7.18 Municipal, medical and hazardous waste incineration

7.18.1 Coverage

This section addresses the incineration of municipal (or domestic) solid waste, hazardous and medical wastes as well as the incineration of sludges from wastewater treatment.

Municipal solid waste (MSW) mainly consists of paper and paperboard, glass, metals, plastics, rubber, leather, textiles, wood, food waste, yard waste, and miscellaneous inorganic waste [1].

Hazardous waste is mainly generated in industrial production processes (e.g. ashes, sludges, and other production waste), energy generation, civil engineering and building activities (e.g. demolition waste, construction site waste, and road construction waste) and by waste incineration (fly ashes) [1].

7.18.2 Emission sources

Municipal solid waste, sewage sludge and hazardous waste can i. a. be treated in incineration plants. Municipal solid waste is mainly incinerated in public owned waste incineration plants, although a certain amount is burned at industrial incineration sites [2].

Different types of thermal treatments are applied to the different types of wastes, however not all thermal treatments are suited to all wastes. This paragraph describes the main technologies for the thermal treatment of wastes [3].

Municipal solid waste can be incinerated via several main combustion systems including moving grate and fluidized bed [4]. Fluidized bed technology requires MSW to be of a certain particle size range - this usually requires some degree of pre-treatment and/or the selective collection of the waste [3].

For the incineration of hazardous and medical waste, rotary kilns and grate incinerators are most commonly used, but fluidized bed incinerators are also applied.

Incineration of sewage sludge takes place in rotary kilns, multiple hearth, or fluidized bed incinerators, but co-combustion in grate firing systems, coal combustion plants and industrial processes is also applied [5][6][7] Sewage sludge has to be dried or mechanically dehydrated before combustion and often additional firing is required to ensure stable combustion.

Grate technology. Municipal waste is the main application for these incinerators, which can be designed to handle large volumes of waste [2]. In Europe approximately 90% of installations treating MSW uses grates.

Different grate firing systems such as rocking grates, reciprocating grates, travelling grates, roller grates (each of them and water cooled or not) have been developed and can be distinguished by the way the waste is conveyed through the different zones in the combustion chamber. The different grate systems have to fulfil special requirements regarding primary air feeding, conveying velocity and raking, as well as mixing of the waste. Main additional features are good control characteristics and a robust construction to withstand the severe conditions in the combustion chamber [1].

Fluidized bed Incinerators are suitable only for reasonably homogeneous materials and are therefore the main designs for the incineration of sewage sludge, but also for mechanically or mechanically-biologically pre-treated waste streams [2].

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 at a temperature between 850 and 950 °C. Above the fluidized bed, a secondary combustion zone is created to ensure a retention time of more than two seconds at a temperature above 850 °C. When the air supply to the fluidized bed is under-stoichiometrical (lambda <1), the bed temperature is significantly lower, e.g. 650°C. In this case, only gasification takes place in the bed itself, and most of the heat is being generated in the secondary combustion zone, i.e. above the fluidized bed, by gas phase oxidation reactions [1].

Fluidized bed incineration systems have the advantage of easy and quick stop of waste supply and hot start behaviour and the advantage of a lower temperature which leads to lower NO_x formation [2] [8]. However, in case of a complete shut-down (e.g. with the aim of bed material removal or maintenance work to be done) or a cold start, it takes significantly longer for a fluidized bed system to cool down or to heat up than for a grate system, as the whole sand load has to be cooled down or heated up to operation temperature

Rotary kiln. In rotary kilns, almost any waste, regardless of type and composition, can be incinerated and temperature restrictions for operation are not as stringent as in the case of fluidized bed or multiple hearth incinerators [1]. They have the benefit of good waste agitation and achieve good burnout, provided waste residence time in the furnace is adequate. They can be used in combination with other designs to provide additional ash burnout [2].The rotary kiln consists of a cylindrical vessel slightly inclined on its horizontal axis. The waste is conveyed through the kiln by gravity as it rotates. In order to ensure complete destruction of toxic compounds, a secondary combustion chamber is generally necessary [1].

Multiple hearth furnaces are mainly applied to the incineration of suldges. Sewage sludge is fed at the top of the furnace and moves downwards through the different hearths counter-current to the combustion air, which is fed at the bottom of the furnace. The upper hearths of the furnace provide a drying zone, where the sludge gives up moisture while the hot flue gases are cooled. The central hearths are in charge of the incineration, and the lower hearths ensure complete burnout. The incineration temperature is limited to 980 °C, because above this temperature the sludge ash fusion temperature will be reached and clinker will be formed. In order to prevent leakage of hot toxic flue gases, multiple hearth furnaces are always operated at a slight vacuum pressure [8].

Other processes have been developed that are based on the decoupling of the phases which also take place in an incinerator: drying, volatilisation, pyrolysis, carbonisation and oxidation of the waste; gasification using gasifying agents such as steam, air, carbon-oxides or oxygen is also applied.

7.18.3 BAT, Associated Emission Levels (AEL)

7.18.3.1 SO2

Sulphur dioxide as well as HCL and HF is formed during combustion of sulphur-(chloride- and fluoride)-containing compounds which are found in waste. Their amount is mainly determined by the amount of sulphur-(chloride- and fluoride) containing compounds present in the waste but operation conditions and incineration technology applied may also have a minor impact.

Raw gas concentrations of SO_2 typically are in a range from 400 to 1000 mg/Nm³, clean gas concentrations are mostly required to be considerably lower [3] [1], making flue gas treatment indispensable.

SO_2 is removed in general from the flue gas by means of wet scrubbers, spray-dry scrubbers and dry scrubbers.

The use of primary measures such as fuel selection, waste selection or segregation techniques, are considered to be BAT [2].

The three main techniques, web scrubbing, semi-dry and dry scrubbing are considered to be BAT for the removal of SO_2 in the incineration of sewage sludges, municipal and medical waste [2].

For wet scrubbers and semi-wet FGT, < 20 mg/m3 can be achieved and water consumption is needed (and effluent may be generated). Reduction rates of 96-98.4 % are achievable. For dry scrubbers < 40 to < 20 mg/m3 can be achieved depending on the reagent.

Table 1: Emission sources and selected BAT SOx control measures with associated emission levels in waste incineration

Emission source	Combination of control measures	Operational SOx emission level associated with BAT[1 2] (mg/Nm^3)
Domestic or municipal waste incineration		
Grate incinerator	Dry scrubber	1- 40[3]
Rotary kiln	Spray dry scrubber	1 - 40
Fluidized bed combustion	Wet Scrubber	1 - 40
Industrial waste incineration (hazardous and medical waste)		
Grate incinerator	Dry scrubber	1 - 40
Rotary kiln	Spray dry scrubber	1 - 40
Fluidized bed combustion	Wet Scrubber	1 - 40
Incineration of sludges from waste-water treatment		
Rotary kiln	Dry scrubber	1 - 40
Multiple hearth furnace	Spray dry scrubber	1 - 40
Fluidized bed combustion	Wet Scrubber	1 - 40

[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.

[2] The ELV of the EU waste incineration directive for SO_2 is 50 mg/m³

7.18.3.2 NOx

Nitrogen oxides are emitted from incineration plants. In many cases they are measured using continuous emission monitors. Emissions at modern plants are reported to be generally in the range between 30 and 200 mg/Nm3. (clean gas, daily average, 11% O_2 [3]).

Emissions of NO_x can generally be lowered by reducing the amount of incinerated waste. This can be accomplished through various waste management strategies, including recycling programmes and composting of organic materials.

Nitrogen oxides are formed predominantly as NO and NO_2. Contrary to high temperature processes, most of the nitrogen oxides generated during waste incineration (furnace temperature between 800 and 1200 °C) originate from the nitrogen contained in the waste (fuel-NO_x) [1]. Therefore, the reduction efficiency of primary measures is generally limited, as a majority of nitrogen oxides originate from fuel bound nitrogen and as the amount of fuel bound nitrogen converted to nitrogen oxides can only be influenced to a limited extent through changes in plant design and operation [9]. However, primary measures are generally of great importance for reducing the formation of NOx at the combustion stage. They mainly relate to the management and preparation of wastes, and particularly to the thermal treatment applied [3].

Primary measures have been developed to reduce NO_x emissions at source during the combustion process by regulating flame characteristics such as temperature and fuel-air mixing. Secondary measures operate downstream of the combustion process and remove NO_x emissions from the flue gas.

For the incineration of sewage sludges as well as municipal and medical waste the use of primary measures such as flue-gas recirculation, air-staged combustion, fuel selection, low NOx burners in combination with secondary measures (e.g., SCR, SNCR) is considered to be BAT.

In general SCR is considered BAT where higher NO_x reduction efficiencies are required (i.e. raw flue gas NO_x levels are high) and where low final flue-gas emission concentrations of NO_x are desired. Actually, SCR is a proven technology in the waste incineration sector, which allow to achieve high NO_x reduction rates (typically over 90%) [1] [3] and NO_x emission of below 50 mg/m^3 [11].

For SNCR ammonia and urea injection are suitable and considered to be BAT. Reducing NO_x by SNCR to 75% requires a higher addition of the reducing agent. With application of SNCR NO_x emission concentrations of 70 mg/m^3 (daily average) [1] [3] can be reached.

An effective emission control of NOx via SCR or SNCR can result in increased NH_3-emissions (NH_3-slip), which again can be converted to NO_X. To achieve a low level of total nitrogen emissions also a NH_3-emission control (NH_3 emissions < 10 mg/m3 are achievable) is necessary. [3]

Table 2 Emission sources and selected BAT NOx control measures with associated emission levels in waste incineration

Emission source	Combination of control measures	Operational NO_x emission level associated with BAT[1 2] (mg/Nm^3)
Waste incineration	SCR	40-100
	no SCR	120-180
[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded. [2] The ELV of the EU waste incineration directive for NO_X is 200-400 mg/m³ (depending on plant capacity and existing/new status)		
Effective control of NOX abatement systems, including reagent dosing contributes to reducing NH3 emissions. Wet scrubbers absorb NH3 and transfer it to the wastewater stream. BAT are considered NH3 emissions <10 mg/m³ (BREF Split view: <5);		

7.18.3.3 Dust

Dust emissions from waste incineration plants mainly consist of the fine ashes from the incineration process that are entrained in the gas flow [3]. Dust is normally measured continuously with reported emissions after treatment of between <0.05 and 15 mg/Nm^3 (11% O_2) [3]).

Dust removal techniques can be divided into pre-dedusting and end-dedusting. Whereas the main purpose of pre-dedusting is to collect residues of different composition separately and to avoid operational problems in down-stream equipment, the main purpose of end-dedusting is to reduce final dust emissions

Dry and wet electrostatic precipitator and fabric filters are the mainly used three types for removing of particulate matter in flue gases. ESPs are effective in collecting dust with particle size in the range of 0.1 µm to 10 µm, and their overall collection efficiency can be 95 to 99 percent [10].

Fabric filters (FF) are considered to be BAT for the incineration of sewage sludge as well as municipal and medical waste. They are a proven technology and when correctly operated and maintained provide reliable abatement of particulate matter to below 5 mg/m^3. Removal efficiencies are very high for a large range of particle size.

In general, electrostatic precipitators (ESPs) either wet or dry are not capable of abating particulate matter to the same extent as fabric filters [2]. In combination with wet scrubbers they are considered to be BAT. Depending on the design system and the place in the flue gas treatment system (pre- or end-dedusting), particulate emission concentration values of 5 to 25 mg/m^3 can be reached [3]. With a wet ESP which is a specific version of the ESP the cleaning takes place continuously by a water flow. This version is applied as end-dedusting after a wet scrubber. Very low particulate matter of below 5 mg/m^3 can be reached [3].

Table 3 Emission sources and selected BAT dust control measures with associated emission levels in waste incineration

Emission source	Combination of control measures	Operational dust emission level associated with BAT[1 2] (mg/m^3)
Waste incineration		1-5
[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded [2] The ELV of the EU waste incineration directive for dust is 10 mg/m^3		

7.18.4 Cost data for emission reduction technologies

Table 4 Cost data for different abatement techniques [11], [3]

Control options	Investments costs (EURO)			Specific costs of maintenance (EURO/t)		
	Throughput per line (t/yr)			Throughput per line (t/yr)		
	75,000	100,000	150,000	75,000	100,000	150,000
SCR	1,200,000	1,500,000	2,000,000	0.30	0.30	0.30
SNCR	700,000	800,000	1,000,000	0.19	0.16	0.13
Wet dedusting system	1,500,000	2,000,000	2,500,000	0.30	0.30	0.30
Dry flue gas cleaning with adsorption	1,725,000	2,175,000	3,000,000	0.23	0.22	0.20
ESP	1,000,000	1,200,00	1,600,000	0.27	0.24	0.21
Dry flue gas cleaning with fabric filter	1,150,000	1,450,000	2,000,000	0.15	0.15	0.13

7.18.5 References used in chapter 7.18

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