On behalf of:

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

of the Federal Republic of Germany

Umwelt Bundesamt

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Improvement of Handling Medical Waste in Healthcare Facilities in two Pilot Regions of the Russian Federation

Technical Standards for Healthcare Waste Treatment Technologies

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ON BEHALF OF THE
FEDERAL ENVIRONMENT AGENCY

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List of Abbreviations

BAT	Best Available Technology
BREF	Best Available Technolgy Reference
HCW	Healthcare Waste
HCWM	Healthcare Waste Management
EWL	European Waste List
IPPC	Integrated Pollution Prevention and Control
MoH	Ministry of Health
IEC	Information, Education, Communication
NGO	Non-Governmental Organization
PPE	Personal Protection Equipment
SanPin	Sanatarian Standards
WHO	World Health Organization
WI	Waste Incineration

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1 Scope

The purpose of this technical standard is to provide guidance and basic knowledge for the safe treatment of healthcare waste. In general there are two different general approaches:

1. Incineration of waste (Chapter 4)
2. Thermal treatment of waste (Chapter 5)

The scope therefore intended to provide a pragmatic view across the available healthcare waste treatment alternatives as a whole, with a particular focus upon those installation and waste types that are most common.

The objective of waste incineration, in common with most waste treatments, is to treat waste so as to reduce its volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances. Incineration processes can also provide a means to enable recovery of the energy, mineral and/or chemical content from waste

The purpose of the thermal treatment of waste is to inactivate microbiological contaminants and thereby to transform hazardous infectious waste into non-hazardous waste. Different kinds of steam based treatment systems are described in this document. Thermal waste treatment technologies are known as environmntal friendly, as no hazardous emissions or residues are generated.

The choice of treatment technolgies are depending beside other on:

- National and regional legal requirments,
- The waste kind which need to be treated,
- The amounts of waste to be treated,
- The financial background for investment,
- The financial background for operation and maintenance,
- The available technical know how.

2 Legal Background

2.1 Russian National and Regional Background

The Russian Standards on healthcare waste management (SanPin 2.1.7.2790-10) is providing guidance on the classification, collection, storage and treatment of waste. Healthcare waste is classified as follows:

Class A - the approximate composition to municipal solid waste

Class B - epidemiologically hazardous waste.

Class C - epidemiologically extremely hazardous waste.

Class D - toxicologically hazardous waste

Class E - radioactive waste.

Chapter V is providing guideance on techniques and methods of decontamination and / or neutralization of medical waste. In specific the treatment requirement of the epidemiologically hazardous waste (Class B) like potiential infectious waste and the epidemiologically extremely hazardous waste (Class C) like highly infectious waste is stated:

- Thermal decontamination of Class B and C waste can be done in a centralised or decentralised way by incineration or other alternative ways.
- Decentral decontamination of Class B waste by specific equipment on the the premises of a medical and / or pharmaceutical facilitiy must be in compliance with the requirements of sanitary legislation of the Russian Federation.
- Class B waste can only be sorted or recycled after decontamination of the waste. It is not allowed to use these recycled materials obtained from medical waste for the production of children's goods, materials and products in contact with drinking water and food, medical products.
- Onsite burial of decontaminated Class B and C waste is only if their physical appearance is changed (milling, sintering, molding, etc.) and if it can not be re-used.
- Decontamination and disposal of vaccines is carried out in accordance with the requirements of sanitary legislation of the Russian Federation to ensure the safety of immunization.

The right to emit hazardous substances into the atmosphere requires a permit that sets out the maximum permissible emission levels of the applicable hazardous substances.

In accorcance to article 14 of the Federal law no. 96-FZ on the protection of atmospheric air, dated 4 May 1999 emissions of the pollutants in the atmosphere by stationary sources shall be authorized by special permit issued by federal executive body in the sphere of environmental protection. The aforesaid authorization for the emission of the pollutants in the atmosphere must set maximum permissible limits and other terms and conditions that shall ensure the protection of the atmospheric air.

Hazardous Waste treatment facilities are licenced by the “Ministerial Decree No. 255”. An air emission permit must be obtained from Rosprirodnadzor. This permit sets the limits of emissions and other conditions for air protection.

2.2 European Legal Background – Incineration

2.2.1 The directive 2000/76/EC (WI Directive)

The Waste Incineration Directive (the WI Directive) entered into force on 28 December 2000. The aim of the WI Directive is to prevent or to reduce as far as possible negative effects on the environment caused by the incineration and co-incineration of waste. In particular, it should reduce pollution caused by emissions into the air, soil, surface water and groundwater, and thus lessen the risks which these pose to human health. The WI directive repealed the former directives on the incineration of hazardous waste (Directive 94/67/EC) and household waste (Directives 89/369/EEC and 89/429/EEC), accordingly the incineration of hazardous medical waste is covered by this directive.

The WI Directive sets emission limit values and monitoring requirements for pollutants to air such as:

- Dust
- Nitrogen oxides (NOx);
- Sulphur dioxide (SO_2);
- Hydrogen chloride (HCl)
- hydrogen fluoride (HF);
- heavy metals;
- dioxins and furans.

The Waste Incinerator Directive makes a distinction between:

1. Incineration plants (which are e.g. dedicated to the thermal treatment of hazardous medical waste) and
2. Co-incineration plants (less seldom used for hazardous medical waste, only in case of the incinerations of small amount of waste in high temperature cement or lime kilns).

In addition, many of the plants that are covered by the WI Directive are also covered by the Integrated Pollution Prevention and Control (IPPC) Directive. In these cases, the WI Directive only sets minimum obligations which are not necessarily sufficient to comply with the IPPC Directive.

2.2.2 The directive 2008/1/EC (IPPC Directive)

The directive 2008/1/EC concerning Integrated Pollution Prevention and Control was adopted on the 15 January 2008. The purpose of this Directive is to achieve integrated prevention and control of pollution arising from defined activities. One of these activities is the Managemetn of Hazardous Waste.

The implementation of the Integrated Pollution Prevention and Control (IPPC-Directive) should help to prevent or reduce emissions from industrial plants to air, water and soil through an integrated concept to the greatest extent possible.

The IPPC Directive requires from hazardous waste treatment activities to have a permit. This permit can only be issued if fixed environmental conditions are met. In order to receive a permit for a hazardous waste installation it must comply with certain basic obligations. In particular, it must:

- use all appropriate pollution-prevention measures, namely the Best Available Techniques – BAT (which produce the least waste, use less hazardous substances, enable the substances generated to be recovered and recycled, etc.);
- prevent all large-scale pollution and use energy efficiently;
- prevent, recycle or dispose of waste in the least polluting way possible;
- ensure accident prevention and damage limitation and return sites to their original state when the activity is over.

The Directive aims at a general European harmonisation which will contribute to both environmental protection and the reduction of distortions of competition between locations. One instrument which is central to the realisation of its goals is the creation of Best AVailable Technology References (BREFs) which lay down the best available techniques (BAT) in Europe for different types of industrial plants.

These BREF documents seek to assist the responsible authorities across Europe in issuing permits for industrial plants. In addition to the best available techniques, the BREFs also contain emission and consumption data, which give them a great factual weight in the approval of industrial plants but also for waste treatment plants and for incinerators. By this, these BREFs become relevant for the hazardous medical waste management.

2.2.3 Relevant „Best Available Techniques Reference"

No specific „Best Available Techniques References (BREF)" for hazardous medical waste treatment and disposal exist. However for the hazardous medical waste treatment sector, two of the BREF documents which are developed for the implementation of the IPPC Directive are of relevance:

- BREF "waste treatment industries": covering especially chemical and physical treatment plants (such as sterilizers and autoclaves for hazardous medical waste)
- BREF "waste incineration": covering installations for the incineration of hazardous and municipal waste which includes medical hazardous waste.

BREF "waste treatment industries"

This BREF covers the installations of a number of waste (hazardous and non-hazardous) treatments, and deals with:

- common waste treatments such as the temporary storage of waste, blending and mixing, repackaging, waste reception, sampling, checking and analysis, waste transfer and handling installations, and waste transfer stations
- physico-chemical treatments of waste such as neutralisation, chromic acid and cyanide treatments, dewatering, filtration, harbour reception facilities, oil/water separation, precipitation, separation of mercury from waste, settlement, solidification and stabilisation, and UV and ozone treatments
- treatments to recover mainly waste material such as the reconcentration of acids and bases, the recovery of metals from liquid and solid photographic waste, the regeneration of organic solvents and spent ion exchange resins, and the re-refining of waste oils etc.

The BREF shows further that waste management (which includes the medical waste management) covers strategic decisions on what type of waste is dealt with in each available waste treatment/process/option or what treatment is given to such a waste. This decision depends on the waste treatment options available at local, regional, national or international level, which also depends on the location where the waste is produced.

BREF "waste incineration”

This BREF covers installations for the incineration of hazardous and municipal waste and also includes the incineration of hazardous medical waste. The BREF divides the incineration sector into five main sub-sectors, of which the fifth is related to medical waste:

“v. Clinical waste incineration – dedicated installations for the treatment of healthcare waste, typically those arising at hospitals and other healthcare institutions, exist as centralised facilities or on the site of individual hospital etc. In some cases certain healthcare waste are treated in other installations, for example with mixed municipal or hazardous wastes.”

In addition to the thermal treatment stage of the installation, this BREF also covers for the different waste types (including hazardous medical waste):

- the reception, handling and storage of medical waste
- the effect of waste pre-treatment on the selection and operation of medical waste incineration processes
- applied flue-gas treatment techniques
- applied residue treatment techniques (for the main residues commonly produced)
- applied waste water treatment techniques
- some aspects of energy recovery, the performance achieved and the techniques used. Details of electrical generation equipment, etc. are not included.

It further includes a specific BAT for clinical waste incineration in addition to the generic measures which are provided.

2.3 Relevant Regulations on Alternative Treatment Technologies – Europe

On European level there are no specific technical standards on alternative treatment technologies. Nevertheless the following preconditions needs to be fulfilled:

- DIN EN 61010-2-040 (IEC 61010-2-040:2005) Safety requirements for electrical equipment for measurement, control and laboratory use - Particular requirements for sterilizers and washer-disinfectors used to treat medical materials
- 97/23/EC Pressure Equipment Directive
- 2006/42/CE Machine Directive
- 2006/95/CE Low Voltage Directive (LVD). Essential principles
- 2004/108/CE Electromagnetic Compatibility (EMC) Directive

Furthermore the manufacturer needs to proofe that the equipment is safely decontaminating the infectious waste. For thermal treatment with moist heat the inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at a 6 Log_{10} reduction or greater; and inactivation of G. stearothermophilus spores and B. atrophaeus spores at a 4 Log_{10} reduction or greater needs tob e proofed (A 4 log 10 reduction is equivalent to a 99.99 % reduction in spores). The legal base for these tests can be found in the following European and German Validation test Norms:

- DIN EN ISO 17665-1 Sterilization of health care products - Moist heat - Requirements for the development, validation and routine control of sterilization process for medical devices

- DIN EN 13060 Sterilization — Steam sterilizers — Large sterilizers (EN 285) and Small steam sterilizers
- The German DIN 58949-3 deals with the use of steam disinfection apparatus for treatment of waste from public and private medical facilities. The standard deals with types of test, test loads, test apparatus and biological indicators, extent of testing as well as procedure and expression of results (German language)

The alternative thermal treatment technologies outlined in chapter 3 are based on technologies used in Europe and the description of the technical requirments are taken from different international guidlines like:

- Safe management of waste from healthcare activities, WHO, 2013
- Compendium of technologies for treatment and destruction of healthcare waste, UNDP, 2012
- Basel Convention (2003). "Technical Guidelines on the Environmentally Sound Management of Biomedical and Health care Wastes (Y1; Y3)," Basel Convention series/SBC No. 2003/3, UNEP, Châtelaine , Switzerland

3 Nature and composition of healthcare waste

Special attention is required when dealing with healthcare waste to manage the specific risks of these wastes (e.g. infectious contamination, needles, etc.), the aesthetic standards (residues of operations etc.) and their treatment behaviour (very variable calorific value and moisture contents).

Specific healthcare waste often contains materials with very high net calorific values (NCVs) like plastics, but also residues with very high water contents (e.g. blood). Healthcare waste therefore usually requires long incineration times to ensure thorough waste burnout and that the residue quality is good.

Similar to hazardous wastes, the composition of specific healthcare waste varies greatly. In the table below the waste classes are listed which can be treated by the different treatment technologies:

Table 1: Treatment technologies for different Waste classes

Waste Class	Incineration	Thermal treatment technologies
Class B	Potential infectious waste sharp materials, e.g. hypodermic needles contaminated clothing/wipes and swabs veterinary wastes body parts	Potential infectious waste sharp materials, e.g. hypodermic needles contaminated clothing/wipes and swabs veterinary wastes body parts
Class C	infectious agents	infectious agents
Class D	pharmaceutical substances laboratory wastes Cytotoxic waste	- - -
Class E	radioactive contaminated materials.	-

Dealing with special wastes involves treatment of hazardous waste as well as hazardous components present in other wastes. Certain Hazardous Wastes cannot be destroyed by any other means than „High Temperature Incineration“, for instance:

- Refrigerants containing chlorofluorocarbon (CFCs) – cause depletion of the ozone layer
- Polychlorinated biphenyl (PCBs) – once in the food chain do not biodegrade, build up in fatty tissue
- Certain cyanide containing waste

4 Healthcare Waste Incineration Standard

The following chapter is based on the European Best Avaialbe Technology Reference „Waste Incinerators“ Chapter 2.2.4: „Clinical Waste“ and 2.3: „The thermal treatment stage.“

Oxidation (normally called incineration) is the controlled burning of waste material, commonly in two stages, to produce minimum amounts of gas and ash. On task is the thermal oxidation, a high temperature incineration of pollutants such as Voltale Organic Compounds (VOCs) and odours in gas streams. Incineration of waste materials converts the waste into incinerator bottom ash, flue gases, particulates, and heat, which can in turn be used to generate electric power. The flue gases are cleaned of pollutants before they are dispersed in the atmosphere. For the treatment of biohazardous waste especially three types of incinerators are used:

1. Grate Firing Incinerators
2. Rotary Kiln Incinerator
3. Addition of healthcare waste to a municipal waste incinerator

Incineration of hazardous and medical waste - rotary kilns are most commonly used, but grate incinerators (including co-firing with other wastes) are also sometimes applied to solid wastes.

4.1 Grate Incinerators

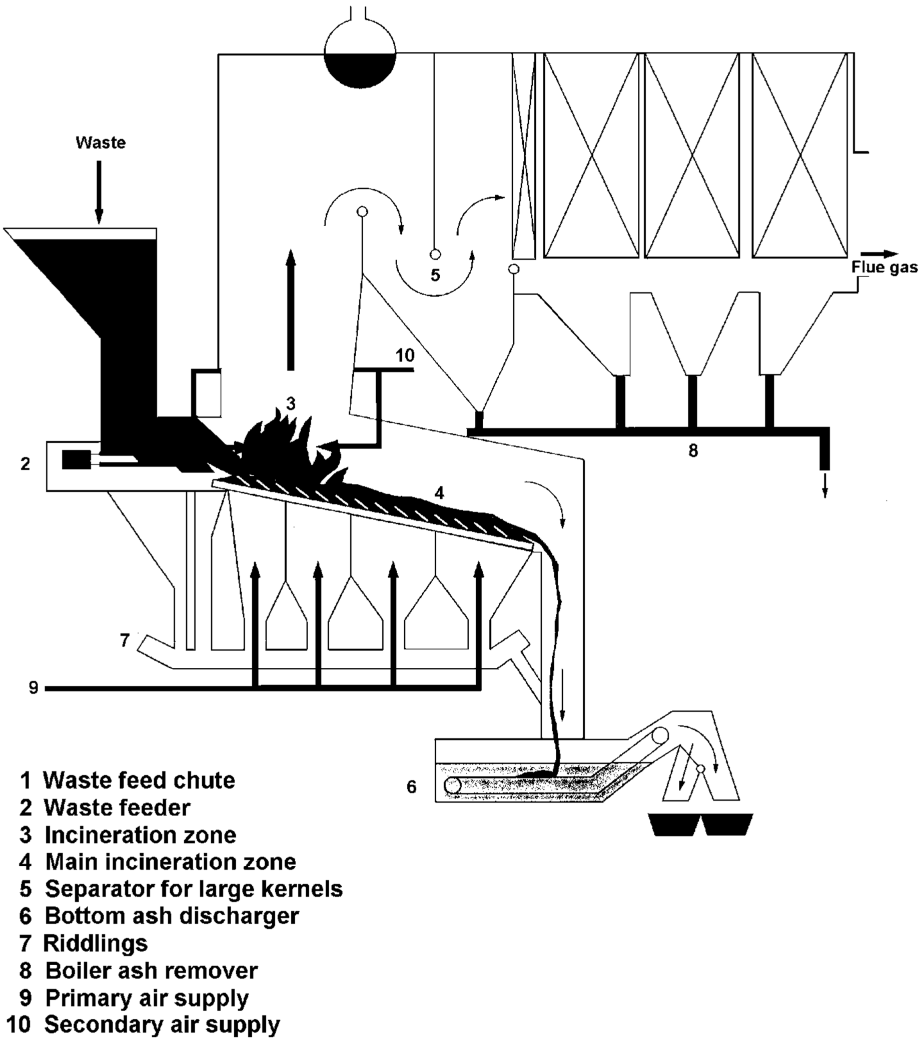
Grate incinerators are widely applied for the incineration of mixed municipal wastes. In Europe approximately 90 % of installations treating MSW use grates. Other wastes commonly treated in grate incinerators, often as additions with MSW, include: commercial and industrial non-hazardous wastes, sewage sludges and certain healthcare waste.

Grate incinerators usually have the following components:

1. waste feeder
2. incineration grate
3. bottom ash discharger
4. incineration air duct system
5. incineration chamber
6. Auxiliary burners.

Figure 1 shows an example of a grate incinerator with a heat recovery boiler.

Figure 1: Grate, furnace and heat recovery stages of an example municipal waste incineration plant



Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

4.1.1 Waste feeder

The waste is discharged from the storage bunker into the feeding chute by an overhead crane, and then fed into the grate system by a hydraulic ramp or another conveying system. The grate moves the waste through the various zones of the combustion chamber in a tumbling motion.

The filling hopper is used as a continuous waste supplier. It is filled in batches by the overhead crane. As the filling hopper surface is exposed to great stress, materials with high friction resistance are selected (e.g. boilerplates or wear-resistant cast iron). The material must survive occasional hopper fires unscathed.

The waste hopper may sometimes be fed by a conveyor. In that case, the overhead crane discharges waste into an intermediate hopper that feeds the conveyor. [74, TWGComments, 2004]

If the delivered waste has not been pretreated, it is generally very heterogeneous in both size and nature. The feed hopper is therefore dimensioned in such a way that bulky materials fall through and bridge formations and blockages are avoided. These blockages must be avoided as they can result in uneven feeding to the furnace and uncontrolled air ingress to the furnace.

Feeder chute walls can be protected from heat using:

- water-cooled double shell construction
- membrane wall construction
- water-cooled stop valves
- fireproof brick lining.

If the feed chute is empty, stop valve equipment (e.g. door seals) can be used to avoid flashbacks and for the prevention of uncontrolled air infiltration into the furnaces. A uniform amount of waste in the filling chute is recommended for uniform furnace management.

The junction between the lower end of the filling chute and the furnace consists of a dosing mechanism. The dosing mechanism may be driven either mechanically or hydraulically. Its feeding rate is generally adjustable. Different construction methods have been developed for the various types of feeder systems, such as:

- chain grates/plate bands
- feeder grates
- variable taper feed chutes
- RAM feeders
- hydraulic ramp
- feed screws.

4.1.2 Incineration grate

The incineration grate accomplishes the following functions:

- transport of materials to be incinerated through the furnace
- stoking and loosening of the materials to be incinerated
- positioning of the main incineration zone in the incineration chamber, possibly in combination with furnace performance control measures.

A target of the incineration grate is a good distribution of the incineration air into the furnace, according to combustion requirements. A primary air blower forces incineration air through small grate layer openings into the fuel layer. More air is generally added above the waste bed to complete combustion.

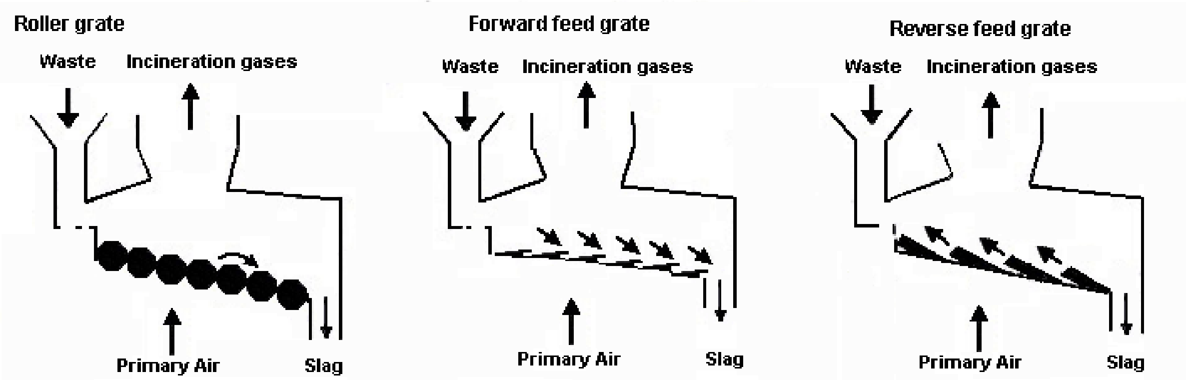
It is common for some fine material (sometimes called riddlings or siftings) to fall through the grate. This material is recovered in the bottom ash remover. Sometimes it is recovered separately and may be recycled to the grate for repeated incineration or removed directly for disposal. When the sifting is recirculated in the hopper, care should be taken not to ignite the waste in the hopper.[1]

Normally, the residence time of the wastes on the grates is not more than 60 minutes.[1]

In general, one can differentiate between continuous (roller and chain grates) and discontinuous feeder principles (push grates). Figure 2 shows some types of grates:

[1] "TWG Comments on Draft 2 on Waste Incineration BREF"; 2004

Figure 2: Different grate types Source



Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

Different grate systems can be distinguished by the way the waste is conveyed through the different zones in the combustion chamber. Each has to fulfil requirements regarding primary air feeding, conveying velocity and raking, as well as mixing of the waste. Other features may include additional controls, or a more robust construction to withstand the severe conditions in the combustion chamber.

Rocking grates

The grate sections are placed across the width of the furnace. Alternate rows are mechanically pivoted or rocked to produce an upward and forward motion, advancing and agitating the waste.[2]

Reciprocating grates

Many modern facilities (for municipal wastes) use reciprocating grates. The quality of burnout achieved is generally good.[2]

This design consists of sections that span the width of the furnace but are stacked above each other. Alternate grate sections slide back and forth, while the adjacent sections remain fixed. Waste tumbles off the fixed portion and is agitated and mixed as it moves along the grate. Numerous variations of this type of grate exist, some with alternating fixed and moving sections, others with combinations of several moving sections to each fixed section. In the latter case, the sections can either move together or at different times in the cycle.

There are essentially two main reciprocating grate variations:

1. Reverse reciprocating grate:
   a. The grate bars oscillate back and forth in the reverse direction to the flow of the waste. The grate is sloped from the feed end to the ash discharge end and is comprised of fixed and moving grate steps.
2. Push forward grate:
   a. The grate bars form a series of many steps that oscillate horizontally and push the waste in the direction of the ash discharge.

Travelling grates

This consists of a continuous metal belt conveyor or interlocking linkages that move along the length of the furnace. The reduced potential to agitate the waste (it is only mixed when it transfers from one belt to another) means that it is seldom used in modern facilities.[2]

[2] IAWG; "municipal solid waste incinerator residues", elsevier, 0-444-82563, 1997

Roller grates

This consists of a perforated roller that traverses the width of the grate area. Several rollers are installed in series and a stirring action occurs at the transition when the material tumbles off the rollers.[2]

Cooled grates

Most grates are cooled, most often with air. In some cases a liquid cooling medium (usually water) is passed through the inside of the grate. The flow of the cooling medium is from colder zones to progressively hotter ones in order to maximise the heat transfer. The heat absorbed by the cooling medium may be transferred for use in the process or for external supply.

Water cooling is most often applied where the calorific value of the waste is higher e.g.>12 - 15 MJ/kg for MSW. The design of the water cooled system is slightly more complex than air cooled systems.

The addition of water cooling may allow grate metal temperature and local combustion temperature to be controlled with greater independence from the primary air supply (normally between the grate bars). This may then allow temperature and air (oxygen) supply to be optimised to suit specific on-grate combustion requirements and thereby improve combustion performance. Greater control of grate temperature can allow incineration of higher calorific value wastes without the normally increased operational and maintenance problems.

4.1.3 Bottom ash discharger

The bottom ash discharger is used for cooling and removal of the solid residue that accumulates on the grate. It also serves as an air seal for the furnace and cools and humidifies the ash.

Water-filled pressure pistons and drag constructions are commonly used to extract the bottom ash. Other bottom ash discharges, such as belt conveyors are also commonly used. Grate ashes, as well as any bulky objects are thus conveyed.

The water used for cooling is separated from the grate ash at the exit, and may be re-circulated to the ash discharger. A water top-up feed is usually required to maintain an adequate water level in the discharger. The top-up water replaces losses with the removed ash and evaporation losses. In addition a water drain may be needed to prevent the build up of salts – such bleed systems can help to reduce the salt content of the residues if the flowrates are adjusted specifically for this purpose. The bottom ash removal shaft is usually fireproof and is constructed in such a way that bottom ash caking is avoided.

Figure 3: Example of a type of ash remover used at a grate incinerator

Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

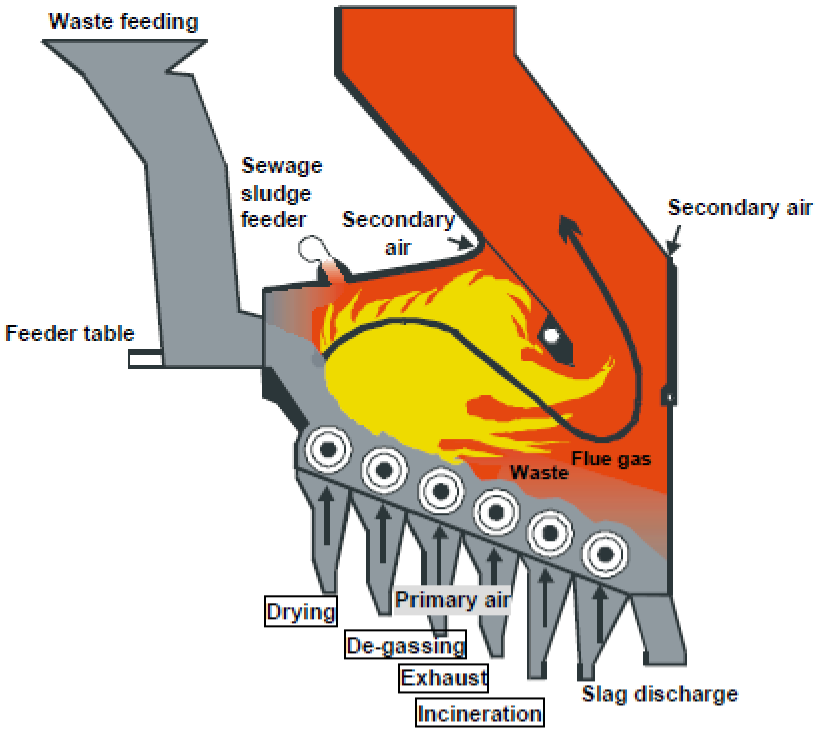
4.1.4 Incineration chamber and boiler

Combustion takes place above the grate in the incineration chamber (see Figure 4). As a whole, the incineration chamber typically consists of a grate situated at the bottom, cooled and non-cooled walls on the furnace sides, and a ceiling or boiler surface heater at the top. As municipal waste generally has a high volatile content, the volatile gases are driven off and only a small part of the actual incineration takes place on or near the grate.

The following requirements influence the design of the incineration chamber:

- form and size of the incineration grate - the size of the grate determines the size of the cross-section of the incineration chamber
- vortexing and homogeneity of flue-gas flow - complete mixing of the flue-gases is essential for good flue-gas incineration
- sufficient residence time for the flue-gases in the hot furnace - sufficient reaction time at high temperatures must be assured for complete incineration
- partial cooling of flue-gases - in order to avoid fusion of hot fly ash at the boiler, the flue- gas temperature must not exceed an upper limit at the incineration chamber exit.

Figure 4: Example of an incineration chamber

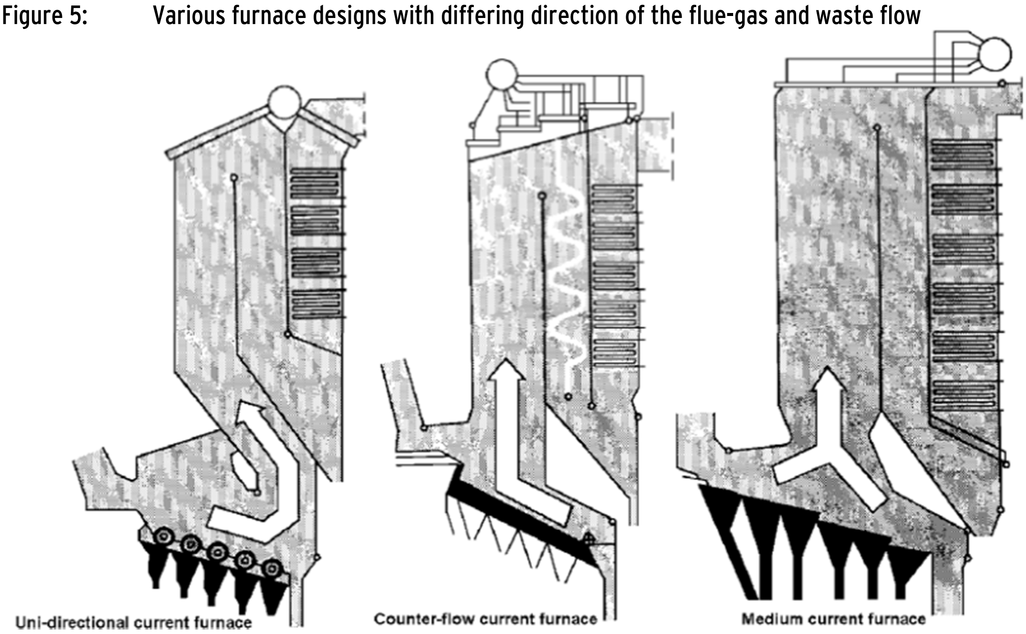


Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

The detailed design of a combustion chamber is usually linked to the grate type. Its precise design demands certain compromises as the process requirements change with the fuel characteristics. Each supplier has their own combination of grate and combustion chamber, the precise design of which is based on the individual performance of their system and their specific experiences. European operators of MSW have found no fundamental advantage or disadvantage for the different designs of the combustion chamber.

In general, three different designs can be distinguished. The nomenclature comes from the flow direction of the flue-gases in relation to the waste flow: unidirectional current; countercurrent and medium current (see Figure 5).

Figure 5: Various furnace designs with differing direction of the flue-gas and waste flow



Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

Unidirectional current, co-current, or parallel flow furnace:

In a co-current combustion arrangement, primary combustion air and waste are guided in a co-current flow through the combustion chamber. Accordingly, the flue-gas outlet is located at the end of the grate. Only a comparatively low amount of energy is exchanged between the combustion gases and the waste on the grate.

The advantage of unidirectional current concepts is that the flue-gas has the longest residence time in the ignition area and that it must pass through the maximum temperature. To facilitate ignition, the primary air must be pre-warmed with very low heat values.

Counter-flow or countercurrent furnace:

In this case, primary combustion air and waste are guided in a countercurrent flow arrangement through the combustion chamber and the flue-gas outlet is located at the front end of the grate. The hot flue-gases facilitate drying and ignition of the waste

Special attention must be paid to avoid the passage of unburned gas streams. As a rule, counter- flow current concepts require higher secondary or upper air additions.

Medium-current or centre-flow furnace:

The composition of municipal solid waste varies considerably and the medium current concept is a compromise for a wide feed value spectrum. A good mixture of all partial flue-gas currents must be considered through mixture-promoting contours and/or secondary air injections. In this case, the flue-gas outlet is located in the middle of the grate.

4.1.5 Incineration air feeding

The incineration air fulfils the following objectives:

- provision of oxidant
- cooling
- avoidance of slag formation in the furnace
- mixing of flue-gas.

Air is added at various places in the combustion chamber. It is usually described as primary and secondary, although tertiary air, and re-circulated flue-gases are also used.

The primary air is generally taken from the waste bunker. This lowers the air pressure in the bunker hall and eliminates most odour emissions from the bunker area. Primary air is blown by fans into the areas below the grate, where its distribution can be closely controlled using multiple wind boxes, and distribution valves.

The air can be preheated if the value of the waste degenerates to such a degree that it becomes necessary to pre-dry the waste. The primary air will be forced through the grate layer into the fuel bed. It cools the grate bar and carries oxygen into the incineration bed.

Secondary air is blown into the incineration chamber at high speeds via, for example, injection lances or from internal structures. This is carried out to secure complete incineration and is responsible for the intensive mixing of flue-gases, and prevention of the free passage of unburned gas streams.

4.1.6 Auxiliary burner

At start-up, auxiliary burners are commonly used to heat up the furnace to a specified temperature through which the flue-gases can pass. This is the main use of auxiliary burners. These burners are usually switched on automatically if the temperature falls below the specified value during operation. During shut down, the burners are often only used if there is waste in the furnace. [74, TWGComments, 2004]

4.1.7 Incineration temperature, residence time, minimum oxygen content

To achieve good burn out of the combustion gases, a minimum gas phase combustion temperature of 850 °C (1100 °C for some hazardous wastes) and a minimum residence time of the flue-gases, above this temperature, of two seconds after the last incineration air supply have been established in legislation (Directive 2000/76/EC and earlier legislation). Derogations from these conditions are allowed in legislation if they provide for a similar level of overall environmental performance.[1]

A minimum oxygen content of 6 % was required by earlier legislation but removed from the most recent EC Directive on incineration.

Operational experiences have in some cases shown that lower temperatures, shorter residence times and lower oxygen levels can, in some situations, still result in good combustion and may result in overall improved environmental performance. However, low oxygen content may lead to significant corrosion risk and therefore require specific material protection.[1]

The carbon monoxide content of the flue-gas is a key indicator of the quality of combustion.

4.2 Rotary Klins

Rotary kilns are very robust and almost any waste, regardless of type and composition, can be incinerated. Rotary kilns are, in particular, very widely applied for the incineration of hazardous wastes. The technology is also commonly used for healthcare waste (most hazardous clinical waste is incinerated in high temperature rotary kiln incinerators[3], but less so for municipal wastes.

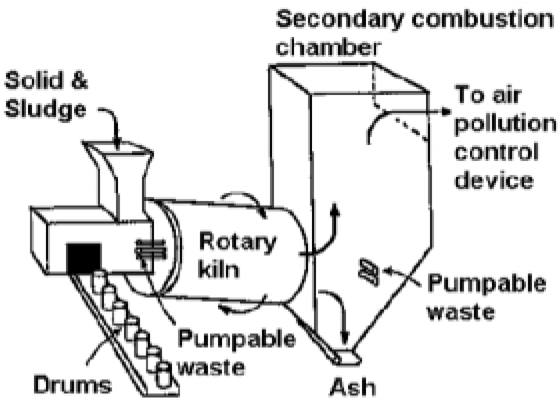
Operating temperatures of rotary kilns used for wastes range from around 500 °C (as a gasifier) to 1450 °C (as a high temperature ash melting kiln). Higher temperatures are sometimes encountered, but usually in non-waste applications.

When used for conventional oxidative combustion, the temperature is generally above 850 °C. Temperatures in the range 900 - 1200 °C are typical when incinerating hazardous wastes.

Generally, and depending on the waste input, the higher the operating temperature, the greater the risk of fouling and thermal stress damage to the refractory kiln lining. Some kilns have a cooling jacket (using air or water) that helps to extend refractory life, and therefore the time between maintenance shut-downs.

A schematic drawing of a rotary kiln incineration system is shown below.

Figure 6: Schematic of a rotary kiln incineration system



Source: "Draft background document on the waste incineration sector"; EGTEI; 2002.

The rotary kiln consists of a cylindrical vessel slightly inclined on its horizontal axis. The vessel is usually located on rollers, allowing the kiln to rotate or oscillate around its axis (reciprocating motion). The waste is conveyed through the kiln by gravity as it rotates. Direct injection is used particularly for liquid, gaseous or pasty (pumpable) wastes – especially where they have safety risks and require particular care to reduce operator exposure.

The residence time of the solid material in the kiln is determined by the horizontal angle of the vessel and the rotation speed: a residence time of between 30 to 90 minutes is normally sufficient to achieve good waste burnout.

Solid waste, liquid waste, gaseous waste, and sludges can be incinerated in rotary kilns. Solid materials are usually fed through a non-rotating hopper; liquid waste may be injected into the kiln through burner nozzles; pumpable waste and sludges may be injected.

4.2.1 Kilns and post combustion chambers for hazardous waste incineration

The operational kiln temperature of installations for incineration usually varies from 850 °C up to 1300 °C. The temperature may be maintained by burning higher calorific (e.g. liquid) waste, waste oils, heating oil or gas. Higher-temperature kilns may be fitted with water-based kiln cooling systems, which are preferred for operation at higher temperatures. The operation at

[3]"TWG Comments on Draft 1 of Waste Incineration BREF"; 2003

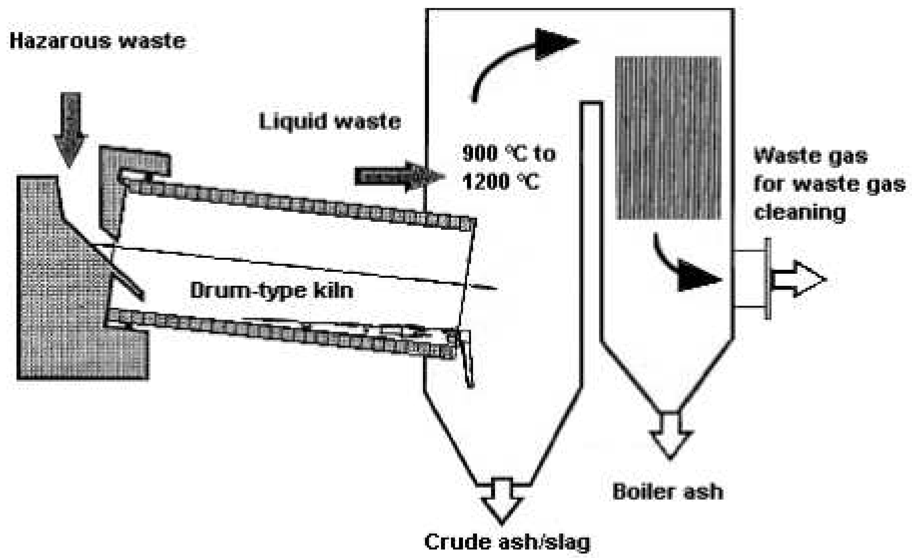
higher temperatures may result in molten (vitrified) bottom ash (slag); at lower temperatures the bottom ashes are sintered.

The temperatures in the post combustion chamber (PCC) typically vary between 900 - 1200 °C depending on the installation and the waste feed. Most installations have the ability to inject secondary air into the post combustion chamber. Due to the high temperatures and the secondary air introduction, the combustion of the exhaust gases is completed and organic compounds (e.g. PAHs, PCBs and dioxins) including low molecular weight hydrocarbons, are destroyed. In several countries exemptions from the 1100 °C rule are granted, on the basis of studies demonstrating that lowering the temperature in the PCC does not influence the quality of air emissions.

4.2.2 Drum kiln with post-combustion chamber for hazardous waste incineration

For the incineration of hazardous waste, a combination of drum-type kilns and post-combustion chambers has proven successful, as this combination can treat solid, pasty, liquid, and gaseous wastes uniformly (see Figure 2.10).

Figure 7: Drum-type kiln with post-combustion chamber



Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

Drum-type kilns between 10 and 15 metres in length, and with a length to diameter ratio usually in the range of 3 to 6, and with an inner diameter between one and five metres are usually deployed for hazardous waste incineration.

Drum-type kiln plants are highly flexible in terms of waste input characteristics. The following range is usual in the composition of the waste input menu:

- solid wastes : 10 – 70 %
- liquid wastes: 25 – 70 %
- pasty wastes: 5 – 30 %
- barrels: up to 15 %.

To protect the drum-type kilns from temperatures of up to 1200 °C, it is equipped with refractory bricks. Bricks with a high content of Al2O3 and SiO2 are used. The decision regarding the selection of bricks appropriate for each application is a function of the waste composition. The bricks can be attacked by alkaline metal compounds (formation of low melting eutectic alloys), as well as by HF. (formation of SiF4). To protect refractory bricks form chemical attacks and from the mechanical impact of falling barrels, a hardened slag layer will usually be formed at the beginning of the operation with the help of good slag forming wastes or materials as mixtures of glass or sand and glass. Later on the kiln temperature is usually managed so as to keep this slag layer, based on the mineral matter of the wastes and perhaps some additives as e.g. sand.

There have been tests with other surfacing systems but neither injected nor stamped refractory masses have proved successful. The surfacing of the drum-type kiln with special alloyed steels was only successful in some special applications. The durability of the fireproof surfacing remains dependent upon the waste input. Service life of between 4000 and 16000 hours is normal.

Cooling the drum-type kilns is a means of lengthening their service life. Several positive experiences have been noted at various plants.

Drum-type kilns are tilted towards the post combustion chamber. This, along with the slow rotation (approx. 3 – 40 rotations per hour) facilitates the transport of solid hazardous wastes that are fed from the front side, as well as the bottom ash produced during incineration, in the direction of the post combustion chamber. These are then removed together with the ash from the post combustion chamber via a wet bottom ash remover. The residence time for solid wastes generally amounts to more than 30 minutes.

The post combustion chamber, provides residence time for the incineration of the flue-gases produced during incineration, as well as for the incineration of directly injected liquid and gaseous wastes. Minimum residence times in excess of two seconds are the basic requirement of EC Directive 2000/76/EC. The size of the post-combustion chamber and gas flows predict the actual residence times achieved. Reducing residence times can increase risks of incomplete gas burnout.

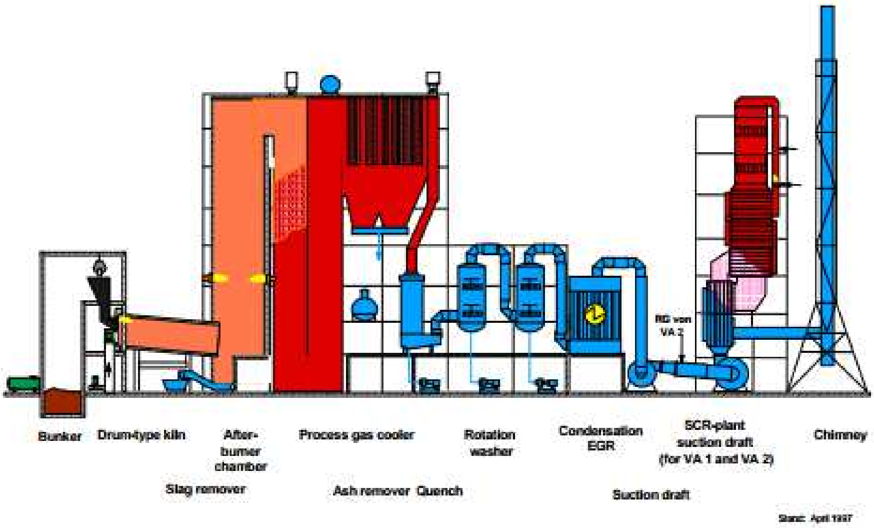
Operational experiences have in some cases shown that lower temperatures, shorter residence times and lower oxygen levels can, in some situations, still result in good combustion and may result in lower overall emissions to air. [74, TWGComments, 2004]

A drum-type kiln incineration plant with an incineration capacity of 45000 tonnes/yr is shown in Figure 8 The plant is divided into three main areas:

1. drum-type kiln with post combustion chamber
2. waste heat boiler for steam generation
3. multi-step flue-gas cleaning.

There is, in addition, the infrastructure for the storage, feed system, and disposal for the waste and waste waters (from wet gas scrubbing) produced during incineration.

Figure 8: Example of a drum-type kiln plant for hazardous waste incineration



Source: "Draft of a German Report for the creation of a BREF-document "waste incineration"", Umweltbundesamt; 2001

4.3 Adding of healthcare waste to a municipal waste incinerator

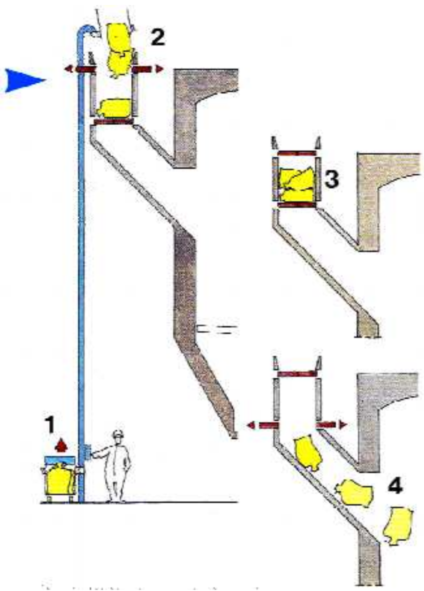
(Denmark 2002) Clinical waste is sometimes added into an existing municipal waste incinerator. Separate loading systems, with airlocks are widly used. The airlock helps to prevent the entry of uncontrolled combustion air and the possibility of fugitive emissions at the loading area. Combustion takes place in the same furnace as the MSW.

Note that Article 6.7 of Waste Incineration Directive requires that infectious clinical waste should be placed straight in the furnace, without first being mixed with other categories of waste and without direct handling. [74, TWGComments, 2004]

Flue-gases from the different wastes are then treated in common flue gas treatment systems.

In Figure 9 below the order of the stages for a separate loading system are shown:

Figure 9: Examples of the stages of a clinical waste loading systems used at a municipal waste incinerator



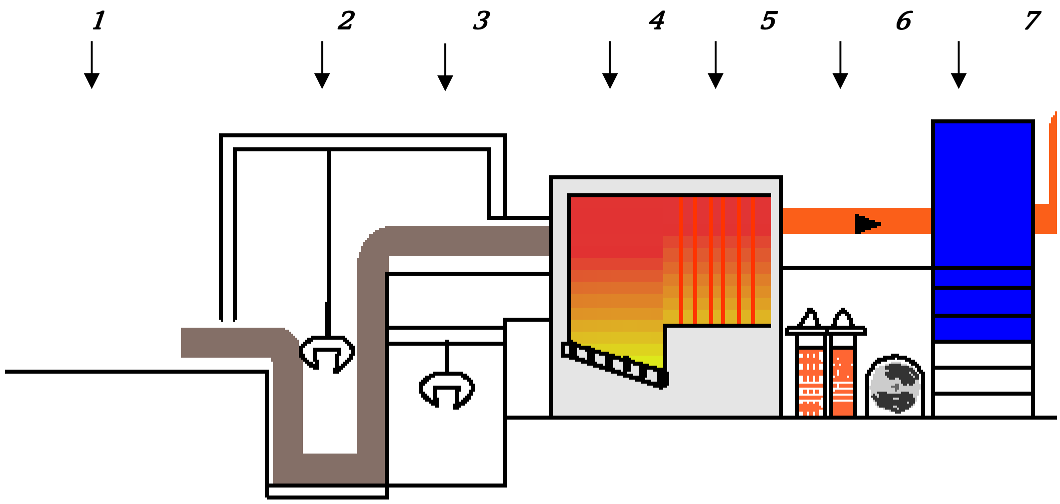
Source: "Clinical waste at I/S Amagerforbraending, Copenhagen", personal Communication; Denmark; 2002

The waste is dumped directly in the waste bunker. The waste will be mixed, to reach an average heating value of the waste of 9.210 kJ/kg. Afterward, the waste will be transferred via a crane onto the grate stoker furnace and will be incinerated on this counter direction, above shear grate. The bed ash and the slag will be collected in the slag bunker.

The heat generated during the incineration process will be partly recovered via an corner tube boiler and transfered in electrical energy. Generated flue gas is treated in the flue gas treatment system.

Figure 10: General way of working – waste incinerator Bielefeld-Herford

1 Waste delivery	**2 Waste Bunker**	**3 Slag (Bed ash) bunker 4 Grate furnace**
5 Steam boiler	**6 Turbines**	**7 Start of the flue gas treatment**

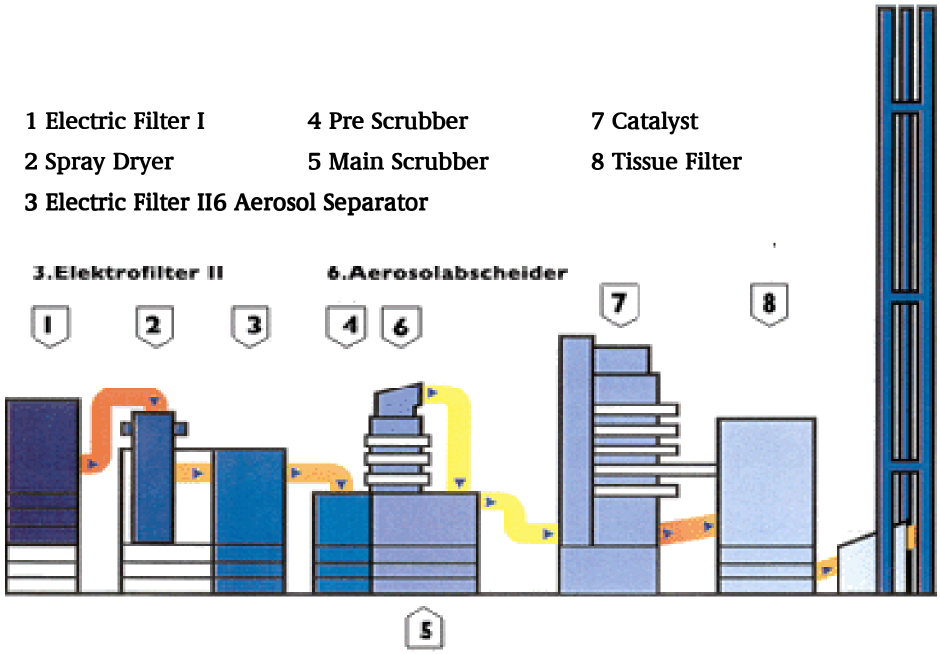


Source: "Clinical waste at the municipal waste incinerator Bielefeld-Herford", personal Communication; Denmark; 2002

4.3.1 The flue gas treatment system

The central waste incineration plant started to operate in 1981. Those days, the flue gas treatment of each process line consisted of a two stage electric filter and a flue gas scrubber. Because of the introduction of new emission standards and laws in 1986 (Technical Guidance Air 86) and in 1991 (17. Federal Emission Protection Law), the plant had to adapt the existing equipment according to the new standard and regulations. These requirements have been fulfilled with an investment volume of 115 million € in 1996. Since 1996 the plant disposes of three flue gas treatment systems with eight stages.

Figure 11: Illustration of the 8-stage flue gas treatment system



Source: "Clinical waste at the municipal waste incinerator Bielefeld-Herford", personal Communication; Denmark; 2002

The flue gas leaves the incinerator with a temperature of about 230°C and pass the electric filter I. At this stage, the dust from the flue gas will be separated.

Afterwards, the flue gas streams into the spray dryer and evaporates the contaminated wash water from the pre-and main scrubber. Solid reaction salts are remaining as residues. In the spray dryer, all process water of the waste incineration plant evaporates. This means, the entire systems runs without any waste water.

Now the flue gas is cooled down to 175°C and goes into the electric filter II. Here, the dust residues and the reaction salts are separated.

Following this, the flue gas goes into the two stage flue gas scrubber, consisting of pre-and main scrubber. As wash fluid, process water (waste water from the adjacent purification plant) is used. The wash fluid goes in a circle through the scrubber. In the pre-scrubber, mainly hydrogen chloride, hydrogen fluoride, as well as mercury are removed. At this stage, process water is mixed with lime water.

Through the addition of a heavy metal precipitant, sulphur dioxide is separated from the flue gas. Due to the addition of the heavy metal precipitant, the in the wash fluid solved heavy metals are converted in acid-and temperature resistant compounds, such as mercury. These mercury compounds can be evaporate in the spray dryer of the three process lines.

In the aerosol separator a micro washing and a water separation in a polypropylene tissue is carried out. The flue gas has now a temperature of about 65°C.

Before the flue gas can be cleaned in the catalyst, it must be pass the flue gas heat exchanger and a flue gas pre-warming unit in order to warm up the flue gas up to 240°C. The catalyst consists of three layers. In the first layer nitrogen oxide is converted with the help of ammoniac water into molecular nitrogen (part of air) and water. In the second and third layer dioxin and furan will be destroyed through oxidation. Also other hazardous organic substances will be destroyed during this process. After the passing of the three layers the flue gas goes into the flue gas heat exchanger. Here the outgoing flue gas gives the heat to the in the catalyst streaming flue gas.

Now the flue gas has a temperature of about 95°C. It goes first into the plenum chamber. At this stage the flue gas is mixed via a spray unit with adsorbents (mixture of lime and coke). This mixture adsorbed remained heavy metals, dioxins and furans. Concluding, the flue gas streams through the tissue filter. After this 8-stage process, the cleaned flue gas can be relased to the atmosphere via a 107 m high chimney.

5 Thermal treatment of Class B and C Waste

The thermal decontamination of materials is an old but proven solution and a wide range of different thermal treatment system is available today. Different treatment systems reach different treatment levels. Therefore in the following an overview of treatment levels and of existing treatment technologies is provided.

Different thermal treatment methods for the decontamination of healthcare waste are today existing which reach different treatment levels. There are four international accepted levels of treatment defined by the Centres for Disease Control and Prevention (CDC), the Robert Koch Institute (RKI) and the World Health Organization (WHO).

Level 1 – Low Level Disinfection:

Inactivation of most vegetative bacteria, fungi, and some viruses. This level of treatment does not inactivate mycobacteria (e.g. bacteria causing tuberculosis) and bacterial spores. This level of treatment is inadequate for HCW treatment and is not recommended.

Level 2 – Intermediate Level Disinfection:

Inactivation of mycobacteria, all viruses, fungi and vegetative bacteria. It does not include the inactivation of bacterial spores. This level is also defined as the destruction of all micro organisms except high numbers of bacterial spores. These two definitions are essentially equivalent. Tests for intermediate level disinfection must show that a 6 log (logarithm to the base 10) reduction of the micro organism most resistant to the treatment is attained. This level does not include inactivation of bacterial spores which are required in Level 3 (e.g. for Anthrax – Bacillus anthracis) and Level 4 (e.g. Tetanus - Clostridium tetani) and therefore is only suitable for the pre-treatment of waste, prior to final treatment.

Level 3 – High Level Disinfection:

The killing nearly all microbial life forms present in a healthcare waste load (including Bacillus anthracis) as evidenced by the inactivation of surrogate pathogens (bacterial spores) having death curves similar to the most resistant human pathogens. Such surrogate pathogens may not be the forms most resistant to a particular treatment process but are similar in resistance to most human pathogens found in infectious waste. This level of treatment requires the inactivation of a specific quantity of a resistant surrogate pathogen, thus assuring that the waste is treated to reduce the quantity of infectious agents present in the waste stream to a level that does not present a significant risk to human health or the environment. A minimum of 4 log reduction of spores of either B. stearothermophilus or B. subtilis by thermal inactivation technologies is accepted as indicating high level and intermediate level disinfection. A 4 log 10 reduction is equivalent to a 99.99 % reduction in spores.

Level 4 – Sterilization:

The killing of all microbial life (including Clostridium tetani) forms as indicated by complete inactivation of specific concentrations of those organisms recognized as most resistant to the treatment process. Sterilization is evidenced by a minimum 6 log reduction in spores of B. stearothermophilus. A 6 log 10 reduction is equivalent to a 99.9999 % reduction in spores.

Level-3 treatment is considered as sufficient (e.g. USA, Germany, etc.) for the treatment of infectious healthcare waste.

5.1 Thermal based treatment technologies

Different kinds of thermal treatment systems are available today. All these technologies have one thing in common which is steam as treatment media. If heat is applied to water, its temperature rises until it reaches its boiling point or saturation temperature at which point water is turned into steam. At atmospheric pressure the saturation temperature of water is 100°C. At higher pressures, the saturation temperature is higher. For example, at a pressure of 3.2 bar, water boils at 134°C. When steam is at its saturation temperature, the condition is referred to as a saturated condition and the steam is known as saturated steam. Autoclaves and other steam-based systems generally operate at saturated conditions.

Thermal systems are inactivating micro organism by heat (coagulation of the proteins). The inactivation process however combines effects of moisture, heat, and pressure. Compared with e.g. the usage of hot air (dry heat disinfection), a steam atmosphere has certain advantages for the treatment of healthcare waste:

- Steam contains more heath energy (the enthalpy energy of the steam will be set free during the condensation on the waste, and has higher specific heat capacity than air) and can therefore transfer more heat to waste than e.g. air
- In a wet condition, germs are more heat sensible then in a dry condition. Due to the moist, even spores will expand and loose their normal heat resistance.
- Steam under heat and pressure works through hydrolysis.

This process has been used for disinfecting or sterilizing medical instruments in hospitals since 1876, when Charles Chamberland built the first pressure steam sterilizer. Infectious healthcare waste may contain many of the same pathogens that are associated with contaminated medical instruments and supplies. Therefore, it was a natural progression to utilize autoclaves to decrease or eliminate the potential bio burden contained in medical waste.

Thermal treatment systems today mainly differ in the way how to remove air out of the treatment chamber and out of the waste - by this in how to guarantee a pure, saturated steam atmosphere for the treatment process.For the quality of a thermal disinfection or sterilization process the most important parameters are therefore:

- The complete removal of the air and replacement with steam to avoid the so called “Cold island problem” – air pockets in the treatment chamber where air was not replaced by steam.
- The quality of the used, saturated steam (minimizing of inert gasses)
- The treatment time and temperature (measured after the waste reached the process temperature)

5.1.1 Gravity displacement autoclaves and retorts

A basic autoclave consists out of a metal chamber sealed by a charging door and surrounded by a steam jacket. Steam is introduced into both the outside jacket and the inside chamber which is designed to withstand elevated pressures. Heating the outside jacket reduces condensation in the inside chamber wall. A “retort” is similar to an autoclave, except that a retort has no steam jacket. It is therefore cheaper to construct but requires a higher steam temperature than an autoclave. The high amounts of condensates generated can be problematic. Retort-type designs are found mostly in large-scale applications.

The system of gravity displacement (or downward-displacement) autoclave relies on gravity for the exchange of cool heavy air for steam (steam is lighter than air). The steam enters at the top of the device and gradually replaces the existing cooler air as it moves toward the outlet at the bottom of the chamber. The removal of all air from the chamber is essential to ensure penetration of heat into the waste. The efficiency of the system therefore highly depends on the method of packing and loading of the waste into the autoclave to prevent the formation of air pockets where the existing air may not be displaced by steam, resulting in partly not treated waste. Problems are occurring if the waste is packed in bags, preventing the displacement of the air. During normal appliance the steam penetration may be less complete, why these systems are not today recommended for healthcare waste treatment.

To minimize the problems of air pockets, systems have been developed which apply a mechanical processing (shredding) before the steam treatment for the purpose of improving the transfer of heat into the waste, achieving more uniform heating of the waste, rendering the waste unrecognizable, and/or making the treatment system a continuous (rather than a batch) process, e.g. by using oil heated auger systems (an auger is essentially a large screw that rotates inside a cylinder, thereby moving the waste forward). These new systems have sometimes been referred to as “advanced” autoclaves.

5.1.2 Microwave systems

Microwave treatment is essentially a steam disinfection process since water is added to the waste and disinfection occurs through the action of moist heat and steam generated by microwave energy. Various studies show that the lethal effect of microwaves on microbial organisms is primarily due to moist heat; without water or steam, microwave energy alone does not result in significant cell inactivation.

Microwaves have wave length of several centimetres and lies in the electromagnetic spectrum between radio waves and infra red light. Microwave disinfection systems consist of a disinfection area or chamber into which microwave energy is directed from a microwave generator (magnetron). Typically, 2 to 6 magnetrons are used with an output of about 1.2 kW each. The waves of microwave energy cycle rapidly between positive and negative at very high frequency, around 2.45 billion times per second.

This causes water and other molecules in the waste to vibrate swiftly as they try to align themselves to the rapidly shifting electromagnetic field. The intense vibration creates friction, which, in turn, generates heat, turning water into steam. Some systems are designed as batch processes and others are semi-continuous. Compared with typical autoclave systems, microwave systems are more complex and have a higher maintenance demand.

5.1.3 Pre-Vacuum Autoclave

An effective method to displace air with steam is the use of a vacuum pump to evacuate air before introducing steam. Pre-vacuum autoclaves remove air from the treatment chamber to create a high vacuum prior to the introduction of steam. This procedure allows the autoclave to reach operating temperatures more rapidly and allows the steam to penetrate the waste load more completely by reducing the chances for air pockets within the waste load.

5.1.4 Fractionated Autoclave

Also called "advanced pre-vacuum autoclave" or Vacuum-Steam-Vacuum Autoclaves (VSV-Autoclaves)

To ensure the total removal of air out of the treatment chamber and the waste load (to guarantee that the entire waste load will be penetrated by steam) certain countries and organizations (e.g. Germany – Robert Koch Institute) recommend the use of the so-called "fractionated, high vacuum-cycle". With this treatment cycle, air is removed by several time creating high vacuums alternating with saturated steam introduction. The advantages of this treatment cycle are evidence based, of special importance is the ability of this type of treatment plants to also safely treat waste packed in bags (due to the several times applied vacuum and steam pulses). In the medical sector, this treatment cycle is today considered as "State-of-the-Art" for steam sterilization. (See also: DIN-EN 285 – Sterilization – Steam sterilizers – Large sterilizers)

5.2 Dry Heat based Technologies

Dry heat sterilization is the exposure of the waste to heat at a temperature and for a time sufficient to ensure sterilization of the entire waste load. In dry heat processes, no water or steam is added. Instead, the waste is heated by conduction, natural or forced convection, and/or thermal radiation using infrared heaters. As hot air has a lower heating value compared with steam, higher temperatures are necessary (normally between 160 – 200°C) and longer sterilization times (2 h – 30 minutes).

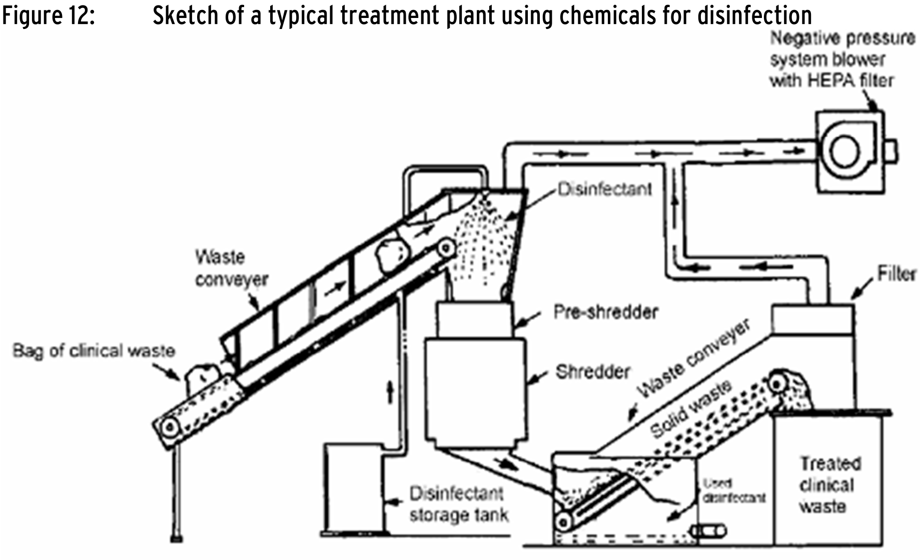
5.3 Chemicals based Technologies

Hospitals and other health care facilities have used chemical agents routinely for decades, in applications ranging from disinfecting reusable instruments to general cleaning of work surfaces. Chemical methods using a disinfecting liquid solution give good results in surface sterilisation. When applied to healthcare waste treatment (heterogeneous materials – necessary treatment of inner surfaces), the main problem is how to ensure contact between the chemical and the infectious waste with a high enough concentration and sufficient exposure time.

Therefore disinfection technologies generally incorporate internal shredding and mixing to resolve the problem of contact between waste and chemical agent. Since chemical processes require shredding, the release of pathogens through aerosol formation may be a concern. Chemical-based technologies should operate as closed systems or under negative pressure passing their air exhaust through HEPA and other filters.

Chemical processes employ disinfectants such as dissolved chlorine dioxide, sodium hypochlorite, peracetic acid, or other dry inorganic chemicals. A novel system uses alkali to hydrolyze tissues in heated stainless steel tanks. To maintain the proper concentration of the chemical agents, chemical technologies must be able to replenish chemicals lost through volatilization, decomposition, adsorption on waste surfaces, and interaction with microorganisms.

Figure 12: Sketch of a typical treatment plant using chemicals for disinfection



Source: "Safe management of waste from healthcare activities"WHO, 2013

Other factors such as pH, temperature, and the presence of other chemicals that may interfere with the disinfection process should also be considered. Depending on the nature of the chemicals, occupational exposures of workers to concentrations in the air and through skin contact may be a concern. Since many chemical-based technologies release substantial quantities of liquid effluent or wastewater into the sewer, the releases must comply with limits set in effluent discharge permits. In addition, it is important to determine what the long-term environmental consequences of those releases might be. Chemical disinfectants are sometimes stored in concentrated form, thus increasing the hazards.

Micro organisms vary in their resistance to chemical treatment. The least resistant are vegetative bacteria, vegetative fungi, fungal spores, and lipophilic viruses; the more resistant organisms are hydrophilic viruses, mycobacteria, and bacterial spores such as B. stearothermophilus. Before using a chemical based process, it should be carefully evaluated if the agent is able to destroy all organisms.

5.4 Irradiation Technologies

Ionizing radiation is created when the electromagnetic radiation has high enough energy to knock out electrons from their atomic orbits; examples are x-rays and gamma rays. At sufficiently high doses of ionizing radiation, extensive damage is done to DNA leading to cell death. Irradiation-based technologies involve electron beams, Cobalt-60, or UV irradiation. These technologies require shielding to prevent occupational exposures. The pathogen-destruction efficacy for infectious waste depends on the dose absorbed by the mass of waste, which, in turn, is related to waste density and electron energy.

Main problem in the application of ionizing radiation is the heterogeneous characteristic of the waste. The radiation energy absorbed by the waste is referred to as the absorbed dose. To determine the proper dose, technology manufacturers generally measure doses in various parts of the treatment area and correlate those to the levels of microbial inactivation required.

6 Annex

6.1 Incineration emission limits Europe

Directive 2000/76/EC on the incineration of waste. Annex V: Air Emission Limit Values:

(A)	Daily Avg. Values	Values	Unit
1	Total dust	10	mg/m3
2	Gaseous and vaporous organic substances, expressed as total organic carbon	10	mg/m3
3	Hydrogen chloride (HCl)	10	mg/m3
4	Hydrogen fluoride (HF)	1	mg/m3
5	Sulphur dioxide (SO2)	50	mg/m3
6	Nitrogen monoxide (NO) and nitrogen dioxide (NO2)expressed as nitrogen dioxide for existing incineration hour or new incineration plants	200	mg/m3(*)
7	Nitrogen monoxide (NO) and nitrogen dioxide (NO2),expressed as nitrogen dioxide for existing incineration plants with a nominal capacity of 6 tonnes per hour or less	400	mg/m3 (*)

(*) :- Until 1 January 2007 and without prejudice to relevant (Community) legislation the emission limit value for NOx does not apply to plants only incinerating hazardous waste.

Exemptions for NOx may be authorized by the competent authority for existing incineration plants:

- with a nominal capacity of 6 tonnes per hour, provided that the
- permit foresees the daily average values do not exceed 500 mg/m3 and this until 1 January 2008,
- with a nominal capacity of >6 tonnes per hour but equal or less than 16 tonnes per hour, provided the permit foresees the daily average values do not exceed 400 mg/m3 and this until 1 January 2010,
- with a nominal capacity of >16 tonnes per hour but <25 tonnes per hour and which do not produce water discharges, provided that the permit foresees the daily average values do not exceed 400 mg/m3 and this until 1January 2008.

Until 1 January 2008, exemptions for dust may be authorized by the competent authority for existing incinerating plants, provided that the permit foresees the daily average values do not exceed 20 mg/m^3.

Since, Hydrogen chloride (HCl), Hydrogen fluoride (HF), Sulphur (S) are not present in feed so, these will not be present in flue gas.

(B)	Half Hourly Avg. Values	Values	Unit

		100 % (A)	97 % (B)	mg/m3
1	Total dust	30	10	mg/m3
2	Gaseous and vaporous organic substances, expressed as total organic carbon	20	10	mg/m3
3	Hydrogen chloride (HCl)	60	10	mg/m3
4	Hydrogen fluoride (HF)	4	2	mg/m3
5	Sulphur dioxide (SO2)	200	50	mg/m3
6	Nitrogen monoxide (NO) and nitrogen dioxide (NO2), expressed as nitrogen dixoide for existing incineration plants with a nominal capacity exceeding 6 tonnes per hour or new incineration plants	400 (*)	200 (*)	mg/m3

(*) Until 1 January 2007 and without prejudice to relevant Community legislation the emission limit value for NOx does not apply to plants only incinerating hazardous waste.

Until 1 January 2010, exemptions for NOx may be authorized by the competent authority for existing incineration plants with a nominal capacity between 6 and 16 tonnes per hour, provided the half-hourly average value does not exceed 600 mg/m3 for column A or 400 mg/m3 for column B.

Since Hydrogen chloride (HCl), Hydrogen fluoride (HF) , Sulphur (S) are not present in feed so, these will not be present in flue gas.

(C) All average values over the sample period of a minimum of 30 minutes and a maximum of 8 hours.

Sr. No.	All average values over the sample period of a minimum of 30 minutes and a maximum of 8 hours			Unit
1	Cadmium and its compounds, expressed as cadmium (Cd)	Total 0.05	Total 0.1 *	Mg / m^3
2	Thallium and its compounds, expressed as thallium (Tl)			
3	Mercury and its compounds, expressed as mercury (Hg)	0.05	0.1 *	Mg / m^3
4	Antimony and its compounds, expressed as antimony (Sb)			
5	Arsenic and its compounds, expressed as arsenic (As)			
6	Lead and its compounds, expressed as lead (Pb)			

7	Chromium and its compounds, expressed as chromium (Cr)	Total 0.5	0.1 *	Mg / m^3
8	Cobalt and its compounds, expressed as cobalt (Co)			
9	Copper and its compounds, expressed as copper (Cu)			
10	Manganese and its compounds, expressed as manganese (Mn)			
11	Nickel and its compounds, expressed as nickel (Ni)			
12	Vanadium and its compounds, expressed as vanadium (V)			

(*) Until 1 January 2007 average values for existing plants for which the permit to operate has been granted before 31 December 1996, and which incinerate hazardous waste only.

These average values cover also gaseous and the vapour forms of the relevant heavy metal emissions as well as their compounds.

(d) Average values shall be measured over a sample period of a minimum of 6 hours and a maximum of 8 hours.

The emission limit value refers to the total concentration of dioxins and furans calculated using the concept of toxic equivalence in accordance with Annex I of the Directive.

Dioxins and furans = 0,1 ng/m^3

(e) The following emission limit values of carbon monoxide (CO) concentrations shall not be exceeded in the combustion gases (excluding the start-up and shut- down phase):

- 50 milligrams/m^3 of combustion gas determined as daily average value;
- 150 milligrams/m^3 of combustion gas of at least 95 % of all measurements determined as 10-minute average values or 100 mg/m3 of combustion gas of all measurements determined as half-hourly average values taken in any 24- hour period.

Exemptions may be authorized by the competent authority for incineration plants using fluidized bed technology, provided that the permit foresees an emission limit value for carbon monoxide (CO) of not more than 100 mg/m^3 as an hourly average value.

6.2 References & Further reading

Russian Standards and Regulations

- Federal law no. 96-FZ on the protection of atmospheric air, 1999
- SanPin 2.1.7.2790-10: Standards on healthcare waste management

European Directives

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