Section V.A.2.

Guidance by source category: Annex C, Part II Source Categories

Waste Incinerators:

Medical Waste

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Draft Guidelines on BAT and BEP

Medical Waste Incineration

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1. Introduction

This paper gives mainly information on the incineration of medical waste (in the following referred to as "health-care waste"), this being only one method of final disposal. Since the incineration of health-care waste can result in significant UPOPs emissions the main focus of the paper is on the best available techniques for the reduction of UPOPs emission due to incineration. Other possible techniques like e.g. the sterilization of infectious waste do not result in UPOPs emissions. The advantages and drawbacks as well as the applicability of these techniques are already described elsewhere and are not repeated in detail here.

Hospitals generate large amounts of waste that falls into different categories (additionally, health-care waste can also originate from other sources like emergency medical care services, transfusion or dialysis centres, laboratories, animal research, blood banks etc.). Between 75 % and 90 % of the waste produced is non-risk or general health-care waste, which is comparable to domestic waste. It comes mostly from the administrative and housekeeping functions of health-care establishments and may also include waste generated during maintenance of health-care premises. The remaining 10-25 % of health-care waste is regarded as hazardous and may create a variety of health risks. Less than 10 % of this waste is of an infectious nature. Other types of waste include toxic chemicals, cytotoxic drugs, flammable and radioactive wastes. This paper is concerned almost exclusively with infectious health-care waste; wastes comparable to domestic waste should be dealt with by the municipal waste disposal mechanisms.

Each hospital should develop a waste management plan that provides for a thorough segregation and treatment of waste. This can lower the costs of the ultimate disposal.

The main aims of hospital waste management are:

- minimizing risk for personnel, general public and environment
- minimizing the amounts of waste being generated
- providing for segregation and separation of wastes
- designation of deposit areas in the wards
- establishment of safe routes for the transportation of the waste
- establishment of a safe and proper area for the temporary storage
- proper waste treatment and disposal

Under the framework of the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal "**Technical Guidelines on the environmentally sound management of biomedical and health-care waste**"[1] have been published. It is strongly advised to use and apply these guidelines which provide detailed information on the hazards of health-care waste, safe management of health-care waste, the proper segregation and collection of wastes as well as treatment and disposal methods and capacity building.

Types of health-care waste

- infectious health-care waste (hazardous)
- chemical, toxic or pharmaceutical waste, including cytotoxic drugs (antineoplastics) (mostly hazardous)
- anatomical and pathological waste (body parts etc.)
- sharps (partly hazardous)
- radioactive waste
- other waste (glass, paper, packaging material etc.)

[1] Basel Convention on the control of transboundary movements of hazardous wastes and their disposal (adopted on 22 March 1989): Technical Guidelines on the environmentally sound management of biomedical and health-care waste, UNEP, Geneva 2002

For the purpose of these guidelines, the following definitions are taken from the technical guidelines on the environmentally sound management of biomedical and health-care waste (Basel Convention):

Infectious health-care waste[2]

Discarded materials or equipment contaminated with blood and its derivatives, other body fluids or excreta from infected patients with hazardous communicable. Contaminated waste from patients known to have blood-borne infections undergoing haemodialysis (e.g. dialysis equipment such as tubing and filters, disposable sheets, linen, aprons, gloves or laboratory coats contaminated with blood);

Laboratory waste (cultures and stocks with any viable biological agents artificially cultivated to significantly elevated numbers, including dishes and devices used to transfer, inoculate and mix cultures of infectious agents and infected animals from laboratories).

Biological health-care waste

All body parts and other anatomical waste including blood and biological fluids and pathological waste that is recognizable by the public or the health-care staff and that demand, for ethical reasons, special disposal requirements.

Sharps

All biomedical and health-care waste with sharps or pointed parts able to cause an injury or an invasion of the skin barrier in the human body. Sharps from infected patients with hazardous communicable diseases, isolated wards or other pointed parts contaminated with the above-mentioned laboratory waste must be categorized as infectious waste.

2. Best Environmental Practices (BEP) concerning health-care waste management

In order to ensure an efficient and state of the art disposal a number of practices prior to the final disposal method or the combustion of the waste itself is considered necessary. These practices are not directly linked to the reduction and avoidance of unintentionally produced POPs but represent general principles which in consequence can influence the generation of waste fractions and which contribute to the safety of the personnel, the public and the environment. In this document only a brief overview of common best practices is given.

Segregation

Above all, segregation is the key to effective health-care waste management. It ensures that correct disposal routes are taken. Segregation should be carried out under the supervision of the waste producer and as close as possible to the point of generation. Segregation must therefore take place at source, that is, in the ward, at the bedside, in the theatre, in the laboratory, in the delivery room, etc., and must be carried out by the person generating the waste, for example the nurse, the doctor or the specialist, in order to secure the waste immediately and to avoid dangerous secondary sorting.

Waste minimization

The generation of hazardous wastes and other wastes within has to be reduced to a minimum. This can be achieved only if everyone who works in the health services sector gives increased thought to this issue and takes action to ensure that the volume and hazardousness of wastes are minimized.

[2] The interpretation of the definition of infectious health-care waste varies according to national circumstances, policies and regulations. International organizations (WHO, the United Nations, etc.) have specific interpretations of the definition. Infectiousness is one of the hazardous characteristics listed in annex III to the Basel Convention and defined under class H6.2 .

Preference should be given to environmentally sounder products and replacement of harmful or disposable products with reusable or alternative products, if these meet the relevant requirements in terms of hygiene and patient safety.

A noticeable reduction in waste volume can be achieved only if disposable products already in use are scrutinized as to their necessity. In principle, disposables such as disposable cutlery, disposable linen (including covering sheets), disposable instruments and equipment (scissors, scalpels, forceps) and disposable containers (kidney dishes, infusion bottles) should be replaced by reusable products and long-lived alternatives.

For more detailed information ample material concerning health-care waste management is available from different sources[3].

The establishment of a proper health-care waste management involves to

- characterise the nature and amount of the different waste fractions
- identify option to avoid or reduce waste generation (package sizes, stock keeping, evaluate work processes, reuse of equipment where feasible)
- draw up a list of rules how to handle the waste
- specify the suitable containers for collection, storage and transport
- lay down the responsibilities of the personnel
- describe the appropriate treatment options for the different waste fractions
- provide for proper documentation and control of the waste disposal
- describe the transport of the waste fraction to the final disposal location and the type of final treatment
- calculate the costs for the different activities

Training of personnel

The personnel should get thorough instructions about:

- risks connected with health-care waste
- classification and codes of the different waste fractions and their classification criteria
- costs of waste treatment
- illustration of the waste management from generation to disposal
- responsibilities
- effects of mistakes and mismanagement

Collection at the site of waste generation

- provide small bins for the disposal of the different waste fractions at suitable places
- proper packaging of the waste: Bags/containers for infectious waste and sharps should be puncture resistant and leak proof. Either solid drums or bags which are placed within a rigid or semi-rigid container having a capacity of 30 – 60 litres should be used. The containers may be recyclable (stainless steel) or single use (thick cardboard or rigid polyethylene). Full containers should have a locking or sealing device.
- proper labelling of containers as infectious, cytotoxic etc. waste
- no overloading of containers
- Highly infectious waste should, whenever possible, be sterilized immediately by autoclaving. It therefore needs to be packaged in bags that are compatible with the proposed treatment process.

[3] e.g. in "Handbook for safe management of wastes from health care activities", WHO, 2000; Basel Convention on the control of transboundary movements of hazardous wastes and their disposal (adopted on 22 March 1989): Technical Guidelines on the environmentally sound management of biomedical and health-care waste, UNEP, Geneva 2002?

Transport to the intermediate storage area

- Once the primary containers are full they must be taken to an intermediate storage area.
- establish a designated storage area (clean conditions, facilities for cleaning/ washing/disinfecting of the containers) where access is only allowed for authorized personnel
- personnel handling the waste must wear protective clothing (gloves, shoes) during collection, transportation and storage
- clear transport routes and times
- no comprimation of waste containing sharps
- no manual sorting of infectious waste fractions

3. New sources

When deciding on waste disposal from health-care activities, priority consideration should be given to alternate processes, techniques or practices that have similar usefulness but which avoid the formation and release of UPOPs.

Due to the high investment and operational costs of waste incinerators operating at the BAT level an economical plant operation seems often impossible, especially for small hospital incinerators. Therefore, centralised incineration units are preferred to decentralised on-site treatment of the health-care waste. Health-care waste incineration lines operated on the same site as other or municipal waste incineration will result in synergy effects and provide economic viability.

4. Existing sources

Due to the poor design, operation, equipment and monitoring of many existing small hospital incinerators these installations cannot be regarded as BAT. A medical waste incinerator without sophisticated pollution abatement devices releases a wide variety of pollutants including dioxins and furans, metals (such as lead, mercury, and cadmium), particulate matter, acid gases (hydrogen chloride and sulphur dioxide), carbon monoxide, and nitrogen oxides. These emissions have serious adverse consequences on worker's safety, public health and the environment.
The cost of retrofitting old plants is a key factor in the consideration of medical waste disposal. In evaluating the costs of a proper incineration unit, decision-makers should take into account, among others, capital and operating costs of the incinerator plus scrubber and other pollution control devices; the cost of secondary chamber retrofits for old incinerators; the costs of periodic stack testing, continuous monitoring, operator training and qualification; and the costs of maintenance and repair especially in relation to refractory wear or failure.
As a consequence, the shutdown of existing inappropriate plants has to be considered along with the introduction of alternative techniques for waste disposal or the transfer of waste to centralised municipal or hazardous waste incineration units.

5. Alternative Techniques

The following alternative techniques do not result in the formation and release of UPOPs and are therefore considered suitable methods for their ultimate elimination. However, they might have advantages and drawbacks in other respects. For more information on these techniques please see the "Technical Guidelines on the environmentally sound management of biomedical and health-care waste" elaborated under the framework of the Basel Convention.

The following methods are suitable for infectious and biological waste and sharps[4]. Hazardous chemical waste, chemotherapeutic waste, volatile organic compounds, mercury and radioactive waste should not be fed into the below systems as this would result in the release of toxic substances into air, condensate or into the treated waste.

Steam sterilization

Steam sterilizing or autoclaving is the exposure of waste to saturated steam under pressure in a pressure vessel or autoclave. The technology does not render waste unrecognizable and does not reduce the waste volume unless a shredder or grinder is added. Offensive odours can be generated but be minimized by proper air handling equipment.
Autoclaves are available in a wide range of sizes and capital costs are relatively low compared to other alternative techniques.
Microwave disinfection is essentially also a steam-based process since disinfection occurs through the action of moist heat and steam generated by microwave energy. Drawbacks are the relatively high capital costs, noise generation from the shredder and possibility of offensive odours.

Dry heat sterilization

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. Internal shreddering is usually included (reduction of waste volume). The technology is simple, automated and easy to use. Odours can occur.

Chemical disinfection/sterilization

This method involves the exposure of waste to chemical agents which possess antimicrobial activity. Chlorine dioxide, sodium hypochlorite, peroxyacetic acid, ozone gas, lime-based dry powder are used. Chemical-based disinfection technologies generally incorporate internal shredding and mixing to resolve the problem of contact and exposure. Chlorine-based systems could form toxic by-products in the wastewater. Safety and occupational exposures should be monitored when using any chemical technology. General disinfectants may not inactivate organisms such as spores, some fungi and viruses and should not be used as the principal treatment methods unless thermal procedures are inappropriate because of the nature of waste or contaminated material. Thermal sterilization should be given preference over chemical disinfection for reasons of efficiency and environmental considerations.

Landfill

Disposing of infectious wastes into a landfill greatly increases the risks to human health and the environment of exposure to infection from this source. If the waste is disturbed by any means, or not properly covered, further risks will arise. It is therefore not good practice to dispose of infectious waste directly into a landfill. To guard against these risks, where landfill is the only available option, infectious wastes should be treated in order to destroy/remove their infectivity, preferably at the site of generation of the waste. This can be done by using known effective techniques such as autoclaving, microwave treatment, dry heat sterilization or chemical disinfection.

The following diagram[5] shows into which waste fractions the health-care waste should be segregated and the appropriate treatment options of these fractions:

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[4] Cost data on the various techniques can be obtained from the following publication: Health Care Without Harm, Non-Incineration Medical Waste Treatment Technologies, 2001, Washington, http://www.noharm.org/nonincineration (Chapter 11)
[5] from Basel Convention Technical Guidelines on the environmentally sound management of biomedical and health-care waste, Chapter 2, Figure 2 (adapted)

HEALTH-CARE WASTE → **SEGREGATION**

TYPES OF HEALTH-CARE WASTE	APPROPRIATE TREATMENT OPTIONS
Infectious health-care waste (including infectious biological waste and infectious sharps)	- Hazardous waste incineration - Alternative techniques: Steam sterilization, dry heat sterilization, chemical disinfection/sterilization, (subsequent landfill)
Biological waste (human anatomical waste), waste with blood and body fluids (not infectious)	- Municipal waste incineration (specially adapted for this purpose!) - Special treatment (e.g. crematoria for amputated body parts)
Sharps (not infectious)	Municipal waste incineration (specially adapted for this purpose)
Chemical, toxic or pharmaceutical waste including cytotoxic drugs	- Return of old pharmaceuticals - Toxic and cytotoxic waste: hazardous waste incineration - Non-hazardous pharmaceutical waste: municipal waste disposal route
Radioactive waste	- Suitable storage for decay - Return to supplier for reprocessing etc.
Other hazardous waste (not exclusive to the health-care sector)	Hazardous waste disposal route
Health-care waste with the same composition as household and municipal waste	Municipal waste disposal route

6. Best Available Techniques (BAT) for the incineration of health-care waste

Sources of unintentionally produced POPs

Currently two major mechanisms for PCDD/F (dioxins and furans) formation during incineration of wastes are known:

- Formation of dioxins/furans in the presence of corresponding chlorinated precursors (such as PCBs, PCPs) by a homogenous gas phase reaction at temperatures between 300 and 800°C.
- De novo synthesis: The formation of PCDD/F will take place during cooling of the exhaust gas under the following conditions:
  - Temperature range between some 200 and 500°C and adequate residence time in this temperature range.
  - Presence of a chlorine source.
  - Presence of oxygen in the exhaust gas.
  - Presence of dust containing heavy metals and carbon which acts as catalyst.

Emissions of organic pollutants and PCDD/F can be reduced by firing and plant specific measures (primary measures) and additionally by secondary measures.

Process description

Incineration is an important method for the treatment and decontamination of biomedical and health-care waste. This chapter gives guidance on the incineration of the following (mostly) hazardous waste fractions: infectious health-care waste, biological health-care waste and sharps.

Incineration is a high-temperature (850º C to 1100º C) dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight.

Semi-pyrolysis is a process of smouldering where thermal conversion occurs in an oxygen deficient atmosphere at a temperature between 500 and 600 °C.

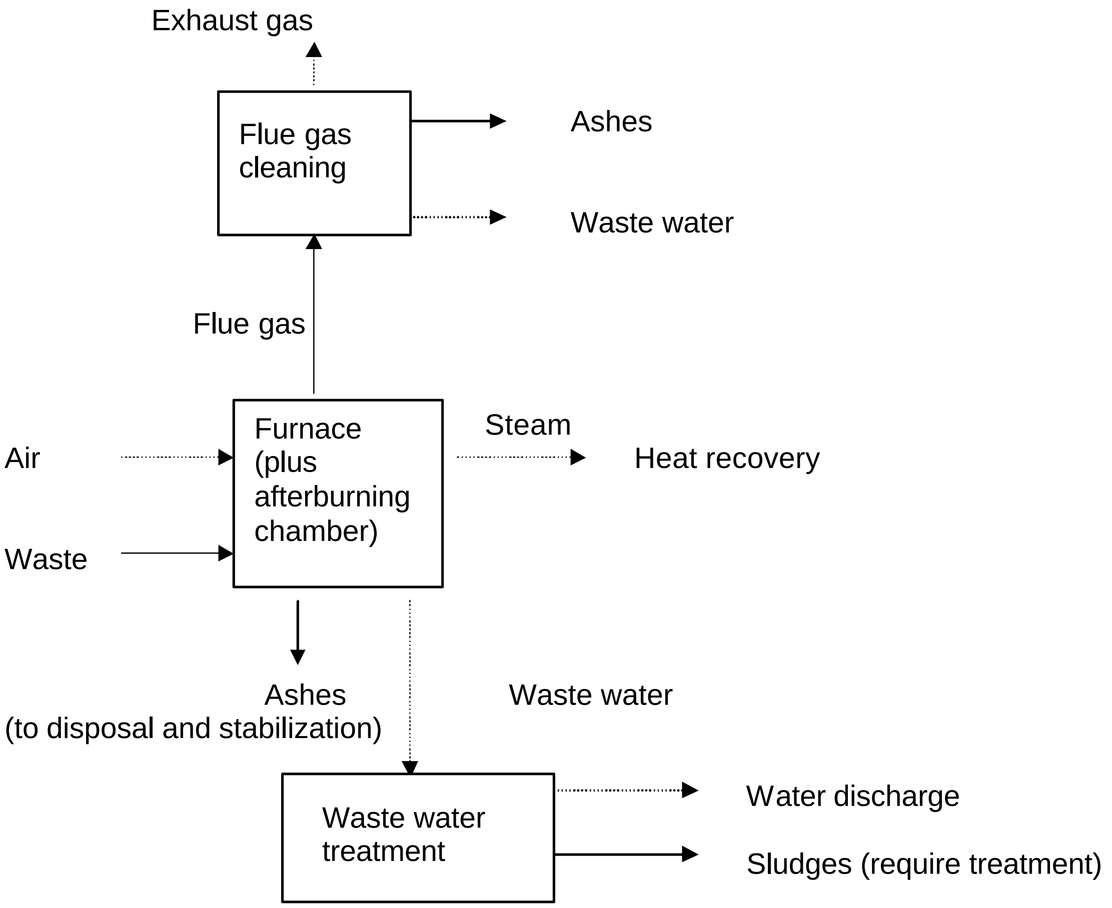
The incineration/pyrolysis should only be carried out in appropriate plants. The system should be designed to cope with the specific characteristics of hazardous health-care waste (high water content, high plastic content). As the following technologies are rather sophisticated only hazardous waste fractions should be burned in these plants. Other health-care waste which is similar to municipal waste should be segregated in advance and be subject to different waste treatment technologies. On-site facilities (i.e. in the hospital) are usually equipped with incinerators up to a capacity of 1 tonne/day.

If infectious waste is not burned immediately (during 48 hours) it must be deposited in a cooled storage room (10 °C max.). Working and storage areas should be designed to facilitate disinfection.

An incineration plant basically consists of the following units:

- furnace or kiln
- afterburning chamber
- dry, wet or catalytic flue gas cleaning devices
- waste water treatment plant

Simplified flow scheme of an incinerator:



The following firing technologies are considered **BAT options** for the thermal treatment of health-care waste:

- degassing and/or gasification of wastes (pyrolysis)
- rotary kiln
- grate incinerator specially adapted for infectious health-care waste (municipal waste disposal line)
- fluidized bed incinerator

Single-chamber, drum and brick incinerators are **not considered as BAT**.

Pyrolytic incinerator

Pyrolysis plants with afterburning chambers are mainly used for smaller plants. These small plants usually operate in a discontinuous mode. For the purpose of health-care waste this is charged packed in barrels or bags. Larger plants should be equipped with automatic loading devices. At plants with degassing and/or gasification the processes drying, degassing and gasification take place in a reactor prior to combustion.

Waste is introduced discontinuously into a distillation chamber that is heated up to a sufficient temperature in order to distil the waste. Gases leaving the distillation chamber are mixed with a continuous airflow in the afterburning chamber and held at a temperature of about 900 °C by co-firing of natural gas. If the quantity of distilled gas is too high the volume of fired natural gas will be reduced automatically. Combustion gases leaving the afterburning chamber are cooled in a downstream hot water boiler and routed to a flue gas cleaning sys-

tem. The boiler converts water into steam. The steam can be used to produce electricity to run a hospital, homes or businesses. The smouldering process is done periodically. In order to ensure a sufficient burnout of the ash it is fired with gas burners before it is discharged from the distillation chamber. At small plants fluctuations of the throughput and inhomogeneities of combusted waste are compensated by the auxiliary fuels.
As to pyrolysis plants the dust content of flue gases is small compared to conventional combustion systems. However, there is a great demand for additional fuels, so that consequently high volumes of flue gas are formed.
Typical incinerator capacities (on-site treatment): 200 kg to 10 tonnes/day

Rotary kiln
Another technology used is the rotary kiln. The combustion of health-care waste can be performed in either small rotary kilns (e.g. in the hospital) or, more common, in larger plants used for the combustion of several hazardous waste fractions.
Wastes are delivered from the bunker into the waste chute which is located in front of the firing using a crane. In most cases a sluice is integrated into the chute where waste can directly be fed into the rotary kiln. Highly viscous and liquid wastes can be inserted through the front wall of the rotary kiln. As a result of the slope and the rotation of the rotary kiln, wastes are transported and circulated, which leads to intensive contact with primary air that flows through the rotary kiln. In contrast to grate firings rotary kilns are closed systems. Therefore also liquid and highly viscous materials can be inserted. Exhaust gases coming out of the rotary kiln are treated in an afterburning chamber. In order to assure high temperatures necessary for complete destruction of organic compounds (850 – 1200 °C depending on the waste) afterburning chambers are equipped with burners that automatically start when the temperature falls below the given value.
At the end of the rotary kiln slag arises either sintered or melted. By dropping into the water of the deslagging unit, granulated slag is formed. When the slag is sintered then this part of the plant is similar to that of a grate firing system. Rotary kilns and afterburning chambers are in most cases constructed as adiabatic, ceramically lined combustion chambers. After the combustion chamber flue gases pass a void zone until a temperature range of about 700 °C is reached. Subsequently heating bundles such as evaporators, super-heaters and feed water pre-heaters are arranged. Waste heat boiler and energy supply system is comparable to that of grate firing systems.
Incinerator capacities: 0.5 to 3 tonnes/hour (for health-care waste incineration)

Grate incinerator[6]
Incineration of health-care waste in municipal waste incinerators requires special adaptations. If infectious health-care waste is to be burned in a municipal waste incinerator it has to be disinfected/sterilized beforehand or fed into the incinerator in appropriate containers by automatic loading. Previous mixing of infectious waste with other waste types and direct handling has to be avoided.

Fluidized bed incinerator
Fluidized bed incinerators are widely applied to the incineration of finely divided wastes e.g. RDF and sewage sludge. It has been used for decades, mainly for the combustion of homogeneous fuels. The fluidized bed incinerator is a lined combustion chamber in the form of a vertical cylinder. In the lower section, a bed of inert material (e.g. sand or ash) on a grate or distribution plate is fluidized with air. The waste for incineration is continuously fed into the fluidized sand bed from the top or side.
Preheated air is introduced into the combustion chamber via openings in the bed-plate, forming a fluidized bed with the sand contained in the combustion chamber. The waste is fed to the reactor via a pump, a star feeder or a screw-tube conveyor. In the fluidized bed, drying, volatilisation, ignition, and combustion take place. The temperature in the free space above the bed (the freeboard) is generally between 850 and 950 °C. Above the fluidized bed

[6] See Guidelines on municipal waste incineration for further information

material, the free board is designed to allow retention of the gases in a combustion zone. In the bed itself the temperature of is lower, and may be around 650 °C. Because of the well-mixed nature of the reactor, fluidized bed incineration systems generally have a uniform distribution of temperatures and oxygen, which results in stable operation. For heterogeneous wastes, fluidized bed combustion requires a preparatory process step for the waste so that it conforms to size specifications. For some waste this may be achieved by a combination of selective collection of wastes and/or pre-treatment e.g. shredding. Some types of fluidized beds (e.g. the rotating fluidized bed) can receive larger particle size wastes than others. Where this is the case the waste may only require only a rough size reduction or none at all.

Flue gas cleaning
Flue gases from incinerators contain fly ash (particulates) composed of heavy metals, dioxins, furans, thermally resistant organic compounds, and gases such as nitrogen oxides, sulphur oxides, carbon oxides and hydrogen halides. Flue gases resulting from uncontrolled batch mode (no flue gas cleaning) will contain around 2000 ng TEQ/m³ (source: UNEP Dioxin and Furan Toolkit).

The following <u>flue gas cleaning measures</u> have to be <u>combined in a suitable manner to ensure the application of BAT</u>:

- Separation of dust and non-volatile heavy metals: Fabric filters, electrostatic precipitators and fine wet scrubbers are used for dust separation. Precleaning of flue gases can be done with cyclones, that are efficient for separation of larger particles.
- HCl, HF, SO_2 and Hg removal: The removal of acid components and Hg can be reached by different dry or wet adsorption methods (adsorption on activated coke or lime) as well as by scrubbing (1- or 2-stage wet scrubbing).
- NO_x removal: Primary measures consist in the use of low-NOx burners, staged combustion and recirculation of the flue gas, secondary measures are SNCR and SCR.
- The reduction of organic emissions and PCDD/F can be performed by primary measures (such as limitation of the de-novo synthesis, optimized combustion) and secondary measures like dust separation (see above), activated coke filter, flow injection with activated coke/furnace coke and lime hydrate, catalytic oxidation.

Fly and bottom ash treatment, waste water treatment
The main waste fractions are fly ash, slag, filter cake from the waste water treatment, gypsum and loaded activated carbon. These wastes are predominantly hazardous wastes and have to be disposed of properly. Landfilling in proper double walled containers, solidification and subsequent landfilling and thermal post-treatment are the most common methods (see Chapter 7.5).

7. Summary of Measures

7.1 General guidance

Measure	Description	Considerations	Other comments
Segregation of waste	Clear classification, segregation at source of health-care waste from other waste and within the health-care waste category to minimize the amount of waste to be treated		not directly effective for UPOPs reduction but part of an integrated concept for the management of waste

Measure	Description	Considerations	Other comments
Alternate Processes	In particular, if performance requirements cannot be met by the existing or planned facility priority consideration should be given to alternate processes with potentially less environmental impacts than waste incineration	Examples for alternate processes to incineration of infectious health-care waste are: - steam sterilization - dry heat sterilization - chemical disinfection/sterilization	
Performance requirements for incineration plants	Health-care waste incineration plants should be permitted to achieve stringent performance and reporting requirements associated with best available techniques.	Consideration should be given to the primary and secondary measures listed in Chapter 7.4 below.	Performance requirements for achievement should include: <0.1 ng TEQ/m^3 for PCDD/PCDF

7.2 Health-care waste incineration - Firing technologies representing BAT

Technology	Considerations	Other comments
Pyrolytic incinerator	suitable for smaller plants (200 kg/day to 10 tonnes/day) and on-site treatment	High investment and maintenance costs[1], well trained personnel required
Rotary kiln	suitable for medium sized plants (0.5 – 3 tonnes/hour)	Use of water cooling for rotary kilns, high investment and maintenance costs, well trained personnel required, high energy consumption
Incinerator with grate (municipal waste incinerator)		Use of water cooling for grates, incineration in municipal waste incinerators requires special adaptations for health-care waste (e.g. automatic loading), no previous mixing or direct handling of infectious health-care waste
Fluidized bed incinerator		Not widely applied for incineration of health-care waste

[1] Investment costs for a pyrolytic incinerator (with energy recovery and flue gas cleaning) in Europe (1 tonne/day): 4 million US$ operating and maintenance costs: about 380 US$ per tonne of waste incinerated (data from 1996)

7.3 Health-care waste incineration - General measures

Management options	Release characteristics	Applicability	Other considerations
No burning of waste containing chlorinated compounds unless specific UPOP reduction measures are taken (secondary measures)			Be also aware of a possible heavy metal content in the waste and take the appropriate secondary measures
Appropriate transport, storage and security of health-care waste according to the needs of types of waste	not directly effective for UPOPs reduction but part of an integrated concept for the management of waste		
Location of the plant: centralised incineration units are preferred to decentralised on-site			Incineration lines for hazardous health-care waste operated on the same site as other

Management options	Release characteristics	Applicability	Other considerations
treatment of hazardous health-care waste			hazardous waste incineration or municipal waste incineration will result in synergy effects and provide economic viability of BAT measures.
Incineration of health-care waste only in dedicated plants or in larger incinerators for hazardous waste			The characteristics of health-care waste (high water and plastics content) require special equipment
If not a dedicated health-care waste incinerator is used a separate charging system for infectious waste should be applied	not directly effective for UPOPs reduction but part of an integrated concept for the management of waste		
Do not burn radioactive waste	no effects for UPOP reduction		

7.4 Primary measures and process optimization to reduce PCDD/F emissions

Management options	Release characteristics	Other considerations
Optimization of combustion conditions:	The primary measures described here should be standard for all activities. By applying primary measures a performance around 200 ng TEQ/m³ can be achieved (source: UNEP Dioxin and Furan Toolkit).	retrofitting of the whole process needed
Introduction of the waste in the combustion chamber only at temperatures of 850 °C; plants should have and operate an automatic system to prevent waste feed before the appropriate temperature is reached		
Installation of auxiliary burners (for start-up and close-down operations)		
In general, avoidance of start and stops of the incineration process		
Avoidance of temperatures below 850°C and cold regions in flue gas		
Sufficient oxygen content; control of oxygen input depending on the heating value and consistency of feed material		average oxygen content: 6 Vol %
Sufficient residence time (minimum 2 sec) above 850°C (1100°C for highly chlorinated wastes, i.e. wastes with more than 1 % halogenated organic substances) and 6 % O_2		sufficient residence time is required especially because of the plastic and water content of the waste
High turbulence of exhaust gases and reduction of air excess: e.g. injection of secondary air or recirculated flue gas, pre-heating of the air-streams, regulated air inflow		optimized air inflow contributes to higher temperatures

Management options	Release characteristics	Other considerations
(On-line) monitoring for combustion control (temperature, oxygen content, CO, dust), operation and regulation of the incineration from a central console		

As it **is unlikely to meet a performance level lower than 0.1 ng TEQ/m³ with solely primary measures** the below mentioned secondary measures[7] should be considered.

7.5 Secondary measures

BAT for flue gas cleaning consists of a suitable combination of the options listed below (efficient dedusting assisted by equipment to reduce PCDD/F emissions):

Management options	Release characteristics	Applicability	Other considerations
Dedusting:			
Avoiding particle deposition by soot cleaners, mechanical rappers, sonic or steam soot blowers, frequent cleaning of sections which are passed by flue gas at the critical temperature range			Steam soot blowing can increase PCDD/F formation rates.
Effective dust removal by the following measures:	< 10 % remaining emission in comparison to uncontrolled mode	Medium	Removal of PCDD/F adsorbed onto particles
- Fabric filters	1 - 0.1 % remaining emission	Higher	Use at temperatures < 260°C (depending on material)
- Ceramic filters	Low efficiency		Use at temperatures 800-1000°C, not common for waste incinerators
- Cyclones (only for pre-cleaning of flue gases)	Low efficiency	Medium	only efficient for larger particles
- Electrostatic precipitation	Medium efficiency		Use at a temperature of 450°C; promotion of the de novo synthesis of PCDD/F possible, low efficiency for fine particles, higher NOx emissions, reduction of heat recovery.
- High-performance adsorption unit with added activated charcoal particles (electrodynamic venturi)			For fine dust removal
Reduction of UPOPs emissions by:			
Catalytic oxidation (SCR)	High efficiency (< 0.1 ng TEQ/m^3)	High investment and low operating costs	Only for gaseous compounds, previous removal of heavy metals and dust necessary, additional NO_x reduction if NH_3 is added; high space demand, catalysts can be reprocessed

[7] which represent BAT in the European Union, Canada, ….

Management options	Release characteristics	Applicability	Other considerations
			by manufacturers in most cases, over-heating when too much CO present, higher energy consumption due to re-heating of flue gas; no solid residues.
Gas quenching			not common in waste incinerators
Fabric filter coated with catalyst	High efficiency (< 0.1 ng TEQ/m^3)		e.g. made from PTFE, with parallel dedusting, lower contamination of filter dusts because of PCDD/F - destruction at the catalytic surface
Different types of wet and dry adsorption methods with mixtures of activated charcoal, open-hearth coke, lime and limestone solutions in fixed bed, moving bed and fluidized bed reactors:			
- Fixed bed reactor, adsorption with activated charcoal or open-hearth coke	< 0.1 ng TEQ/m^3	High investment, medium operating costs	High demand of space, disposal of solid residues from flue gas cleaning (=hazardous waste) necessary, permanent monitoring of CO necessary, increase of dust emissions due to aggregation with coal particles possible, consumption of open-hearth-coke in comparison with activated charcoal 2 to 5 times higher, incineration of used adsorption agent in the plant possible, fire/explosion risk
- Entrained flow or circulating fluidized bed reactor with added activated coke/lime or limestone solutions and subsequent fabric filter	< 0.1 ng TEQ/m^3	Low investment, medium operating costs	not common for plants burning exclusively health-care waste, disposal of solid residues from flue gas cleaning (=hazardous waste) necessary, fire/ explosion risk
Appropriate fly and bottom ash and waste water treatment - catalytic treatment of fabric filter dusts under conditions of low temperatures and lack of oxygen - scrubbing of fabric filter dusts by the 3-R process (extraction of heavy metals by acids) - combustion for destruction of organic matter (e.g. rotary kiln, Hagenmeier-Trommel) with subsequent fabric filter, scrubber - vitrification of fabric filter dusts or other immobilization			sludges from waste water treatment and from cooling of fly ash are hazardous waste flue gas can be lead back into the combustion chamber of the incinerator

Management options	Release characteristics	Applicability	Other considerations
methods (e.g. solidification with cement) and subsequent landfilling - application of plasma technology (emerging technique)			

7.6 Organisational measures

Measure	Considerations
- Well-trained personnel - operation and monitoring of the incinerator by periodic maintenance (cleaning of combustion chamber, declogging of air inflows and fuel burners, personnel should wear protective clothing) - regular and/or continuous measurement of the relevant pollutants - development of environmental monitoring (establishing standard monitoring protocols) - development and implementation of audit and reporting systems - general infrastructure, paving, ventilation	Operation of incinerators requires qualified incinerator operators. It should be remembered that the availability of such operators in certain regions should be verified before purchasing high-technology incinerators. If qualified operators are not available, health-care establishments should either resort to alternative health-care waste disinfection technologies or contract the incineration out through a regional facility.

8. References

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Medical waste: http://www.epa.gov/epaoswer/other/medical/

Annex

BAT associated emission levels for releases to air from clinical waste incinerators (source: European IPPC Bureau, BAT Reference Document "Waste Incineration", 2nd Draft March 2004)

Substance(s)	BAT associated emission level for releases to air in mg/Nm^3 (or as stated)			
	Value for noncontinuous samples	½ hour average	24 hour average	Annual average
Total dust		1-15	0.5-2.5	<2
Hydrogen chloride (HCl)		1-50	1-5	<2
Hydrogen fluoride (HF)		<2	<1	<1
Sulphur dioxide (SO_2)		0.1-100	0.1-50	0.1-5
Nitrogen monoxide (NO) and nitrogen dioxide (NO2) expressed as nitrogen dioxide for all installations above 150000 t/yr capacity and those below 150000 t/yr that are using SCR		50-220	50-100	50-100
Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide for installations below 150000 t/yr not using SCR		50-220	120-180	120-180
Ammonia (NH_3)	<10	1-10	<5	<5
Nitrous oxide (N_2O)	<20	<20	<10	<5
Gaseous and vaporous organic substances, expressed as TOC		0.1-20	0.1-10	<2
Carbon monoxide (CO)		10-100	10-30	<15
Mercury and its compounds (as Hg)	<0.03	<0.03	<0.02	<0.005
Cadmium and its compounds (as Cd)	<0.003			
Arsenic and its compounds (as As)	<0.001			
Lead and its compounds (as Pb)	<0.05			
Chromium and its compounds (as Cr)	<0.002			
Cobalt and its compounds (as Co)	<0.002			
Copper and its compounds (as Cu)	<0.001			
Nickel and its compounds (as Ni)	<0.002			
Total cadmium and thallium (and their compounds expressed as the metals)	<0.05		<0.5	<0.1
S other metals	<0.5		<0.5	<0.1
S PCB	<0.001			<0.001
S PAH	<0.001			<0.001
Dioxins and furans (ng TEQ/Nm^3)	<0.005			0.002-0.05

Notes:
S other metals = sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V and their compounds expressed as the metals
Non-continuous measurements are averaged over a sampling period of between 30 minutes and 8 hours.
Sampling periods are generally in the order of 4 – 8 hours for such measurements.
Data is standardised at 11 % Oxygen, dry gas, 273K and 101.3kPa

PCCD/F country emission limits for (medical) waste incineration

Country	Emission limit values to air	Comments
European Union[8] Hazardous and non-hazardous waste incineration:	New and existing sources: 0.1 ng I-TEQ /m³	for existing sources to be achieved by December 28, 2005
Canada[9] Hazardous and non-hazardous waste incineration:	New and existing sources: 80 pg I-TEQ /m³	for small existing sources (< 26 tonnes/year) this is a target value
United States of America Hazardous waste incineration[10]:	Existing sources: 0.28 ng TEQ/dscm New sources: 0.11 ng TEQ/dscm	dioxin and furan - sources equipped with waste heat boilers or dry air pollution control system
	Existing sources: 0.20 ng TEQ/dscm; or 0.40 ng TEQ/dscm and temperature at inlet to the initial particulate matter control device 400°F New sources: 0.20 ng TEQ/dscm	dioxin and furan - sources not equipped with waste heat boilers or dry air pollution control system
Hospital/ medical/infectious waste incineration:	New or modified sources[11]: Small (<200 lb/hr): 125 ng/dscm total CDD/CDF (55 gr/10^9 dscf) or 2.3 ng/dscm TEQ (1.0 gr/10^9 dscf) Medium (>200 and <500 lb/hr): 25 ng/dscm total CDD/CDF (11 gr/10^9 dscf) or 0.6 ng/dscm TEQ (0.26 gr/10^9 dscf) Large (>500 lb/hr): 25 ng/dscm total CDD/CDF (11 gr/10^9 dscf) or 0.6 ng/dscm TEQ (0.26 gr/10^9 dscf) Existing sources (before June 20, 1996)[12]: Small: 125 ng/dscm total CDD/CDF (55 gr/10^9 dscf) or 2.3 ng/dscm TEQ (1.0 gr/10^9 dscf) Medium: 125 ng/dscm total CDD/CDF (55 gr/10^9 dscf) or 2.3 ng/dscm TEQ (1.0 gr/10^9 dscf) Large: 125 ng/dscm total CDD/CDF (55 gr/10^9 dscf) or 2.3 ng/dscm TEQ (1.0 gr/10^9 dscf)	
Switzerland Waste incineration:	Currently no ELVs for PCDD/F emissions from waste incineration, planned in the near future: 0.1 ng I-TEQ /m³	waste incinerators below 350 kW thermal output not allowed

[8] European Directive 2000/76/EC on the incineration of waste
[9] Canadian Council of Ministers of the Environment (CCME), *Canada-wide Standards for PCDD and Furans*
[10] National Emission Standards for Hazardous Air Pollutants: Proposed Standards for Hazardous Air Pollutants for Hazardous Waste Combustors (Phase I Final Replacement Standards and Phase II)
(The Administrator of EPA signed this proposed rule on March 31, 2004 and EPA has submitted it for publication in the *Federal Register*; no official version; official version in a forthcoming *Federal Register* publication; http://www.epa.gov/fedrgstr
[11] 40 CFR Part 60 Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Hospital/ Medical/Infectious Waste Incinerators; Final Rule; http://www.epa.gov/hwcmact/newmact/hazmact.htm
[12] 40 CFR Part 62 Federal Plan Requirements for Hospital/ Medical/Infectious Waste Incinerators Constructed On or Before June 20, 1996; Final Rule; http://www.epa.gov/hwcmact/newmact/hazmact.htm