with or without energy recovery. This would result in an increase in costs amounting to ~40.3 million Euros per year (see Table 80). Those additional costs would still be acceptable, however the limit value would also entail the fact that ~312.1 kt/a of the rubber waste (~62% of the total rubber waste in Germany) could not be recovered any longer. For the SCCP-containing sealants, no additional increase in costs would result from a limit value below 350 ppm.

Concerning the SCCP-containing sealants, it is assumed that ca. 1/3 of the waste (~0.11 kt/a) can be separated successfully and is disposed of separately in hazardous waste treatment plants. As to the remaining 2/3 of the waste stream (~0.22 t/a) it is assumed that they adhere to construction and demolition waste (e.g. concrete, tiles, bricks and ceramics) due to their properties and that they are recovered and disposed of together with those wastes (mixed contamination ~0.8 ppm). Only at a limit value of 0.8 ppm, theoretically a considerable amount of contaminated construction and demolition waste would have to be treated alternatively (>54 million t/a construction and demolition waste).Owing to the large mineral fraction of the waste stream, the bulk of this waste would have to be stored underground (~260 €/t). This would entail an increase in costs of several billion Euros.

Table 84: Economic impacts at possible LPCL (SCCP)

SCCP	Current costs [million €/a]	Costs at a specific POP concentration limit [million €/a]	Changes [million €/a]
350 ppm			
Landfilling	420.0	420.0	0
Underground disposal	0	0	0
Hazardous waste incineration	0.09	0.09	0
Incineration (D10)	1.2	86.5	+53.1
Energy recovery (R1)	32.2		
Material recovery	2,056.5	2,043.7	-12.8
Total	2,510.0	2,550.3	~40.3

The limit value should not range below 0.8 mg/kg (increase in costs of several billion Euros). In order to avoid the consequence that ~62% of the total rubber waste in Germany could not be recycled any longer, the limit value should lie above 350 mg/kg. As an alternative, a concentration limit could be set in a range between 1 mg/kg and 350 mg/kg, in case the SCCP-containing rubber waste is separated successfully from the other rubber waste and treated separately.

Table 81 sums up the evaluation of the economic impacts associated with different possible LPCLs.

Table 85: Overview of the results for limitation criterion W

Substance/Substance group	Result [mg/kg]
HBCD	Option 1: 1,000 Option 2: 100
HCBD	0.1
PCN	0.1
PCP	0.1
SCCP	Option 1: 1,000 Option 2: 100

7.3.2 Evaluation of the upper limitation criteria

7.3.2.1 (GW) Limit values

Existing limit values on a national and international scale were taken into account as upper limitation criterion, in order to avoid possible conflicts between existing limit values and proposed LPCL (see section 2.4.3.5). The evaluation was especially focused on the question whether and how existing limit values delimit possible LPCLs.

In the scope of the research the existence of occupational exposure limits and biological limit values was examined as well[66].

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[66] Sources of information:

GESTIS –Stoffdatenbank http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Stoffdatenbank/index.jsp

GESTIS International Limit Values http://limitvalue.ifa.dguv.de/

BAuA Technische Regeln für Gefahrstoffe: TRGS 900 (http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-900.html/) und TRGS 903 (http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-903.html)

For the substances/substance groups relevant in the context of this project, only a few limit values are established or proposed at European or national level. Relevant information and, if applicable, conclusions concerning possible LPCL are listed in the following for the individual substances.

HBCD

HBCD is subject to different national and international regulations (see section 3.2.3). The corresponding relevant limit values are listed in Table 82.

Table 86: Relevant legislation and sources of information concerning limit values HBCD

Basis	Content	Limit value
REACH Regulation (EC) No 1907/2006	HBCD is listed as PBT substance in Annex XIV (list of substances subject to authorisation). After the sunset date, the placing on the market and the use of the substance is prohibited, unless a certain use of that substance has been authorised. It has to be taken into account that in accordance with Article 56(6) (a), the authorisation requirement does not apply to PBT substances as HBCD, in case they are present in mixtures below concentration limits of 0.1 % (w/w).	0.1% (1,000 mg/kg)
Proposal for the RoHS Directive 2011/65/EC [UBA AT 2014]	In a recent study on the RoHS Directive (EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment) a limit value for HBCD in electronic and electrical devices is proposed: “For the maximum concentration of HBCDD to be tolerated in homogenous materials in EEE it is proposed to set the same value as defined for POPs waste in Annex IV to the EU POP Regulation (850/2004/EC) for most POPs, i.e. 0.005%.” (source: [UBA AT 2014])	Proposed limit value: 0.005% (50 mg/kg)

The current draft amendment to the EU-POP Regulation contains no LPCL proposal for HBCD.

Hitherto, no occupational exposure limits or biological limit values have been established for HBCD.

Conclusion: A possible LPCL should not exceed the existing limit value in accordance with REACH, above which the placing on market and the use of HBCD is prohibited (0.1%). The proposal in the recent study performed by UBA Austria is based exclusively on existing limit values under the EU-POP Regulation without specific explanation and is not stipulated in any legal regulation. Hence it does not represent a limitation criterion for a possible LPCL. A possible LPCL for HBCD should therefore not be set above 0.1% (1,000 mg/kg).

HCBD

HCBD is subject to various national and international regulations (see section 3.3.3). Relevant limit values for HCBD are not defined.

In Germany, no occupational exposure limit has been defined for HCBD. 10 states worldwide have defined occupational limit values for HCBD (0.2 to 0.24 mg/m^3; source: GESTIS). These occupational limit values, referring to the concentration in the air, are not directly related to the LPCLs. Biological limit values have not been established.

ILO: ICSC database http://www.ilo.org/dyn/icsc/showcard.home

In the current draft amendment to the POP Regulation an LPCL of 100 mg/kg and an MPCL of 1,000 mg/kg are proposed. The LPCL should not exceed 100 mg/kg, unless there are relevant reasons for that.

PCN

PCN are subject to various national and international regulations (see section 3.4.3). A relevant limit value is defined in the Basel Convention (see Table 83).

Table 87: Relevant legislation and sources of information concerning limit values PCN

Basis	Content	Limit value
Annex VIII, Basel Convention	Wastes containing polychlorinated naphthalenes are classified as hazardous in accordance with Annex VIII to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The set limit value is 50 mg/kg.	50 mg/kg

Further relevant limit values for PCN could not be identified.

In Germany, no occupational limit value has been defined for PCN. Between 14 and 17 states worldwide have defined occupational exposure limits for trichloronaphthalenes (17 states; between 0.2 and 5 mg/m^3), tetrachloronaphthalenes (14 states; 2 mg/m^3), pentachloronaphthalene (16 states, 0.5 mg/m^3), hexachloronaphthalenes (14 states; 0.2 mg/m^3) and octachloronaphthalene (15 states; 0.1 mg/m^3), (source: GESTIS).

These occupational limit values, referring to the concentration in the air, are not directly related to the LPCLs. Biological limit values have not been established.

In the current draft amendment to the POP Regulation an LPCL of 10 mg/kg and an MPCL of 1,000 mg/kg are proposed. The LPCL should not exceed 10 mg/kg, unless there are relevant reasons for that.

PCP

PCP is subject to different national and international regulations (see section 3.5.3). The corresponding relevant limit values are listed in Table 84 and Table 85.

EU/International

Table 88: International legislation and sources of information concerning limit values PCP

Basis	Content	Limit value
REACH Regulation (EC) No 1907/2006, Annex XVII, Number 22	Pentachlorophenol and its salts and esters *Shall not be placed on the market or used:* – *as a substance,* – *as a constituent in other substances, or mixtures, in a concentration equal to or greater than 0.1 % by weight*	0.1% (1,000 mg/kg)

Germany

Table 89: German legislation and sources of information concerning limit values PCP

Basis	Content	Limit value
Chemicals Prohibition Ordinance (Chemikalienverbots-verordnung /ChemVerbotsV), Annex re Art.1, Para. 15	*Amongst others it is prohibited to put in circulation:* ▸ *the substance* ▸ *formulations with 0.01% by weight pentachlorophenol, its salts and compounds* ▸ *manufactures, treated with a formulation containing the above-mentioned substances*	0.01% (100 mg/kg)

The waste samples database of the German federal state North Rhine – Westphalia (ABANDA) contains further relevant guidance-, limit-, assignment-, orientation-, inspection-, concentration- and minimis threshold limit -values for PCP (see Table 49).

A possible LPCL should not exceed the existing limit value in accordance with ChemVerbotsV (Annex re Art.1, Para. 15). The LPCL for PCP should not exceed 0.01% (100 mg/kg).

SCCP

According to the EU POP Regulation the production, placing on the market and use of SCCP on their own, in preparations or as constituents of articles are prohibited. In accordance with Annex I, Part B to the Regulation the following derogations are granted for the use of SCCP as fire retardants in rubber used in conveyor belts in the mining industry and as fire retardants in dam sealants.

In February 2013, a draft amendment of the Annexes IV and V to the EU POP Regulation was submitted to the EU Member States for commenting until mid-March 2013. Concerning SCCP the draft amendment contained a LPCL of 1,000 mg/kg and a maximum limit value (MPCL) of 5,000 mg/kg. The current draft amendment of 12/03/2014 was adjusted accordingly. 10,000 mg/kg (~1%) are proposed for LPCL and MPCL each, in order to avoid a conflict with the concentration threshold of 1% by weight determined in Annex I.

Unless there are relevant reasons, the LPCL should not exceed 10,000 mg/kg.

Table 86 Table 70presents a summary of the results elaborated for the criterion “limit values”:

Table 90: Overview of the results for limitation criterion GW

Substance/substance group	Existing limit value	Result upper limitation criterion
HBCD	1,000 mg/kg (prohibition of placing on market and use)	1,000 mg/kg
HCBD	No existing limit value, an LPCL of 100 mg/kg is proposed in the current draft amendment to the POP Regulation	100 mg/kg
PCN	Limit value for the classification as hazardous waste under the Basel Convention is 50 mg/kg; an LPCL of 10 mg/kg is proposed in the current draft amendment to the POP Regulation	10 mg/kg
PCP	A possible LPCL should not exceed the existing limit in accordance with the Chemicals Prohibition Ordinance (Annex re Art.1, Para. 15). The LPCL for PCP should not lie above 0.01% (100 mg/kg)	100 mg/kg

SCCP	The current draft amendment to the EU POP Regulation of 12/03/2014 was adjusted. 10,000 mg/kg are proposed for LPCL and MPCL each, in order to avoid a conflict with the concentration threshold of 1% by weight determined in Annex I.	10,000 mg/kg

7.3.2.2 (UG) Possible adverse effects on human health and the environment

Limit values should be established in a way that adverse effects on human health and the environment are avoided and human health and the environment are protected from persistent organic pollutants as far as possible (cf. section 2.4.3.6).

In order to assess possible effects, (P)NEC values, occupational exposure limits (OELs) and biological limit values (BLVs) were investigated. Table 87 gives an overview of the available (P)NEC values. The comparison given in Table 88 indicates that typical sewage sludges pose no immediate risk for human health and the environment regarding their content of the relevant substance groups.

Further relevant information for the evaluation of possible risks for human health and the environment regarding to the relevant substances/substance groups is presented in the following.

Regarding all relevant substances/substance groups, with the exception of PCN, distinctive (P)NEC values are available. For HCBD, PCN and PCP, occupational exposure limits have been established in different countries. The available (P)NEC values can serve as information for the derivation of a quantitative limitation criterion. For the derivation of the limitation criterion it has to be taken into consideration, whether a certain waste can be released directly into the environment (sewage sludge for instance) or if and how it can indirectly cause an exposure of humans or the environment to POPs.

In case the POP-containing waste can be released directly into the environment, the (P)NEC can be used directly as upper limitation for the relevant compartment.

In other cases, the risk is reduced in accordance with the specific frame conditions. In order to analyse the frame conditions, the pre-treatment, treatment and finally the disposure/recovery of the waste are discussed. In the analysis (see section 6), especially the following questions were taken into account:

- Are disposal and recovery operations (D9, D10, R1, R4), permitted according to Annex V, part 1, appropriate to destroy or irreversibly transform the relevant substances/substance groups?
- Can the corresponding processes lead to an unintended generation of new POPs?
- Can disposal or recovery cause a risk to human health or the environment (i.e. a relevant exposure of humans or the environment)? The emission of significant amounts of POPs into the environment is generally considered a risk.

To this end, relevant information on the essential exposure pathways has to be taken into account and possible health and environmental risks resulting from different procedures in waste recovery and disposal have to be discussed.

Table 91: Overview of available (P)NEC values for the relevant substances/substance groups

Pollutant [source]	Water		Sediment		Soil	Food chain (oral intake)	Microbiol. activity
	Freshwater	Seawater	Freshwater	Seawater			
HBCD [ECB 2008]	0.31 µg /l	0.031 µg /l	0.86 mg/kg (dry)	0.17 mg/kg (dry)	5.9 mg/kg (dry)	5 mg/kg food	0.15 mg/l
HCBD [Euro Chlor 2002]		0.13 µg /l (fish 111mg/kg)		24.4 µg/kg (dry)			
Mono CN [Environment Canada 2009]		10 µg /l					
Di- to Octa-chloro-naphthalene *							
PCP [Euro Chlor 1999]	0.2 µg /l - 2 µg /l	1 µg /l	12.4 µg /kg - 124 µg /kg	62 µg /kg			
SCCP [RAR 2008]	0.5 µg /kg	0.1 µg /l	2.17 mg/kg (wet)	0.43 mg/kg (wet)	1.76 mg/kg (wet)	5.5 mg/kg food	6 mg/l

* CAS numbers 28699-88-9, 1321-65-9, 1335-88-2, 1321-64-8, 1335-87-1, 32241-08-0, 2234-13-1

(P)NEC values are most relevant for sediments or soils in order to evaluate the risks posed by different wastes. Wastes containing the relevant substances/substance groups above this concentration should not enter the environment (e.g. be applied on agricultural soil as sewage sludge). As far as PCN are concerned, only a (P)NEC value for mono-PCN[67] in seawater exists. This value lies in similar ranges as the corresponding (P)NEC values for HCBD and PCP in seawater. Table 88 contains a comparison of (P)NEC values for soils and sediments for the relevant substances/substance groups and typical contents in sewage sludge.

Table 92: Comparison of (P)NEC values for soils and sediments for the relevant substances/substance groups and typical contents in sewage sludge

Substances/Substance groups	(P)NEC values for soils and sediments	Typical contents in sewage sludge
HBCD	0.17 – 5.9 mg/kg	~ 60 µg/kg
HCBD	24.4 µg/kg	~ 6 µg/kg
PCN	n.a.	n.a.
PCP	12.4 -124 µg/kg	~20 µg/kg
SCCP	1.76 – 2.17 mg/kg	0.38 mg/kg

The comparison illustrates that typical sewage sludges present no immediate risk for human health and the environment regarding their content of relevant substance groups.

In case the waste management operations of other relevant types of waste containing the relevant substance groups lead to the exceeding of (P)NEC values or occupational exposure limits, possible adverse effects on human health or the environment have to be expected. The corresponding discussion is reflected in section 6.

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[67] mono-PCN = Chloronaphthalene; CAS 25586-43-0

If the evaluation is based on the lowest (P)NEC value for each substance, it can be assumed that the corresponding environmental concentrations cause no risk. Provided that the risk of causing environmental contamination is reduced by a factor of 10,000 through appropriate recovery and disposal operations (i.e. due to the operations, the concentration in waste will occur in the environment in not more than a tenthousandth of this concentration), it can be concluded that the waste will cause no risk when treated appropriately.

On the basis of these premises, (P)NEC values can be multiplied by 10,000 and serve as a quantitative upper limitation criterion. Table 89 shows the results of this procedure:

Table 93: Derivation of proposals for the limitation criterion UG

Substance/ Substance group	Lowest (P)NEC for soils/sediments	Factor	Result criterion UG (mg/kg)	Proposal criterion UG (mg/kg)
HBCD	0.17 mg/kg	10,000	1,700	1,000
HCBD	24.4 µg/kg	10,000	244	200
PCN	n.a.	10,000	n.a.	100*
PCP	12.4 µg/kg	10,000	124	100
SCCP	1.76 mg/kg	10,000	17,600	18,000

* As far as PCN are concerned, only a (P)NEC value for mono-PCN[68] in seawater exists. This value lies in similar ranges as the corresponding (P)NEC values for HCBD and PCP in seawater. Therefore, the limitation criterion UG for PCN is chosen similarly to HCBD and PCP.

Further relevant information for the evaluation of possible risks for human health and the environment regarding to the relevant substances/substance groups is presented in the following. The information are taken into consideration in the risk assessment. Table 90 shows an overview of the essential exposition pathways for the relevant substances/substance groups.

Table 94: Overview of essential exposure pathways for the relevant substances/substance groups (sources: GESTIS, BAUA and ILO[69])

Substance/ Substance group	Essential exposure pathways	Sources (from BiPRO 2011)
HBCD	Inhalation, oral and dermal exposure	Humans can be exposed to HBCD by inhalation of vapour and airborne dust, ingestion and by dermal contact. In addition there is a risk that babies can be exposed during pregnancy and due to breast-feeding [ECB 2008a].
HCBD	Oral exposure as most relevant pathway	Exposure of the general public to HCBD mainly occurs indirectly via drinking-water and food with high lipid content [see IPCS 1993].

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[68] mono-PCN = Chloronaphthalene; CAS 25586-43-0

[69] Sources of information:

GESTIS –Stoffdatenbank http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Stoffdatenbank/index.jsp

GESTIS International Limit Values http://limitvalue.ifa.dguv.de/

BAuA Technische Regeln für Gefahrstoffe: TRGS 900 (http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-900.html/) und TRGS 903 (http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-903.html)

ILO: ICSC database http://www.ilo.org/dyn/icsc/showcard.home

Substance/ Substance group	Essential exposure pathways	Sources (from BiPRO 2011)
PCN	Oral exposure as most relevant pathway	The main route of exposure of humans to PCN is probably by ingestion of fish [Haskoning 2002].
PCP	Inhalation, oral and dermal exposure	General population exposure may occur through contact with contaminated environmental media, particularly in the vicinity of hazardous waste sites. Important routes of exposure appear to be inhalation of contaminated air, ingestion of contaminated groundwater used as a source of drinking water, ingestion of contaminated food, and dermal contact with contaminated soils or products treated with the compound [IEP 2008].
SCCP	Oral exposure as most relevant pathway	Generally, private individuals are not expected to handle materials and mixtures that contain SCCP apart from a few cases such as sealants or paints, commercial tents, etc [RPA 2010]. Ingestion of food is the main exposure pathway of SCCP to humans, but it did not pose any health risk in Japan in 2003 [POPRC.5/2/Rev.1].

Table 91 gives an overview of relevant information on occupational exposure.

Table 95: Information on occupational exposure

Substance/ Substance group	Information on occupational exposure	Source
HBCD	Occupational exposure particularly possible during production or waste disposal. Exposition particularly by inhalation of dust. (see BiPRO 2011, Table 9-38)	[Swerea 2010]; [ECB 2008] (in BiPRO 2011)
HCBD	Occupational exposure particularly possible during production and use of HCBD-containing substances and products. (see BiPRO 2011, Table 9-38)	[IARC 1999] (in BiPRO 2011)
PCN	Occupational exposure particularly possible during production of Chloronaphthalenes. (see BiPRO 2011, Table 9-38)	[IPCS 2001] (in BiPRO 2011)
PCP	Occupational exposure particularly possible by dermal contact during the handling of PCP treated woods (due to high PCP concentrations in the outermost layers of treated woods) or by inhalation on wood preservation facilities. (see BiPRO 2011, Table 9-38)	[IEP 2008] (in BiPRO 2011)
SCCP	Occupational exposure particularly possible by dermal contact but also by inhalation during the production, formulation and use of the different applications. (see BiPRO 2011, Table 9-38)	[ERA 2000]; [ECHA 2009] (in BiPRO 2011)

Table 92 lists the results for the upper limitation criterion possible “adverse effects on human health and the environment” (derivation see Table 89).

Table 96: Overview of the results for limitation criterion UG

Substance/substance group	Proposal for criterion UG (mg/kg)
HBCD	1,000
HCBD	200

PCN	100
PCP	100
SCCP	18,000

7.3.3 Results of the evaluation of the upper and lower limitation criteria

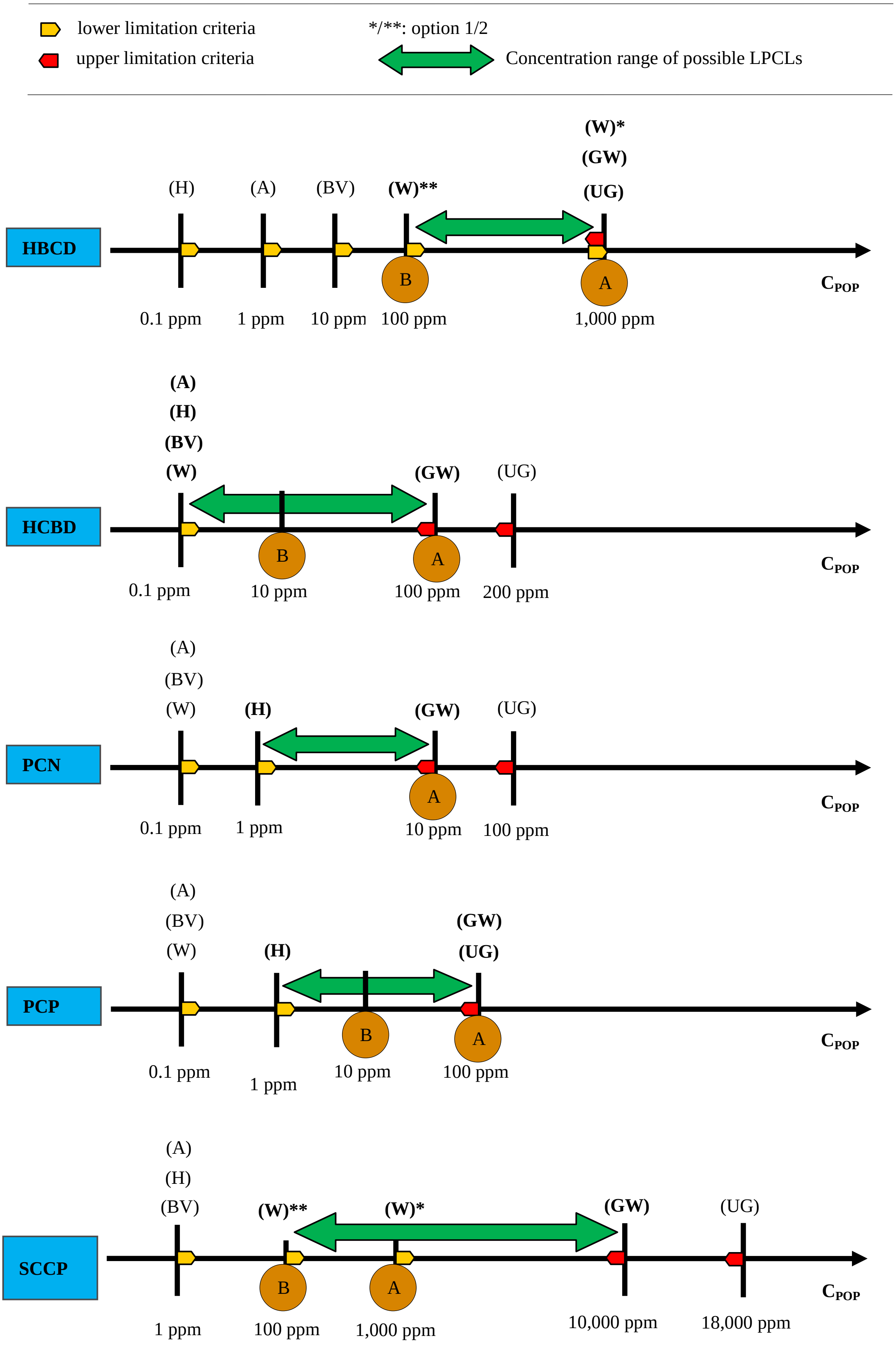
Table 93 shows the results of the evaluation of the upper and lower limitation criteria for the selected substances/substance groups. Figure 61 illustrates the results. The results present an essential discussion basis for recommending LPCLs and appropriate waste management operations, particularly in combination with the elaborated substance flows and the risk assessment.

Table 97: Results of the preliminary evaluation of the upper and lower limitation criteria for the selected substances/substance groups (in mg/kg)

	HBCD	HCBD	PCN	PCP	SCCP
Lower limitation criteria (mg/kg)					
(A) Analytical potential	1.0	0.1	0.1	0.1	1.0
(H) Background contamination	0.1	0.1	1.0	1.0	1.0
(BV) Disposal and recovery capacities	10	0.1	0.1	0.1	1.0
(W) Economic feasibility	Option 1: 1,000 Option 2: 100	0.1	0.1	0.1	Option 1: 1,000 Option 2: 100
Upper limitation criteria (mg/kg)					
(GW) Limit values	1,000	100	10	100	10,000
(UG) Possible adverse effects on human health and the environment	1,000	200	100	100	18,000
Preliminary conclusions					
Value in the current draft amendment of the EU POP Regulation	n.a.	100	10	n.a.	10,000
Proposed LPCL option A	1,000	100	10	100	1,000
Proposed LPCL option B	100(a)	10(b)		10(c)	100(d)
Comment	LPCLs only apply in case a waste does not directly enter the environment, but is directed to an appropriate waste treatment operation, otherwise (P)NEC values are relevant (see Table 88).				

(a) For flame prevention of textiles in the automotive sector, HBCD was used especially for seat covers, door trim panels as well as for rugs in fond, bunk and engine compartment until about the year 2007. To what extent HBCD transfer into the shredder light fraction is actually relevant (i.e. in this case especially whether the possible LPCL of 100 mg/kg is exceeded) has to be clarified if necessary. (b) Option A follows the current draft amendment. In order to minimise risks, setting the LPCL for HCBD to 10 mg/kg (or even below down to1.0 mg/kg) would also be possible. (c) Option B serves risk minimisation. It is possible to set the LPCL for PCP to 10 mg/kg (or even to 1.0 mg/kg). (d) Option B serves risk minimisation. It is possible to set the LPCL for SCCP to 100 mg/kg.

Figure 63: Results from the evaluation of the limitation criteria (Explanations in Table 93)



8 Recommendations on limit values and treatment operations

On the basis of the results of this research project, proposals for limit values and waste treatment operations can be derived. On the one hand they are intended to ensure pollutant removal to the maximum extent possible and on the other hand to enable environmentally sound recycling processes.

The proposals for limit values concern the LPCL which is relevant in Germany. Specifically, it refers to the concentration limit in accordance with Article 7(4)a of the EU POP Regulation.

Table 94 contains a summary of proposed low POP concentration limits as well as recommended disposal and recovery operations for the five selected substances/ substance groups (detailed information can be found in each of the following subsections 8.1 - 8.5):

Table 98: Overview of proposals for limit values and recommendations for waste treatment operations

HBCD – Proposal for potential LPCL: 100 – 1,000 mg/kg	
Sector	**Recommendation**
Material recovery HBCD free EPS/XPS products	Generally the mixture of HBCD-containing and HBCD-free material (e.g. EPS packaging) should be avoided in material recovery of HBCD-free products. Separate collection and treatment of EPS insulation material and EPS packaging waste as far as reasonably possible.
Energy recovery EPS/XPS insulation materials	Incineration in incineration plants equipped with the best available technologies and professional mixture in the bunker of the plant. Avoidance of dust generation during handling of insulation materials. It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of HBCD-containing dust.
Landfilling EPS/XPS	Minimisation of landfilling through separation in demolition and reconstruction as far as reasonably possible. Minimisation of land filling through separation of impurities from the mineral fraction of construction waste as far as possible and appropriate treatment (energy recovery).
Export of old electronic devices (HBCD in HIPS and other POPs)	Export of old electronic devices only to countries, where adequate recovery and disposal of old electronic devices is ensured.
Material recovery HIPS from electronics industry	Minimisation of the release into recyclates through separation of brominated plastics from WEEE as far as possible in accordance with Directive 2012/19/EU and appropriate treatment (energy recovery).
Energy recovery HIPS from electronics industry	State-of-the-art incineration
Landfill HIPS from electronics industry	Minimisation of landfilling through separation of plastics containing bromine from WEEE as far as possible in accordance with Regulation 2012/19/EU and appropriate treatment (energy recovery).
Flame retarded textiles from the institutional sector	Recommendation for energy recovery for flame retarded textiles from the institutional sector produced before 2007.

Flame retarded textiles from automobile sector	Examination whether temporarily energy recovery of the shredder light fraction should be carried out due to possibly significant HBCD concentration.

HCBD – Proposal for potential LPCL: 0.1 – 100 mg/kg

Sector	**Recommendation**
No relevant waste	As a basic principle: state-of-the-art incineration.

PCN – Proposal for potential LPCL: 1 – 10 mg/kg

Sector	**Recommendation**
No relevant waste	As a basic principle: state-of-the-art incineration.

PCP – Proposal for potential LPCL: 1 – 100 mg/kg

Sector	**Recommendation**
Material recovery of impregnated waste wood (wood chips for the production of wood based materials)	According to the German AltholzV, the recovery of waste wood classified as waste wood of category AIV for the production of wood based materials (e.g. chipboard) is not permitted. However in practice parts of impregnated wood can be disseminated into other waste wood categories and be directed to material recovery. Annex II to §3, Abs. 1 of AltholzV sets a limit value of 3 mg PCP/kg dry matter for wood chips for the production of wood based materials. Plant operators are obliged to comply with this limit value.
Energy recovery/incineration of impregnated waste wood (waste wood category AIV)	Waste wood treated with wood preservatives (waste wood category IV) is to be recovered/ disposed of thermally in accordance with the AltholzV. In order to guarantee high destruction rates, the incineration temperature should reach at least 800°C (destruction rate › 99.9%). Under controlled incineration conditions, the formation of new POPs is can be excluded to the largest extent possible. Avoidance of dust generation in mechanical breakdown of contaminated waste wood. Personal precautionary measures (breathing masks) It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of PCP-containing dust.
Recovery of impregnated waste wood (without energy recovery) (waste wood category AIV)	Recovery operations permitted in Germany for waste wood of waste wood category IV are the production of synthesis gas for further chemical purposes as well as the production of activated carbon/industrial charcoal. As in the corresponding processes similar process temperatures as in energy recovery/incineration are used, it can be considered that the PCP content in waste wood is almost completely destroyed. However, specific destruction rates in these processes are not known. Avoidance of dust generation in mechanical breakdown of contaminated waste wood. It might be reasonable to apply personal protection measures (breathing masks) in order to avoid potential inhalation of PCP-containing dust.
Landfill of impregnated waste wood	Landfilling of waste wood is not permitted in Germany. The AltholzV restricts waste wood disposal to thermal disposal.

SCCP – Proposal for potential LPCL: 100 – 10,000 mg/kg

Sector	**Recommendation**
Material recovery (rubber from rubber conveyor belts for the use in underground mining)	Minimisation of the release into recyclates through separation of SCCP-containing rubber conveyor belts from underground mining as far as possible and appropriate treatment (energy recovery/incineration). Prior to the material recovery the metal fraction of the conveyor belt has to be separated from the rubber fraction as far as possible. This can re-

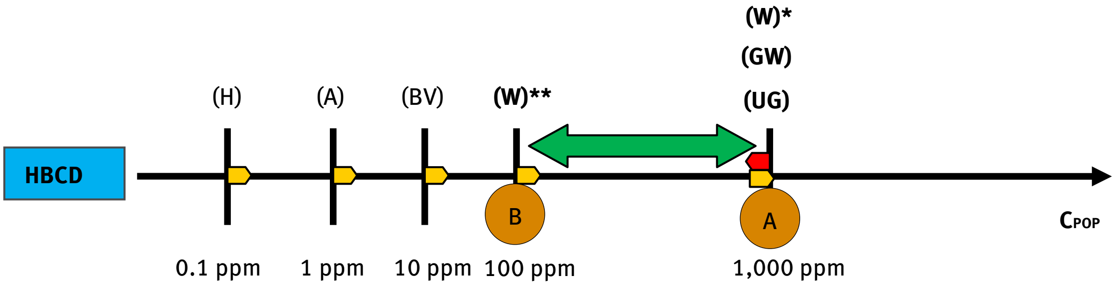
	sult in dust generation and presents a potential environmental and health risk. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Energy recovery/incineration (rubber from rubber conveyor belts for the use in underground mining)	Due to high incineration temperatures in energy recovery/incineration (>800°C) it can be assumed that the SCCP content in used rubber conveyor belts is almost completely destroyed. However, exact destruction rates for SCCP have not been identified. Environmental and health risks are expected if SCCP-containing waste has to be comminuted mechanically prior to energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Landfill (rubber from rubber conveyor belts for the use in underground mining)	Not relevant
Material recovery (sealants from construction and demolition waste)	Minimisation of the release into recyclates through separation of SCCP-containing sealants from construction and demolition waste and appropriate treatment (energy recovery/incineration, hazardous waste incineration). Complete separation is not feasible in practice. When removing sealants from buildings, fast running machines should not be used in order to avoid heat generation. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Energy recovery/incineration (sealants from construction and demolition waste)	Due to high incineration temperatures in energy recovery/incineration (>800°C) it can be considered that the SCCP content in sealants is almost completely destroyed. However, specific destruction rates for SCCP are not available. Environmental and health risks can be expected if SCCP-containing waste has to be comminuted mechanically prior to energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be prevented by the use of breathing masks.
Hazardous waste incineration (sealants from construction and demolition waste)	In practice, it is not expected that SCCP-containing sealants can be completely separated and treated separately (as they adhere to the surface of the construction materials). Successfully separated waste streams should be treated in hazardous waste incineration plants. Due to high incineration temperatures (>1,000°C) it can be considered that the SCCP content is almost completely destroyed. However, exact destruction rates for SCCP are not available.
Landfill (sealants from construction and demolition waste)	Landfilling generally involves the risk that SCCP may be released into the environment in the long term. Presuming that the SCCP-containing waste stream is treated together with concrete, tiles, bricks and ceramic waste, the amount of the mixed waste stream would be very high, while the theoretical SCCP concentration would be insignificant. Due to the insignificant SCCP concentration no specific environmental or health risks are expected. Global distribution can be restricted through separation to the largest extent possible.

8.1 HBCD

8.1.1 Low POP concentration limit

Based on the analysis of the evaluation criteria, a range of 100 to 1,000 mg/kg results for the LPCL for HBCD (see section 7.3.3 and Figure 62):

Figure 64: Results from the evaluation of the limitation criteria for HBCD (Explanations in Table 93)



The LPCL should not exceed the existing limit value according to the REACH-Regulation, above which the placing on the market and use of HBCD is prohibited (1,000 mg/kg).

The current draft amendment to the EU-POP Regulation contains no LPCL proposal for HBCD.

According to the project results, significant quantities of waste will be affected by an LPCL in the range of 100 to 1,000 mg/kg.

Relevant waste and recyclates containing HBCD may originate from the following areas:

- Expanded Polystyrene (EPS) especially from the former use of HBCD in EPS for the construction sector
- Extruded Polystyrene (XPS) especially from the former use of HBCD in XPS for the construction sector
- Recyclates from EPS insulation material und EPS packaging (mixed)
- High Impact Polystyrol (HIPS) from the former use of HBCD in HIPS for electrical and electronic devices
- Flame retarded textiles from the former use of HBCD-containing polymer dispersions

At an LPCL of 1,000 mg/kg all waste from products, in which HBCD is intentionally used, would be affected (i.e. EPS/XPS insulation material, HBCD-containing HIPS, HBCD-containing PD flame retarded textiles), since the HBCD concentration used is consistently significantly higher (usually higher than or equal to 7,000 mg/kg). Further, recyclates from EPS insulation material and EPS packaging (mixed) would be affected if their HBCD contents exceed 1,000 mg/kg (confirmed by measurements in some individual cases).

According to the project results, the following waste/recyclates would be additionally affected at an LPCL of 100 mg/kg:

- recyclates from EPS insulation material and EPS packaging (mixed), provided that their HBCD contents exceed 100 mg/kg
- HIPS recyclates from WEEE, provided that their HBCD contents exceed 100 mg/kg (confirmed by measurement in one individual case)
- shredder light fraction from the recycling of end-of-life vehicles, provided that its HBCD content exceeds 100 mg/kg (questionable whether practically relevant)

If an LPCL of 100 mg/kg should be chosen, it would be useful to determine the actual HBCD content in shredder light fractions in Germany, in order to determine whether this waste stream would be affected and to therewith ensure better assessment of consequences (see below).

8.1.2 Recommendations for recovery and disposal operations

Concern of waste/recyclates

According to the project results, an LPCL in the range of 100 to 1,000 mg/kg will have a significant impact and affect the following amounts of waste and recyclates (see also Table 36):

EPS in the construction sector

Annually arising EPS waste amounts, resulting from former use of EPS in insulation panels in the construction sector, contain about 161 t HBCD (reference year 2012, further increase is forecasted to be about 960 t HBCD per year by 2050). This corresponds to an EPS waste amount of around 23,050 t in 2012 (HBCD content of 7,000 mg/kg).

XPS in the construction sector

Annually arising waste amounts resulting from former use of XPS insulation panels contain about 41 t HBCD in the reference year 2012 (further increase is forecasted to be about 460 t HBCD per year by 2050). This corresponds to an XPS waste amount of about 2,745 t in 2012 (HBCD content of 15,000 mg/kg).

EPS and XPS apart from the construction sector

Apart from the construction sector, EPS is mainly used in the packaging sector. Currently, HBCD is no longer used in this application, and due to the generally short life cycle times of packaging, arising EPS packaging waste is not affected in general. In practice, HBCD-containing EPS insulation materials are partly mixed and recycled with EPS packaging waste in Germany. The recyclates have considerable HBCD contents above 1,000 mg/kg (see Table 61). Specific information regarding the concerned amounts is not available.

High Impact Polystyrol (HIPS)

At European level, about 2% of the total HBCD consumption was used for HIPS products in the past. Typical uses mentioned in the relevant literature are audio and visual equipment, distribution boxes for electrical lines in the construction sector and refrigerator lining (required HBCD content 1-7%).

There is no concrete evidence that HBCD is still used in HIPS in Germany (assumed end of use: 2011). It is expected, that due to the assumed life cycle times of electrical appliances (9 +/- 5 years) and due to imports, HBCD continues to enter waste streams and possibly recyclates from its previous use (estimated current waste amounts generated in the reference year 2012: about 70 t HBCD, trend decreasing; this corresponds to a HIPS waste amount of around 1,750 t in 2012, HBCD content of 4,000 mg/kg).

HBCD-containing HIPS from WEEE would therefore be affected by an LPCL in the range of 100 to 1,000 mg/kg. However, according to Directive 2012/19/EU, there is already the obligation to separate plastics which contain brominated flame retardants during the management of WEEE.

The sample of a HIPS recyclate from WEEE has a HBCD concentration of 184 mg/kg (see Table 61). Corresponding recyclates can therefore be affected by an LPCL of 100 mg/kg. However, if the obligation for the separation of brominated plastics is met, no relevant HBCD concentration should occur in the recyclates.

Polymer dispersions for textiles

At European level, about 2% of the total HBCD consumption was used for the production of polymer dispersions for textiles in the past (about 8% HBCD in flame retarded textiles). The HBCD-containing polymer dispersions were processed in the textile industry and especially used for upholstered furniture, upholstered seats in transportation, curtains and drapes, mattress ticking, home textiles and automotive textiles.

According to industry information, HBCD has no longer been used for textiles in Germany since 2007 and due to limited product life cycle times it is only of minor relevance in waste. Also at European level, it is assumed that HBCD is currently no longer used in polymer dispersions for textiles.

In Germany, HBCD was mainly used in venues in the institutional sector, as well as in the automotive sector. From both areas HBCD-containing waste from flame retarded textiles may be relevant for a few more years (reference year 2012: about 290 t HBCD; waste amount about 3,600 t; further decreasing relevance).

Treatment of concerned waste/recyclates, risks and recommendations

EPS and XPS in the construction sector

During the PS-E production cut-offs and other waste arise and are recycled back into the production process. Cut-offs from professional use (installation of insulation panels) and other EPS waste is collected and recycled. There are no corresponding collection systems available for XPS insulation material (usually it is incinerated with energy recovery due to its ODS content). Cut-offs are estimated to be 2%. This type of waste arises as sorted plastics and can be recycled mechanically or incinerated with energy recovery to a high degree. At EU level, about 1% of EPS waste is recycled (in the sense of mechanical recycling) and about 1% is treated otherwise as waste (usually thermally recovered). HBCD is already being substituted in the production of new EPS/XPS insulation material. By August 2015, HBCD will no longer be used in German EPS/XPS products.

Considerable amounts of EPS/XPS waste arise from demolition and reconstruction (increasing trend until about 2050). These are often already removed during demolition and fed separately to recovery or disposal. The majority (assumption: > 95%) of the foam waste from demolition and reconstruction is usually energetically recovered. Separate removal, however, is costly and often difficult in practice.

A comparatively small amount of HBCD-containing EPS/XPS insulation material is recycled. In construction waste EPS/XPS insulation material is seen as contamination or impurity and is separated as far as possible. A (small) non-quantifiable proportion of EPS waste is recovered or disposed of together with the mineral fraction of construction waste.

Material recovery for HBCD-containing products:

Mechanical recycling of process waste and cut-offs of HBCD-containing EPS/XPS insulation material in the manufacturing process of HBCD-containing insulation products poses no risk and will no longer be relevant in Germany at the latest after August 2015.

Material recovery for HBCD-free products:

Generally the mixing of HBCD-containing and HBCD-free material (e.g. EPS packaging material) should be avoided in the recycling of HBCD-free products. In the recycling processes, HBCD is usually not destroyed. HBCD is preserved over long time periods in the recyclates and entails the risk of further transfer of the HBCD content into various plastic products, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised by separate collection and treatment of EPS insulation material and EPS packaging waste as far as reasonably possible.

Energy recovery:

A maximum share of 2% EPS and XPS insulation panels in a mixture with other waste can be appropriately treated in state-of-the-art waste incineration plants. The incineration process largely destroys HBCD (destruction rate for incineration in incineration plants >99.99%) and does not contribute to the generation of other POPs. Crucial for a professional incineration is the expert mixture in the bunker of the plant. For a share of 1 percent by weight (equivalent to about 15 percent by volume) customary insulation panels can be handled without any problems in the incineration process.

During the product life cycle time, nearly 100% of the HBCD content is preserved in the insulation panels. During demolition and reconstruction and works dealing with EPS/XPS insulation panels as well as during the handling of the boards for recovery and disposal, dust could be generated and cause an exposure via inhalation. In order to minimise environmental and especially health risks, dust generation should be avoided and it might be reasonable to apply personal protection measures (breathing masks), in order to avoid potential inhalation of HBCD-containing dust.

Landfilling:

HBCD is landfilled only unintentionally and in small amounts adhering to mineral construction waste. Through separation of impurities from the mineral fraction to the largest extent possible and their appropriate disposal (energy recovery) the effect of transfer and global distribution can be minimised.

EPS and XPS apart from the construction sector

In practice, HBCD-containing EPS insulation materials are partly mixed and recycled with EPS packaging waste in Germany. This practice leads to the risk of further transfer of the HBCD content into various plastic products and thus to uncontrolled global distribution, with the corresponding risks for human health and the environment. The risk can be minimised by separate collection and treatment of EPS/XPS insulation materials and EPS packaging to the largest extent possible.

High Impact Polystyrene (HIPS) in the electronic industry

Typical HIPS products usually occur as WEEE or possibly to a small extent as plastic fraction in construction waste. In addition, a certain proportion of WEEE enters the household waste. The plastic fractions of construction and household waste are typically energetically recovered.

Post-consumer plastic waste arising from electrical and electronic devices is energetically recovered (90.0%), recycled (7.5%) or landfilled (2.5%).

Hence the majority of plastics from WEEE are used for energy recovery. In individual cases HIPS from the treatment of WEEE is used for the manufacture of PS recyclates. A minor share of the plastic waste is landfilled.

A relevant part of the used electronic equipment is exported from Germany. Adequate disposal or recovery leading to the destruction of the POP content is not necessarily ensured in the importing countries. Thus the disposal of WEEE in the recipient countries and its contribution to global distribution cause risks to human health and the environment. This risk can be minimised by a restriction of corresponding exports to countries, where appropriate recovery and disposal of WEEE are ensured.

Mechanical recycling:

Analytical results of a PS recyclate from WEEE confirm a significant HBCD content of 184 mg/kg in the recyclate.

During the recycling processes, POPs are usually neither destroyed nor generated. The HBCD content is preserved and entails the risk of a further transfer of HBCD into various plastic products, thus resulting in uncontrolled global distribution and the corresponding risks for human health and the environment.

A specific health or environmental risk is possible in case the shredding processes lead to the emission of HBCD-containing dust into the environment or to the exposure of workers via inhalation.

The risk can be minimised by separation of brominated plastics from WEEE to the largest extent possible, as already stipulated in Directive 2012/19/EU. As not all brominated plastics are separated in practice, it has to be assumed that HBCD is transferred into recyclates.

Energy recovery:

It can be assumed that HBCD-containing waste can be incinerated in state-of-the-art waste incineration plants in such a way, that the HBCD content is largely destroyed and that the risk of other POPs being generated in relevant amounts is kept at a minimum.

Landfilling:

A minor share of the plastics from WEEE is landfilled. Specific health or environmental risks cannot be excluded and are represented in the long run especially due to the risk of uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised through separation of HBCD-containing plastics to the largest extent possible and through their appropriate disposal.

HBCD-containing polymer dispersions for textiles – institutional sector

Flame retarded textiles from the institutional sector are disposed of together with mixed municipal waste or bulky waste in Germany and it is assumed that they are predominantly incinerated or recovered (>90%). A fraction of less than 10% of the relevant waste amount may be mainly recycled, or to a low extent also landfilled.

The risk of uncontrolled global distribution and associated risks to human health and the environment are related to material recycling and landfilling, which should therefore be avoided as far as possible. For this purpose, thermal recovery of flame retarded textiles from the institutional sector produced before 2007 could be recommended.

It can be assumed that HBCD-containing waste can be incinerated in state-of-the-art waste incineration plants in such a way, that the HBCD content is largely destroyed and that the risk of other POPs being generated in relevant amounts is kept at a minimum.

HBCD-containing polymer dispersions for textiles – automotive sector

Flame retarded textiles from the automotive sector are disposed of and recovered together with end-of-life vehicles. During the recovery of end-of-life vehicles, textiles usually enter the shredder light fraction and are generally incinerated with energy recovery/disposed of (about 58%) or recycled (about 42%). According to estimates, the theoretical HBCD concentration in the shredder light fraction (total volume 400,000 t/a) amounts to 364 mg/kg. Consequently, the shredder light fraction would be affected by an LPCL of 100 mg/kg. Measurements regarding the HBCD content of the shredder light fraction in Germany are not available. Measurements carried out in Norway in 2007 and 2008 indicate that HBCD is rather irrelevant in the shredder light fraction from the recovery of end-of-life vehicles. Whether and to what extent HBCD is actually contained in the shredder light fraction in Germany could be examined by chemical analyses.

If the HBCD contents in the shredder light fraction are above 100 mg/kg, an LPCL of 100 ppm would mean that about 170 kt/a of the shredder light fraction would have to be incinerated with energy recovery/disposed of instead of being recycled as before. This would imply significant additional costs and the energy recovery of the shredder light fraction also acts counter to the aim of increasing the recycling rate for used vehicles.

In case the shredder light fraction has significant HBCD contents, its recycling could lead to uncontrolled global distribution and the corresponding risks to human health and the environment and should therefore be avoided as far as possible (e.g. by complete energy recovery of the shredder light fraction or the separation of flame retarded textiles produced before 2007).

It can be assumed that HBCD-containing waste can be incinerated in state-of-the-art waste incineration plants in such a way, that the HBCD content is largely destroyed and that the risk of other POPs being generated in relevant amounts is kept at a minimum.

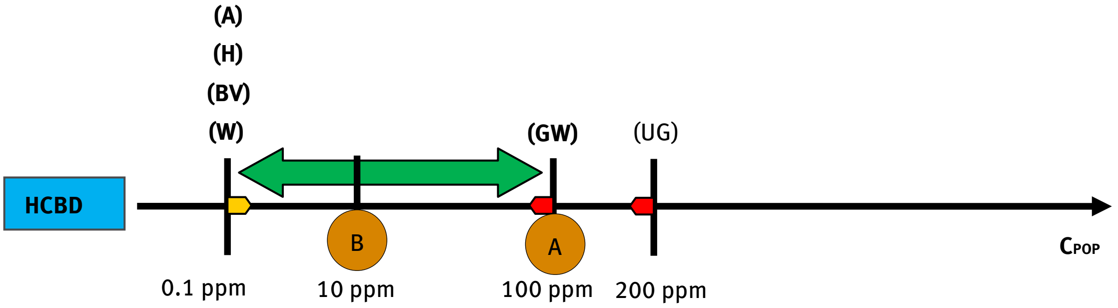
An overview of recovery and disposal operations for HBCD and other substances/substance groups is given at the beginning of section 8 (see Table 94).

8.2 HCBD

8.2.1 Low POP concentration limit

Based on the analysis of the evaluation criteria, a range of 0.1 to 100 mg/kg results for the LPCL for HCBD (see section 7.3.3 and Figure 63).

Figure 65: Results from the evaluation of the limitation criteria for HCBD (Explanations in Table 95)



According to the project results, an LPCL of up to 0.1 mg/kg will not affect any relevant waste fractions or recyclates.

In the current draft amendment to the EU POP Regulation, a value of 100 mg/kg is proposed. Unless there are relevant reasons, the LPCL should not exceed 100 mg/kg. In order to minimise risks, it would also be possible to set the LPCL for HCBD to 10 mg/kg (or even below) without any practical consequences.

8.2.2 Recommendations for recovery and disposal operations

In 1982, the worldwide production of HCBD was about 10,000 t/a. This amount occurred mainly as a by-product during chlorination processes. In Germany, HCBD was never produced intentionally. However, in the late 1970s, about 4,500 t were formed annually as by-product during low-pressure chlorolysis in the production of perchloroethylene (PER) and tetrachloromethane (TETRA). According to estimations of the UNEP POPRC Committee, HCBD is no longer intentionally produced and used in Germany and the whole UNECE region. In Germany, HCBD has already no longer been used since 1987. Disregarding historical uses and emissions of HCBD, the unintentional production of HCBD is cited as the largest source of emissions (see section 3.3.4).

In principle the following sources are possible:

- Products from historic uses, which enter the waste stream

- Unintentional production –production of organochlorine compounds
- Unintentional production – incineration processes
- Unintentional production – production of plastics
- Waste resulting from waste water treatment (sewage sludge)

According to the results of this research project, HCBD-containing waste streams or recyclates result from none of the possible sources in Germany.

Against the legal background - also due to the expected entry of HCBD in the Stockholm Convention in addition to the EU POP Regulation - it is assumed that also in the future, HCBD will not be contained in relevant amounts in wastes and products in Germany.

As a result of this assessment, HCBD-containing wastes have no practical significance in Germany. Therefore the recommendation of specific recovery and disposal operations is not necessary.

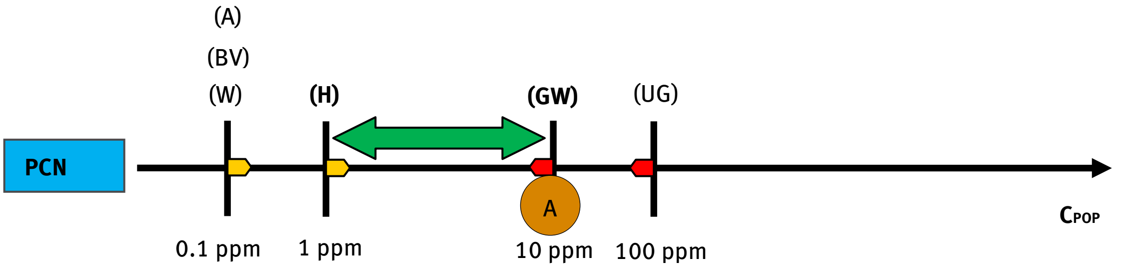
Basically, it can be assumed that HCBD is largely destroyed by the controlled incineration in accordance with Directive 2000/76/EC. During state-of-the-art incineration, destruction rates of more than 99.9% can be achieved (see [BiPRO 2011]).

8.3 PCN

8.3.1 Low POP concentration limit

Based on the analysis of the evaluation criteria it is proposed to set the LPCL for PCN in the range of 1 to 10 mg/kg (see section 7.3.3 and Figure 64).

Figure 66: Results from the evaluation of the limitation criteria for PCN (Explanations in Table 95)



In the current draft amendment to the EU POP Regulation, a limit value of 10 mg/kg is proposed. Unless there are relevant reasons, the LPCL should not exceed 10 mg/kg. In order to minimise risks, it would also be possible to set the LPCL for PCN to 1 mg/kg without any practical consequences. A limit value below 1 mg/kg could lead to conflicts due to existing background contaminations.

According to the project results an LPCL of 10 mg/kg would not affect relevant waste fractions or recyclates in Germany. However, it cannot be entirely excluded, that waste from the production of secondary copper may contain relevant amounts of PCN.

The current draft amendment to the POP Regulation does not specify what the proposed limit value applies to. For a clear setting of the limit value and the practical implementation it is necessary to establish adequate specifications.

Theoretically, all 75 PCN congeners can be analysed and quantified. For this purpose, however, an enormous effort is required. As a pragmatic approach, it is advisable to refer the limit value to the sum concentration of certain indicator congeners. As indicator congeners, congeners should be selected which are available for the chemical standard substances. Standard substances are required for a reliable quantification.

As a pragmatic approach, it seems reasonable to base chemical analyses on the indicator congeners selected during the present research project, taking into account the practical feasibility (i.a. due to the availability of standards). The following congeners were analysed:

▸ 1,2,3,4-TetraCN	(CN 27)	CAS 20020-02-4
▸ 1,2,3,5,7-PentaCN	(CN 52)	CAS 53555–65–0
▸ 1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	(CN 66/67)	CAS 103426–96–6/103426–97–7
▸ 1,2,3,5,7,8-HexaCN	(CN 69)	CAS 103426–94–4
▸ 1,2,3,4,5,6,7-HeptaCN	(CN 73)	CAS 58863–14–2
▸ OctaCN	(CN 75)	CAS 2234–13–1

For the applied method, the detection limits are indicated as follows: detection limits of 10-100 µg/kg for PCN-free samples; for samples with significantly higher contents, the detection limit can be correspondingly higher due to lower required initial weights or higher dilution.

In this research project the samples were analysed for the above-mentioned congeners with detection limits <5 µg/kg. If these detection limits were added up, a sum detection limit <30 µg/kg (0.03 ppm) would result.

Against this background, it could be useful to apply the limit value of 10 mg/kg for PCN to the sum concentration of the congeners 27, 52, 66/67, 69, 73 and 75. After an initial assessment these congeners are relevant in environmental samples and commercial PCN.

For further considerations on the definition of a reference parameter for a PCN limit value the draft standard for the investigation of PCN in water from March 2014 (DIN ISO 16780) and its further development as well as the quantitative relevance of the congeners should be taken into account. For the setting of a limit value in waste, a consideration of the toxicological relevance is not necessarily required. A draft standard exists since March 2014 (ISO 16780) for the PCN analysis in water. This draft provides for the analysis of a significantly larger number of PCN congeners[70]. The laboratory assumes that this larger PCN extent can be covered by appropriate standard substances[71].

8.3.2 Recommendations for recovery and disposal operations

Waste containing PCN is classified as hazardous waste under the new Annex VIII of the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal. The limit value amounts to 50 mg/kg.

Due to the limited life cycle time of relevant products, it is assumed that the PCN amounts remaining in products are small and that currently only insignificant amounts enter the waste stream in this way in Germany (see section 3.4.5).

Commercial PCB mixtures contained traces of PCN. It is therefore possible that PCN traces can be found in PCB-containing waste. In the context of Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCBs/PCTs), i.e. the disposal of all PCB-containing products by 2010, it is to assume that no or negligibly few PCN-containing products are still in circulation.

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[70] Mono-CN: 1 congener; Di-CN: 1 congener; Tri-CN: 1 congener; Tetra-CN: 6 congeners; Penta-CN: 6 congeners (1x as co-elution of 2 congeners); Hexa-CN: 9 congeners (3x as co-elution of 2 congeners); Hepta-CN: 2 congeners; Octa-CN: 1 congener

[71] Personal notification, Eurofins, August 2014

Apart from the release of PCN by former uses, different industrial –in particular thermal – processes can play a role. These include

- Waste incineration
- Production of secondary copper
- Production of secondary aluminium
- Chlor-alkali electrolysis

According to the results of this research project, relevant PCN-containing waste streams or recyclates result neither from former uses nor from the examined processes in Germany. For the production of secondary copper no samples could be obtained and chemically analysed for the verification of this assessment. Against the legal background – also due to the expected entry of PCN in the Stockholm Convention in addition to the EU POP Regulation – it is assumed that also in the future, PCN will not be contained in relevant amounts in waste and products in Germany.

As a result of this assessment PCN-containing waste has no practical significance in Germany. Therefore the recommendation of specific recovery and disposal operations is unnecessary.

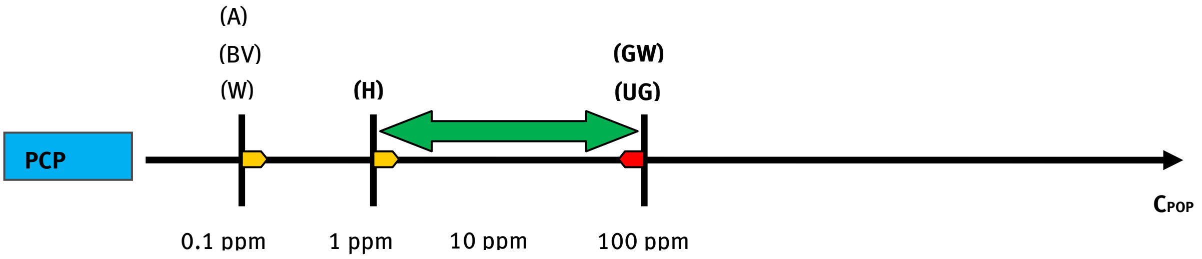
Basically, it can be assumed that PCN are largely destroyed by the controlled incineration in accordance with Directive 2000/76/EC. During the incineration of PCN-containing waste (municipal waste and contaminated conveyor belts) destruction rates between 99.32 and 99.96% are achieved [Noma et al. 2004].

8.4 PCP

8.4.1 Low POP concentration limit

The current draft amendment to the POP Regulation does not contain a proposed limit value for PCP. Based on the analysis of the evaluation criteria it is proposed to set the LPCL for PCP in the range of 1 to 100 mg/kg (see section 7.3.3 and Figure 65).

Figure 67: Results from the evaluation of the limitation criteria for PCP (Explanations in Table 95)



As an upper limit criterion, the existing limit values for PCP at national and international level were considered in order to avoid possible conflicts between the existing and the proposed LPCLs. The possible LPCL for PCP should not exceed the existing limit according to the Chemicals Prohibition Ordinance (ChemVerbotsV; original designation in German: Chemikalienverbotsverordnung), (Appendix to § 1, section 15). The LPCL for PCP should therefore not exceed 100 mg/kg. Moreover, by applying a limit value of less than 100 mg/kg, possible effects on human health and the environment are largely avoided.

In order to minimise risks, it would be possible to further reduce the LPCL to 10 mg/kg or even to 1.0 mg/kg. However, it is recommended not to set the LPCL below 1.0 mg/kg as the limit value should be above the existing environmental background contamination of PCP. A limit value below the background contamination would have considerable economic consequences.

8.4.2 Recommendations for recovery and disposal operations

PCP is currently neither produced nor used in Germany. PCP was the most widely used active substance in wood preservatives for a long time period. Due to the partly very long life cycle time of preserved wooden products, especially in the construction sector, it has to be assumed that PCP-containing wood continues to arise as waste and will have to be recovered and/or disposed of in the future. For instance, PCP still poses problems in connection with the recycling of construction wastes and has been identified over the recent years in the scope of documentation and verification. Moreover, in the course of this research project, PCP was detected analytically in relatively low concentrations in four waste wood samples (~0.04 – 0.4 mg/kg). The use of PCP in textile and leather products, paper, inks, adhesives, etc. was reported decades ago, but has no longer been confirmed since then. Due to the relatively short life cycle times of many of these products, it can be assumed that these occurred as waste already many years ago and were subsequently recovered or disposed of. The corresponding waste streams were therefore not further considered.

The Wood Waste Ordinance (original designation in German: Altholzverordnung; AltholzV) regulates the recovery and disposal of wood waste in Germany. Depending on the content of contaminants, wood waste has to be classified in different wood waste categories (categories AI – AIV) and has to be treated accordingly. According to the AltholzV, the recovery of wood waste classified as wood waste of category AIV as wood chips for the manufacture of derived timber products (e.g. chipboard) is not permitted in Germany. However in practice, parts of impregnated wood waste can be disseminated into other wood waste categories and therefore be recycled. Annex II to §3, Abs. 1 of AltholzV sets a limit value of 3 mg PCP/kg dry matter for wood chips for the manufacture of derived timber products. Plant operators need to ensure compliance with the set limit value. In order not to exceed the set limit values, the operators of wood waste treatment installations have to take samples batchwise and analyse them. Basically, it cannot be excluded that derived timber products contain PCP also in higher concentrations. In the course of this research project, one random sample (large chipboard with waste wood fraction) was analytically examined on PCP. In this chipboard, a PCP concentration of ~0.03 mg/kg was measured. Hence the contamination lies significantly below the concentration threshold of 3 mg/kg determined in the AltholzV.

Landfilling of waste wood is not permitted in Germany. It is assumed that PCP-contaminated wood waste is recovered and disposed of together with other wood waste classified as hazardous. About 95% of the wood waste classified as hazardous is currently used for energy recovery and incinerated. The remaining 5% is used for the production of synthesis gas and the manufacture of activated carbon.

Due to high incineration temperatures in energy recovery/incineration it can be assumed that the PCP content in wood waste is almost completely destroyed. In order to guarantee a high destruction rate, the incineration temperature should reach at least 800°C. Thus, destruction rates of >99.9% can be reached. Under controlled incineration conditions, the generation of new POPs can also be excluded. An environmental and health risk remains if PCP-containing wood waste has to be broken down mechanically before energy recovery/incineration, as dust can be generated during the handling of contaminated wood waste. In order to minimise possible environmental and especially health risks, dust generation should be avoided as far as possible. Personal protection measures should be applied, in order to avoid potential inhalation of PCP-containing dust.

A comparatively small amount of PCP-containing wood waste (~5%) is recovered (without energy recovery). The recovery operations permitted in Germany for wood waste of wood waste category IV are the production of synthesis gas for further chemical purposes as well as the production of activated carbon/industrial charcoal (installations licensed pursuant to §4 of the German Federal Immission Control Act/BImSchG). At an LPCL of 100 ppm, approximately 57.5 kt/a of waste wood, which is currently used for the production of synthesis gas and activated carbon, would have to be directed to incineration and/or energy recovery. As it is assumed that the PCP content in the waste is almost completely destroyed during both recovery operations (due to similarly high process temperatures as during thermal disposal/recovery), an alternative treatment of the concerned waste stream may not be required. However, corresponding destruction rates are not known. If the waste is to be recovered/disposed of thermally nevertheless, sufficient incineration capacities are available in Germany.

The PCP amount in impregnated waste wood arising in 2013 was estimated to be ca. 140 t. This is equivalent to a waste stream of approximately 224 kt. Since no new PCP inputs into the economic cycle have occurred in Germany for a long time period, it is expected that the annual arising amounts of PCP-containing wastes will decrease continuously over the next years. Relevant waste amounts are theoretically to be expected until 2030. It is recommended to further use the recovery and disposal operations currently existing in Germany. In order to avoid PCP being transferred into derived timber products, wood waste should be collected separately in different categories according the AltholzV and should be directed to the different permitted recovery and disposal operations. Generally, the recovery of wood waste can also be performed abroad, if done in compliance with the provisions of the Council Regulation on waste shipments and the German waste shipment law.

8.5 SCCP

8.5.1 Low POP concentration limit

In the current draft amendment of the EU POP Regulation a limit value of 10,000 mg/kg is proposed in order to avoid conflicts with the concentration threshold of 1% by weight determined in Annex I of the Regulation. According to Annex I the following derogations are granted for the use of SCCP:

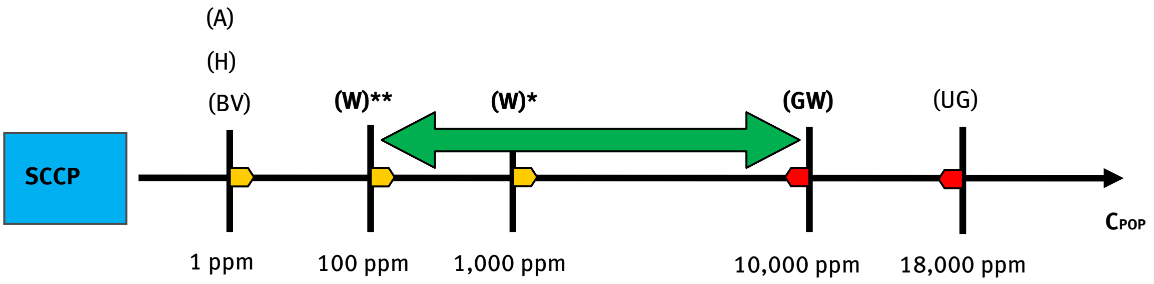
1. *"By way of derogation, the production, placing on the market and use of substances or preparations containing SCCP in concentrations lower than 1 % by weight shall be allowed.*
2. *By way of derogation, the production, placing on the market, and use of the following applications shall be allowed provided that Member States report to the Commission no later than 2015 and every four years thereafter on the progress made to eliminate SCCP:*

   a) fire retardants in rubber used in conveyor belts in the mining industry;

   b) fire retardants in dam sealants."

Based on the analysis of the evaluation criteria it is proposed to set the LPCL for SCCP in the range of 100 to 10,000 mg/kg (see section 7.3.3 and Figure 66).

Figure 68: Results from the evaluation of the limitation criteria for SCCP (Explanations in Table 95)



The existing limit values for SCCP at national and international level were taken into account as upper limitation criteria in order to avoid conflicts between the existing limit values and the proposed LPCL. For SCCP a possible LPCL should not exceed the existing limit value according to Annex I of the EU POP Regulation. The LPCL should therefore not exceed 10,000 mg/kg.

In order to minimise risks, it is possible to set the LPCL for SCCP to 1,000 mg/kg or even to 100 mg/kg. The limit value would have to lie above 350 mg/kg (for instance at 1,000 mg/kg), as otherwise a large proportion of the total rubber waste in Germany could not be directed to material recovery any longer. As an alternative, the LPCL could be set to 100 mg/kg, in case the SCCP-containing rubber waste is separated successfully from other rubber waste and is treated separately. However, it is recommended not to set the LPCL below 100 mg/kg in order to avoid adverse economic effects.

8.5.2 Recommendations for recovery and disposal operations

SCCP have no longer been produced in Germany since the mid-90s. Current information on SCCP imports and exports to/from Germany is not available. In the past, imports of SCCP from non-EU countries played a minor role. This could have changed due to the increased prices for chlorinated paraffins.

Assuming that the estimated total SCCP consumption in the EU has remained constant and that the consumption is roughly proportional to the size of the population, a current total SCCP consumption of about 85 t was roughly estimated for Germany. At present the most important application fields for SCCP are the use as flame retardants in rubber conveyor belts for the mining industry (about 26 t) and the use as softeners and flame retardants in sealants for the construction sector (about 38 t).

However, the European Commission proposes to adjust Annex I to the POP Regulation to technological progress and to delete the above-mentioned applications from the Annex to the Regulation. Whether and when this will be realised is not certain yet. Thus, it is not possible to elaborate a prognosis on the future development of SCCP. In general it is expected that the use of SCCP will cease and the annual arising waste amounts will decrease continuously. Nowadays, appropriate alternatives for both applications are on the market. Some companies have already managed to substitute SCCP successfully.

On the basis of former and current consumption quantities of SCCP, the relevant waste amounts were estimated for Germany. The most relevant waste streams are rubber waste from used rubber conveyor belts and sealants from construction and demolition waste. In 2013, an estimated 1,760 t of rubber from SCCP-containing rubber conveyor belts and an estimated 330 t of SCCP-containing sealants were recovered and disposed of.

Rubber waste

In Germany, rubber from used rubber conveyor belts is directed to material recovery. In this context, it cannot be excluded that SCCP might also be released into recyclates. In the absence of specific information on the disposal of used rubber conveyor belts from underground mining, and under consideration of the information gathered in interviews with rubber recycling companies, it is assumed that the relevant rubber waste from used conveyor belts is treated/disposed of together with other rubber waste in Germany. The SCCP concentration of the total waste is therewith reduced to about 350 ppm. Approximately 62% (312.1 kt/a) of the rubber waste is directed to material recovery in Germany.

During the recycling processes, POPs are usually neither destroyed nor generated. Therefore there is the risk that SCCP might be released into recyclates (e.g. floorings for halls, playgrounds etc.). Relatively small SCCP concentrations are preserved in the recyclates, respectively in various rubber products, for long time periods, resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. The risk can be minimised through separation of SCCP-containing rubber conveyor belts from underground mining as far as possible and through the choice of appropriate treatment operations. Moreover, further environmental and health risks before the actual material recovery cannot be excluded. The material recovery is only possible for minor amounts of non-dangerous, small metal impurities. Larger metal components would damage the shredders and mills. Hence, the metal fraction of the conveyor belt has to be separated from the rubber fraction as far as possible before the actual material recovery. This can result in dust generation and therefore presents a potential environmental and health risk. In order to minimise the risk, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.

In consultation with the UBA, two rubber samples (used rubber conveyor belt and granules from used conveyor belts) were analysed regarding SCCP. The small SCCP concentration of the analysed rubber conveyor belt indicates that the random sample was not obtained from an SCCP-containing conveyor belt. As to the analysed granules from used rubber conveyor belts, it can also be excluded that SCCP-containing rubber was recovered in the production of the granules. In the course of the project, several well-known producers of conveyor belts, mining companies and rubber recycling companies were contacted. There was little willingness to contribute information and samples to the project. The use of SCCP for the treatment of rubber conveyor belts is still permissible and relevant waste amounts arise annually in Germany and have to be treated/disposed of. Therefore, it cannot generally be excluded that SCCP might be transferred into recyclates. Since, under the described circumstances, no further relevant samples could be gathered, no final statement could be made concerning the relevance of this sector. In order to assess the relevance of this sector in Germany regarding the occurrence of SCCP, samples from rubber conveyor belts for the use in underground mining or corresponding granules would have to be analysed.

Sealants

In the absence of exact information on treatment/disposal of sealants and due to their properties it is assumed, that a considerable share of sealants and adhesives applied in the construction sector adheres to the surface of the construction materials (especially on concrete, tiles, bricks and ceramics) and is treated together with these types of waste. Hence in practice, it is not expected that the sealants can be separated completely and treated separately. It is assumed that about two thirds of the SCCP-containing waste stream are treated/disposed of together with other construction waste. One third of the relevant waste stream is separated successfully and is subsequently disposed of in hazardous waste incineration plants.

In consultation with the UBA, four samples of joint sealants from construction waste processing facilities were analysed regarding SCCP. Three of the four analysed joint sealants have SCCP contents above 1,000 ppm. In one joint sealant a significantly lower SCCP concentration was detected. As partly relatively high concentrations of MCCP were detected in the samples, influences of MCCP cannot be excluded. The analysed samples could also be MCCP-containing sealants, which have an SCCP share of about 0.5-1%. In case the joint sealants were treated with SCCP exclusively, the concentrations should be significantly higher (at least 5%).

During recycling processes, POPs are usually neither destroyed nor generated. Therefore there is a specific risk that SCCP might be released into recyclates and therefore into various products. Relatively small SCCP concentrations are preserved for long time periods in various products used in the construction industry, resulting in uncontrolled global distribution and the corresponding risks for human health and the environment. However, due to the mixture, the expected SCCP concentration in the products would be negligible. The risk can be minimised through separation of SCCP-containing sealants as far as possible. However, complete separation is not feasible in practice, especially due to their properties. In case the sealants and adhesives can be separated successfully, it can be assumed that they are disposed of thermally (e.g. suspected PCB-containing joint sealants have to be collected separately and directed to hazardous waste incineration). Due to high incineration temperatures (>1,000°C) it can be assumed that the SCCP content in the waste is almost completely destroyed. However, the exact destruction rates for SCCP have not been identified. When removing sealants from buildings, fast running machines should not be used in order to avoid heat generation.

In general, landfilling involves the risk that SCCP could be released from the landfill site into the environment. Under the presumption that the SCCP-containing waste stream is treated together with concrete, tiles, bricks and ceramic waste, the mixed waste stream would be relatively extensive, while the theoretical SCCP concentration would be negligible. Due to the minor SCCP concentration no specific environmental or health risks have to be expected. Separation to the largest extent possible can minimise the effect of transfer and global distribution.

Rubber waste and sealants

SCCP are thermally decomposed at only 200 C. Due to high incineration temperatures in energy recovery/incineration (>800°C), it can be assumed that the SCCP content in used rubber conveyor belts and sealants is almost completely destroyed. However, exact destruction rates for SCCP have not been identified. A health or environmental risk has to be expected in case SCCP-containing rubber waste has to be broken down mechanically before the energy recovery/incineration (dust generation). In order to minimise environmental and especially health risks, dust generation should be avoided as far as possible. Inhalation of contaminated dust can be avoided by the application of breathing masks.

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10 Annex

Results of the laboratory analyses – HBCD

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	1 HBCD	Containing PS-E insulation material (grinded XPS from insulation materials from the construction sector, which is used for the production of recyclates)	alpha-HBCD	17,600.000	74.9
			beta-HBCD	3,820.000	16.3
			gamma-HBCD	2,070.000	8.8
			HBCD (Sum alpha, beta, gamma)	**23,500.000**	**100.0**
Detection limit: 15 mg/kg					

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	2 HBCD	Waste from construction waste processing facility, containing PS-E insulation material (grinded EPS from insulation materials from the construction sector)	alpha-HBCD	407.000	11.7
			beta-HBCD	273.000	7.9
			gamma-HBCD	2,790.000	80.4
			HBCD (Sum alpha, beta, gamma)	**3,470.000**	**100.0**
Detection limit: 1.5 mg/kg					

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	5 HBCD	Recyclate from PS-E insulation material (granules from recycled PS)	alpha-HBCD	13,900.000	74.3
			beta-HBCD	3,110.000	16.6
			gamma-HBCD	1,690.000	9.0
			HBCD (Sum alpha, beta, gamma)	**18,700.000**	**100.0**
Detection limit: 15 mg/kg					

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	**8 HBCD**	PS-E packaging waste (EPS-mixed fraction; packaging waste)	alpha-HBCD	0.037	22.4
			beta-HBCD	0.011	6.7
			gamma-HBCD	0.116	70.3
			HBCD (Sum alpha, beta, gamma)	**0.165**	**100.0**
Detection limit: 0.00015 mg/kg					

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	**9 HBCD**	PS-E packaging waste (grinded packaging material)	alpha-HBCD	1.520	3.6
			beta-HBCD	3.310	7.9
			gamma-HBCD	37.200	88.6
			HBCD (Sum alpha, beta, gamma)	**42.000**	**100.0**
Detection limit: 1.5 mg/kg					

	Sample number	Sample description	Parameter	Result [mg/kg]	Share of isomers [%]
	**10 HBCD**	Recyclate from PS-E packaging and insulation material (granules from recycled PS)	alpha-HBCD	1,920.000	43.5
			beta-HBCD	436.000	9.9
			gamma-HBCD	2,050.000	46.5
			HBCD (Sum alpha, beta, gamma)	**4,410.000**	**100.0**
Detection limit: 1.5 mg/kg					

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**	**Share of isomers [%]**
	11 HBCD	PS-E packaging waste (packaging chips)	alpha-HBCD	7.280	n.a.
			beta-HBCD	2.400	n.a.
			gamma-HBCD	< 1.70	n.a.
			HBCD (Sum alpha, beta, gamma)	**9.670**	**100.0**
Detection limit: 1.7 mg/kg					

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**	**Share of isomers [%]**
	12 HBCD	Recyclate from PS-E packaging and insulation material (granules from recycled PS)	alpha-HBCD	867.000	55.9
			beta-HBCD	282.000	18.2
			gamma-HBCD	403.000	26.0
			HBCD (Sum alpha, beta, gamma)	**1,550.000**	**100.0**
Detection limit: 1.5 mg/kg					

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**	**Share of isomers [%]**
	12 b HBCD	Recyclate from PS-E packaging	alpha-HBCD	7.220	73.5
			beta-HBCD	1.630	16.6
			gamma-HBCD	0.960	9.8
			HBCD (Sum alpha, beta, gamma)	**9.820**	**100.0**
Detection limit: 0.00015 mg/kg					

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**	**Share of isomers [%]**
	13 HBCD	Brominated waste from WEEE	alpha-HBCD	1.990	68.6
			beta-HBCD	0.510	17.6
			gamma-HBCD	0.390	13.4
			HBCD (Sum alpha, beta, gamma)	**2.900**	**100.0**
Detection limit: 0.00015 mg/kg					

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**	**Share of isomers [%]**
	13 b HBCD	PS recyclate from WEEE	alpha-HBCD	132.000	71.7
			beta-HBCD	31.000	16.8
			gamma-HBCD	20.600	11.2
			HBCD (Sum alpha, beta, gamma)	**184.000**	**100.0**
Detection limit: 1.5 mg/kg					

Results of the laboratory analyses – HCBD

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	14 HCBD	Slag facility A batch 1	HCBD	< 0.00887
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	15 HCBD	Slag facility A batch 2	HCBD	< 0.00924
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	16 HCBD	Sewage sludge (municipal waste water treatment)	HCBD	< 0.00054
< - concentration below the indicated detection limit				

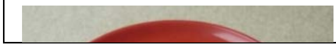
Results of the laboratory analyses - HCBD/PCN

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	18 HCBD/ PCN	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	1,2,3,4,5,6,7-HeptaCN	< 0.00494
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00494
			1,2,3,4-TetraCN	< 0.00494
			1,2,3,5,7,8-HexaCN	< 0.00494
			1,2,3,5,7-PentaCN	< 0.00494
			OctaCN	< 0.00494
			HCBD	< 0.00987
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	19 HCBD/ PCN	Slag MWI facility A (slag is generated as a mixture with solid residues from flue gas scrubbing)	1,2,3,4,5,6,7-HeptaCN	< 0.00491
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00491
			1,2,3,4-TetraCN	< 0.00491
			1,2,3,5,7,8-HexaCN	< 0.00491
			1,2,3,5,7-PentaCN	< 0.00491
			OctaCN	< 0.00491
			HCBD	< 0.00982
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	20 HCBD/ PCN	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	1,2,3,4,5,6,7-HeptaCN	< 0.00481
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00481
			1,2,3,4-TetraCN	< 0.00481
			1,2,3,5,7,8-HexaCN	< 0.00481
			1,2,3,5,7-PentaCN	< 0.00481
			OctaCN	< 0.00481
			HCBD	< 0.00962
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	21 HCBD/ PCN	Ash MWI facility A (filter ash and boiler ash are generated as a mixture)	1,2,3,4,5,6,7-HeptaCN	< 0.0047
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.0047
			1,2,3,4-TetraCN	< 0.0047
			1,2,3,5,7,8-HexaCN	< 0.0047
			1,2,3,5,7-PentaCN	< 0.0047
			OctaCN	< 0.0047
			HCBD	< 0.0094
< - concentration below the indicated detection limit				

	**Sample**	**Sample description**	**Parameter**	**Result**

	number			[mg/kg]
	22 HCBD/ PCN	Filter ash MWI, facility B (mixed sample from 4 vessels over the time period of the 3rd Quarter 2013)	1,2,3,4,5,6,7-HeptaCN	< 0.00446
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00446
			1,2,3,4-TetraCN	< 0.00446
			1,2,3,5,7,8-HexaCN	< 0.00446
			1,2,3,5,7-PentaCN	< 0.00446
			OctaCN	< 0.00446
			HCBD	< 0.00892
< - concentration below the indicated detection limit				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	23 HCBD/ PCN	Filter dust HWI facility 1	1,2,3,4,5,6,7-HeptaCN	< 0.00469
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00469
			1,2,3,4-TetraCN	< 0.00469
			1,2,3,5,7,8-HexaCN	< 0.00469
			1,2,3,5,7-PentaCN	< 0.00469
			OctaCN	< 0.00469
			HCBD	< 0.00937
< - concentration below the indicated detection limit				

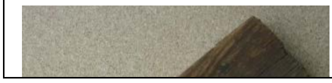
	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	24 HCBD/ PCN	Filter dust HWI facility 2	1,2,3,4,5,6,7-HeptaCN	< 0.00492
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00492
			1,2,3,4-TetraCN	< 0.00492
			1,2,3,5,7,8-HexaCN	< 0.00492
			1,2,3,5,7-PentaCN	< 0.00492
			OctaCN	< 0.00492
			HCBD	< 0.00983
< - concentration below the indicated detection limit				

Results of the laboratory analyses - PCN

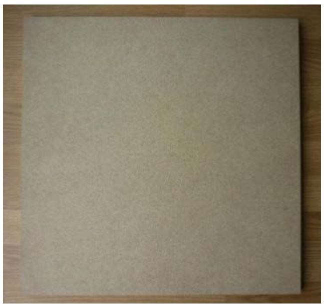
	Sample number	Sample description	Parameter	Result [mg/kg]
	**26 PCN**	Filter dust sec. Al facility	1,2,3,4,5,6,7-HeptaCN	< 0.00471
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00471
			1,2,3,4-TetraCN	< 0.00471
			1,2,3,5,7,8-HexaCN	< 0.00471
			1,2,3,5,7-PentaCN	< 0.00471
			OctaCN	< 0.00471
< - concentration below the indicated detection limit				

	Sample number	Sample description	Parameter	Result [mg/kg]
	**28 PCN**	Salt slag sec. Al facility	1,2,3,4,5,6,7-HeptaCN	< 0.00503
			1,2,3,4,6,7-/1,2,3,5,6,7-HexaCN	< 0.00503
			1,2,3,4-TetraCN	< 0.00503
			1,2,3,5,7,8-HexaCN	< 0.00503
			1,2,3,5,7-PentaCN	< 0.00503
			OctaCN	< 0.00503
< - concentration below the indicated detection limit				

Results of the laboratory analyses – PCP

	Sample number	Sample description	Parameter	Result [mg/kg]
	**31 PCP**	Impregnated waste wood (waste wood category IV, shredded, mostly railway sleepers)	PCP	0.041
Detection limit: 1 µg/kg				
	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**

	32 PCP	Impregnated waste wood (wood from exterior use; fence type "Jägerzaun", ca. 35 years)	PCP	0.073
Detection limit: 1 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	33 PCP	Recycled chipboard (large chipboard, produced in Germany)	PCP	0.031
Detection limit: 1 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	34c PCP	Chipboard (from waste wood processing facility)	PCP	0.064
Detection limit: 1 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	35 PCP	Impregnated waste wood (wood poles from exterior use, probably in contact with soil)	PCP	0.401
Detection limit: 1 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	36 PCP (= 54 SCCP)	Special textile A (military poncho from mid/late 80s)	PCP	0.844
Detection limit: 1 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	37 PCP	Special textile B (textile covered military air mattress from mid/late 80s)	PCP	3.700
Detection limit: 100 µg/kg				

Results of the laboratory analyses - SCCP

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	44 SCCP	Used rubber conveyor belt from mining industry	SCCP	1.210
Detection limit: 250 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	47b SCCP	Granules from used conveyor belts	SCCP	0.094
Detection limit: 25 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	48 SCCP	Joint sealant A	SCCP	1,030.000
Detection limit: 250,000 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	49 SCCP	Joint sealant B	SCCP	1.200
Detection limit: 250 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	50 SCCP	Joint sealant C	SCCP	1,190.000
Detection limit: 250,000 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	51 SCCP	Joint sealant D	SCCP	1,550.000
Detection limit: 250,000 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	53 SCCP	Special textile A (pilot’s cap from mid/late 80s)	SCCP	17.700
Detection limit: 2,500 µg/kg				

	**Sample number**	**Sample description**	**Parameter**	**Result [mg/kg]**
	54 SCCP (= 36 PCP)	Special textile B (military poncho from mid/late 80s)	SCCP	0.152
Detection limit: 25 µg/kg				