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BASEL CONVENTION

Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
Fourteenth meeting
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Item 4 (b) (i) of the provisional agenda*

Matters related to the implementation of the Convention: scientific and technical matters: technical guidelines

Draft updated technical guidelines on incineration on land (D10)

Note by the Secretariat

1. As is mentioned in the note by the Secretariat on technical guidelines (UNEP/CHW.14/7), Argentina and Canada, in consultation with the small intersessional working group on specially engineered landfill and incineration on land, updated the technical guidelines on incineration on land (D10), as set out in the annex to the present note.

2. The changes made to the technical guidelines adopted by decisions II/13 and III/13[1] have not been indicated using the track-change function as the new document has been structured in a different manner to the original one. Therefore, a track-change version is difficult to generate in a readable format.

3. The present note, including its annex, has not been formally edited.

* UNEP/CHW.14/1.

[1] The previous version of the technical guidelines on incineration on land is available on the Convention website: http://basel.int/Implementation/Publications/LatestTechnicalGuidelines/tabid/5875/Default.aspx.

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Annex

Draft updated technical guidelines on incineration on land (D10)

Draft of February 15, 2019

Contents

Glossary *(still under development)*

Ash:
Fly ash:
Bottom ash:
Particular matter:
Slag:
Flue gas:
Emission:
Release:
Best available techniques (BAT): Technologies which allow to reach the most effective emission reduction with the lowest impact on the environment.

Complete oxidation: Complete burnout with no organics left in the ashes.

Abbreviations and acronyms

BAT	Best available technique
BEP	Best environmental practices
CEMS	Continuous emission monitoring systems
ESM	Environmentally sound management
FBC	Fluidized bed combustion
MSW	Municipal solid waste
MSWI	Municipal solid waste incineration
PCB	Polychlorinated biphenyls
PCDD/PCDF	Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo–furans
POPs	Persistent organic pollutants
PPE	Personal protective equipment
RDF	Refuse derived fuel
SCR	Selective catalytic reduction (of nitrogen oxides)
SNCR	Selective non-catalytic reduction (of nitrogen oxides)
TOC	Total organic carbon

I. Introduction

A. Scope

1. The present technical guidelines provide guidance on the environmentally sound incineration of hazardous wastes and other wastes, pursuant to decisions BC-13/6 and BC-14/[ ] of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal (hereinafter referred to as “the Convention”). This document supersedes the Technical guidelines on incineration on land of September 1995.

2. These technical guidelines refer to “hazardous wastes” and to “other wastes” as defined in Article 1, paragraph 1 and 2 of the Convention, respectively. They apply to the disposal operation D10: Incineration on land, in Annex IV.A of the Convention.[1]

3. It should be noted that the present technical guidelines do not provide guidance on the disposal operation R1: Use as a fuel, other than in direct incineration or other means to generate energy, in Annex IV.B of the Convention, and other thermal treatment processes. They also do not provide guidance on steps and procedures for upgrading incinerators that are not environmentally sound to bring them in line with the guidance provided in the present guidelines.

4. The term "incinerators for hazardous wastes" is used in the present document to refer to incinerators designed for hazardous wastes while the term "incinerators for household wastes" refers to incinerators for wastes collected from households (i.e. wastes belonging to category Y46 in Annex II to the Convention[2]). When needed, the term "incinerators" will be used to encompass both terms. It should be noted that also wastes from other sources that are similar than household wastes may be incinerated in incinerators for household wastes. These guidelines provide:

(a) Overarching and common guidance on the location, types of incinerators and operational procedures of incinerators;

(b) Specific guidance on incinerators for hazardous waste and incinerators for household wastes.

5. Incineration is a thermal treatment process in which wastes are converted into gases and incombustible solid residues. Thermal treatment processes are generally classified according to the treatment temperatures and to the amount of oxygen/air that is present as reactant for conversion:[3]

(a) Pyrolysis – no oxygen ($\lambda = 0$), typical temperatures ca. 400-850 °C;

(b) Gasification – limited oxygen ($\lambda < 0.5$), typical temperatures ca. 600-1600 °C;

(c) Incineration – excess oxygen ($\lambda > 1$), typical temperatures ca. 800-1300 °C.

6. In addition to the processes referred to in the previous paragraph, there are thermal treatment processes using electrical power to create high temperatures by a plasma arc (plasma processes) (typical temperatures ca. 3000°C) or in an oil bath (liquefaction processes). Pyrolysis and plasma processes may be an option for the treatment of special fractions, such as organo-halogens compounds.

7. In principle, two different approaches can be applied for the incineration of wastes: incineration and co-incineration. Incineration may be covered by disposal operation D10 in Annex IV.A to the Convention or by disposal operation R1 in Annex IV.B to the Convention while co-incineration can be regarded as a recovery operation R1 in Annex IV.B.

8. Co-processing is the use of waste in manufacturing processes for the purpose of energy and/or of resource recovery and to replace the use of conventional fuels/and or raw materials. Due to the high operating temperatures (up to 2000 °C) and long gas residence times (ca. 8 seconds), cement kilns are especially suitable for this purpose. For guidance on co-processing of hazardous waste in cement kilns, see the Basel Convention technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP, 2011). For specific guidance on incineration of persistent organic pollutant (POP) wastes, see the General technical guidelines on POPs (currently

[1] Annex IV is currently being reviewed by the Expert Working Group on the review of Annexes.

[2] Annex II also covers “Residues arising from the incineration of household wastes” (Y47) which is an output of incinerators for household wastes.

[3] The combustion air ratio (λ) is a dimensionless measure, which indicates the mass ratio of air and fuel in a combustion process.

under revision), in particular sections IV.G.2 (b), (e) and (g) that address incineration.

9. For specific guidance on the reduction of mercury releases from thermal treatment of waste, such as incineration, see the Basel Convention Technical guidelines on the environmentally sound management (ESM) of wastes consisting of, containing or contaminated with mercury or mercury compounds (UNEP, 2015).

B. Overview of incineration

10. The purpose of waste incineration is the total oxidation of all organic compounds, at temperatures of about 800-1300 °C, by applying air or oxygen as a reactant. Possible waste input materials should be combustible, i.e. they need to offer a sufficient amount of organic material and the contents of water and inorganic materials should not be too high. If inert waste fractions, e.g. contaminated waste water or brine, are treated, auxiliary fuel (gas, oil) should be applied in order to reach sufficient temperatures. Outputs from incineration are flue gas and a solid residue and depending on the flue gas treatment, also liquids or sludgy wastes.

11. If air is used as a reactant, the flue gas contains an excess (> 50 vol-%) of nitrogen (N2) and the oxygen (O2) remaining after combustion. Main combustion products from the decomposition of the organics are carbon dioxide (CO2) and water vapor (H2O). Carbon monoxide (CO) and some organic compounds (total organic carbon (TOC)) are also present in the gas (at least traces of these). Depending on the composition of the waste, also other pollutants are transferred into the gas phase. Typical contaminants from waste incineration are nitrogen oxides (nitrogen oxide (NO), nitrogen dioxide (NO2) and also nitrous oxide (N2O)), the acidic gases hydrogen fluoride (HF), hydrogen chloride (HCl) and the sulfur oxides (sulfur dioxide (SO2) and sulfur trioxide (SO3)). Particularly problematic for the environment are volatile heavy metals, in elemental form, as chlorides and oxides (especially mercury and cadmium) and toxic organic pollutants, like polycyclic aromatic hydrocarbons and persistent organic pollutants such as polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo–furans (PCDD/PCDF) and polychlorinated biphenyls (PCB).

12. The solid residue contains (non-volatile) minerals, metals and smaller amounts of unburnt material, which can be recycled to the furnace. Depending on the temperature of the incineration process, the solid residue may have the characteristics of ash, slag or a mixture of both. Due to the high temperature in hazardous waste incinerators, the inorganic residue is often (partly) molten and emerges as a slag. The bottom ash from municipal solid waste incineration (MSWI) is exposed to lower temperature and therefore only sintered. Typically, the metals (iron and non-ferrous metals) in the ash/slag can be mechanically separated and recycled in the metallurgical industry. Depending on the quality (especially on the elution of heavy metals), also the mineral fraction may be used as a building material.

13. In general, the requirements for the incineration of hazardous wastes are different than for the incineration of household waste: for instance, higher temperatures and greater effort for logistics and (separate) storage are necessary. Often also more sophisticated flue gas treatment methods are applied. Nevertheless, some types of hazardous wastes can also be incinerated in MSWI facilities.

14. Incineration for hazardous wastes and other wastes is well established for decades and facilities are widespread in Europe, America and Asia. The main advantages of waste incineration, when operated in accordance with best available techniques (BAT) and best available practices (BEP) are the following:

(a) Safe and permanent destruction of all organic (hazardous) constituents;

(b) Safe and permanent sanitation;

(c) Complete oxidation;

(d) Immobilization and concentration of inorganic pollutants (heavy metals) in the flue gas cleaning residues;

(e) Reduction of mass and volume of the waste and hereby preservation of landfill or underground disposal volume;

(f) Possibility to recover the energy content of the waste;

(g) Possibility to recover metals and in many cases also minerals (building material) from the bottom ash/slag.

II. Relevant provisions of the Basel Convention and international linkages

15. A number of multilateral environmental agreements provide guidance on the incineration of hazardous wastes and/or household wastes. The following sections present a brief explanation and description of relevant Articles of the Basel Convention and linkages with other Conventions such as the Stockholm and Minamata Conventions to illustrate their complementarity.

A. Basel Convention

16. The Basel Convention, which entered into force on 5 May 1992, aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes. It does this via a set of provisions on the transboundary movement of wastes and their ESM. In particular, the Basel Convention stipulates that any transboundary movement (export, import or transit) of wastes is permissible only when the movement itself and the planned disposal of the hazardous or other wastes are environmentally sound.

17. A set of provisions of the Basel Convention lays out Parties obligations to ensure the ESM of hazardous wastes and other wastes. These are listed in paragraphs 18 to 20 below.

18. In Article 2 ("Definitions"), paragraph 1, the Basel Convention defines waste as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". Paragraph 2 defines management as "the collection, transport and disposal of hazardous wastes or other wastes, including after-care of disposal sites". Paragraph 4 defines disposal as "any operation specified in Annex IV" to the Convention. Paragraph 5 defines approved site or facility as "a site or facility for the disposal of hazardous wastes or other wastes which is authorized or permitted to operate for this purpose by a relevant authority of the state where the site or facility is located". Paragraph 8 defines the ESM of hazardous wastes or other wastes as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes."

19. Article 4 ("General obligations"), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision. Paragraph 1 (a) states: "Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13." Paragraph 1 (b) states: "Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such wastes, when notified pursuant to subparagraph (a)."

20. Article 4, paragraphs 2 (a) – (e) and 2 (g), contains key provisions of the Basel Convention directly pertaining to ESM, waste prevention and minimization and waste disposal practices aimed at mitigating adverse effects on human health and the environment:

Paragraph 2 (a) – (e) and (g): "Each Party shall take appropriate measures to:

(a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social, technological and economic aspects;

(b) Ensure the availability of adequate disposal facilities, for the ESM of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;

(c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;

(d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement;

(e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting;

(g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner."

B. Stockholm Convention on Persistent Organic Pollutants

21. The Stockholm Convention is a global treaty aimed at protecting human health and the environment from persistent organic pollutants.

22. The objective of the Stockholm Convention, which entered into force on 17 May 2004, is set forth in Article 1 ("Objective"): "Mindful of the precautionary approach as set forth in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Convention is to protect human health and the environment from persistent organic pollutants."

23. The Stockholm Convention provides guidance on best available techniques and best environmental practices as they apply to the prevention or minimization of the formation and release of unintentional POPs from the anthropogenic sources listed in Annex C to the Convention, such as incineration. Guidelines on BAT and provisional guidance on BEP relevant to Article 5 and Annex C to the Stockholm Convention were adopted by the Conference of the Parties to the Convention at its third meeting, in 2007 (UNEP, 2007).

C. Minamata Convention on Mercury

24. The objective of the Minamata Convention, which entered into force on 16 August 2017, is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

25. The Minamata Convention provides guidance related to best available techniques and best environmental practices to assist Parties in fulfilling their obligations which emissions of mercury and mercury compounds to the atmosphere from point sources listed in Annex D to the Convention, such as waste incineration facilities. Guidance in relation to mercury emissions (Article 8, referred to in paragraphs 8 (a) and 8 (b)) were adopted by the Conference of the Parties to the Convention at its first meeting, in 2007 (UNEP, 2007).

III. General considerations on environmentally sound management

26. ESM is a broad policy concept that is understood and implemented in various ways by different countries, stakeholders and organizations. The provisions and guidance documents pertaining to the ESM of hazardous wastes and other wastes provide for a common understanding and international guidance to support and implement the ESM of hazardous wastes and other wastes.

27. The 2013 Framework for the ESM of hazardous wastes and other wastes ("ESM framework") (UNEP, 2013) was adopted at the eleventh meeting of the Conference of the Parties to the Basel Convention.[4] The framework establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM. It is intended as a practical guide for governments and other stakeholders participating in the management of hazardous wastes and other wastes and constitutes the most comprehensive guidance on ESM to complement the Basel technical guidelines.

28. As presented in paragraph 14 of this document, Article 4 of the Basel Convention contains provisions related to the ESM of hazardous wastes and other wastes. ESM is also the subject of the following declarations:

(a) The 1999 Basel Declaration on Environmentally Sound Management, which was adopted at the fifth meeting of the Conference of the Parties to the Basel Convention calls on the parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention, taking into account social, technological and economic concerns, and through further reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention;

[4] UNEP/CHW.11/3/Add.1/Rev.1.

(b) The 2011 Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes, which was adopted at the tenth meeting of the Conference of the Parties to the Basel Convention and reaffirms that the Basel Convention is the primary global legal instrument for guiding the ESM of hazardous wastes and other wastes and their disposal.

29. The Organization for Economic Co-operation and Development has adopted a recommendation on ESM of wastes which includes various items, inter alia core performance elements of ESM guidelines applying to waste recovery facilities, including elements of performance that precede collection, transport, treatment and storage and also elements subsequent to storage, transport, treatment and disposal of pertinent residues (OECD, 2004).

30. Parties should develop a range of measures (strategies, policies, legislation, regulations and programmes) and monitor their implementation to support the meeting of ESM objectives. The implementation of national strategies, policies and programmes are effective tools to complement the implementation of legislation and regulations; monitoring and enforcement; incentives and penalties; technologies; and other tools in which all key stakeholders participate and cooperate (UNEP, 2013a). The following sections should be taken into account when establishing, implementing or evaluating ESM.

31. The prevention and minimization of hazardous wastes and other wastes are the first and most important steps in their overall ESM. In Article 4, paragraph 2, the Basel Convention calls on Parties to "ensure that the generation of hazardous wastes and other wastes is reduced to a minimum". Waste prevention should be the preferred option in any waste management policy. According to the framework for the ESM of hazardous wastes and other wastes, the need to manage wastes and/or the risks and costs associated with doing so are reduced by not generating wastes and by ensuring that generated wastes are less hazardous.

32. The waste management hierarchy covers prevention, minimization, reuse, recycling, other recovery including energy recovery, and final disposal; in doing so, encouraging treatment options that deliver the best overall environmental outcome, taking into account life-cycle thinking.

33. The incineration of hazardous waste and household wastes as per operation D10 falls under final disposal and should therefore be one of the least favoured options. Other options in the waste hierarchy should be duly considered such as energy recovery (i.e. production of heat and/or electricity). Waste incineration can be a sink for pollutants, by destruction of organic compounds and concentration of inorganic contaminants.

IV. General Guidance on Environmentally Sound disposal in incinerators

34. ESM involves the use of facilities operated under quality assured management regimes, according to appropriate BAT and BEP. Waste incineration according to BAT and BEP is associated with higher costs compared to other disposal technologies, especially landfilling. Planning, design, building a waste incineration facilities requires significant financial investment.

35. To establish and operate incineration facilities requires that efforts by the responsible legal authorities have to be made, including regulatory law, administrative execution, financial incentives (e.g. landfill taxes) and subsidies (e.g. to provide lower, affordable tipping fees).

A. Legislative and Regulatory Framework

36. Most countries already have in place some form of legislation that outlines broad environmental protection principles, powers and rights. Such legislation should make ESM operational and include requirements for protection of both human health and the environment. Such enabling legislation can give governments the power to enact and enforce specific rules and regulations on hazardous wastes and other wastes, conduct inspections and establish penalties for violations.

37. A legislative and regulatory framework should be in place to ensure that incinerators are fully protective of the environment and human health. Such legislation should contain detailed requirements for the location, design and operation of incinerators. Examples of national legislation can be found in Annex II.

38. Specific components or features of a regulatory framework applicable to the requirements of an incineration facility should be, at least:

(a) Site selection;

(b) Design standards for facilities;

(c) Training of operators of the facility;

(d) Environmental assessment;

(e) Operation/discharge standards;

(f) Monitoring and control;

(g) Emergency and contingency plans;

(h) Measurements and management systems;

(i) Records and record-keeping;

(j) Decommission;

(k) Treatment of slag and dust from the incineration facility.

B. Location

39. Site selection should be considered a phased decision process that examines each potential location on the basis of protecting human health and property from contaminants as well as protecting the environment and offering appropriate logistic conditions for waste supply and energy delivery.

40. For potential sites, an environmental impact assessment should be done to determine the environmental impacts and a detailed assessment to determine the, technical, legal, social and economical feasibility of establishing the proposed facility. At least the following issues should be considered:

(a) Site topography, geology (e.g. seismically active areas), hydrology (e.g. wetlands, presence of shorelines, flood zones), and hydrogeology;

(b) Presence of sensitive habitat (e.g. national parks);

(c) Urbanization of surrounding areas;

(d) Socio-economic aspects, including impacts of transportation (public acceptance);

(e) Distances for transport (proximity principle), accessibility (e.g. existence of roads or railroad connection);

(f) Access to the grid, to district heating networks or potential energy users;

(g) Symbiosis with industrial clusters.

41. Public consultations should be held with community members and other relevant stakeholders on the location of the incineration facility and minimum separation distances. Community engagement strategies should be developed to reach the various stakeholders, including workers pursuing their livelihoods in the informal economy.

42. Consideration should be given to the general property boundary (EPA, 2007); distance between the facility and residential and public areas; and distance between the facility and heritage, cultural and archaeological sites to mitigate health and environmental risks to the community, as follows:

(a) The property boundary should be designed so that a minimal buffer zone between the operational area of the facility and public roadways and highways be maintained.

(b) An adequate distance from a heritage, cultural or archaeological site should be maintained to prevent frictions between the community and the waste facility.

C. General considerations on incineration methods

43. The choice of an appropriate incineration method depends on the type and character of the waste that should be treated. Therefore, understanding the characteristics of different waste streams and hazardous constituents of wastes is necessary to ensure proper selection and design of the incineration process to be used.

44. Typically, the rotary kiln furnace is used for the incineration of hazardous wastes, regardless of the aggregate state. This device is suitable to treat solid, pasty, liquid and in especially equipped facilities also gaseous wastes. Even the feeding of entire barrels is possible for certain types of waste. For the sole combustion of liquid hazardous waste fractions, simple burning chambers can be applied, in which the liquid waste is atomized.

45. Household wastes are typically incinerated in grate firing systems or, after pre-processing, as refuse derived fuels (RDF) in fluidized bed furnaces. For pasty substances like sludges multiple hearth furnaces may be used. A detailed description of these incineration methods is available in Section IV.B of this document.

46. Every incinerator should be equipped with a flue gas cleaning system. Modern systems according to BAT are designed to reduce all harmful pollutants (as specified in section I.B above) by orders of magnitude to a marginal level. Typically applied systems are described in Section IV.C.

47. Energy recovery is an important added value of waste incineration facilities. MSWI facilities typically produce steam in a boiler connected to the furnace, which is converted into electricity (by means of steam turbines), and/or used for district heating or is directly delivered to adjacent industrial facilities. When technically possible, hazardous waste incinerators are also equipped with a boiler for energy recovery. Hazardous waste incinerators should preferably be located within industrial areas (e.g. chemical parks), so that the produced steam can be utilized in adjacent facilities.

1. Types of incinerators

48. In the following paragraphs, the currently relevant furnace systems for waste incineration, designed according to BAT, are described. Other systems than those contained in this chapter are not commonly used and should be extensively evaluated by experienced experts on the basis of an existing and stable operating pilot plant, before being considered as a possible option.

Grate incinerators

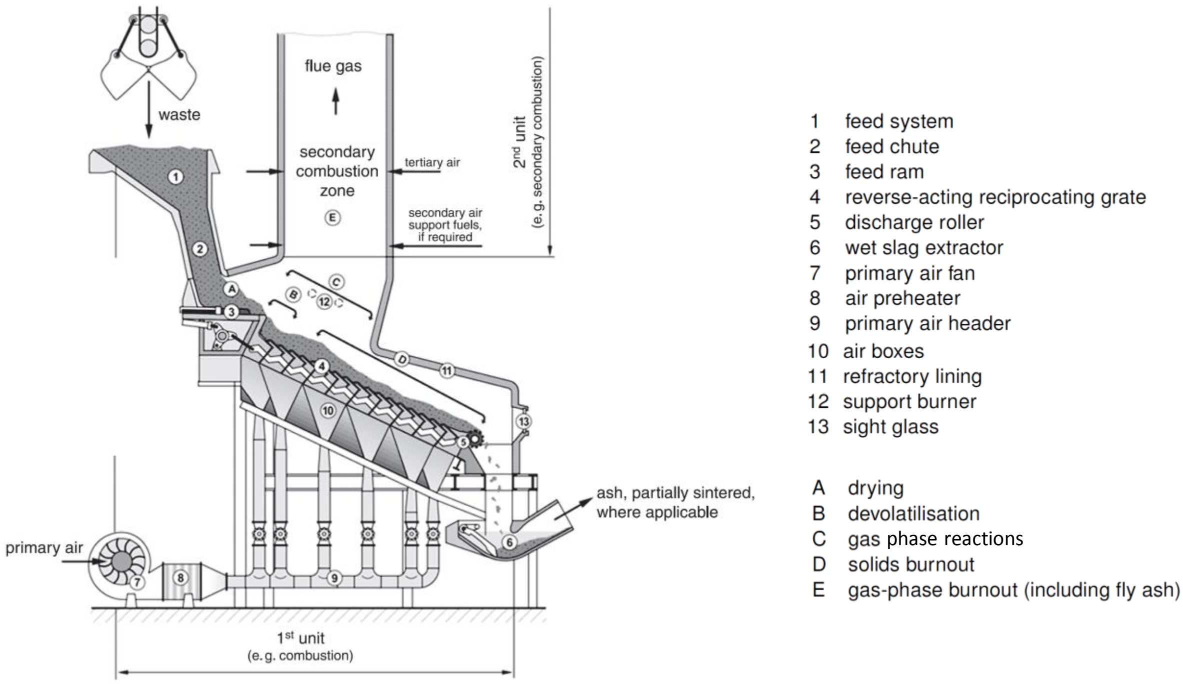
49. Typically, grate incinerators (see Figure 3) are used for the combustion of municipal solid waste (MSW). The waste is usually fed via hopper and stoker onto the metal grate, which consists of moving elements (e.g. oscillating steps or rotating drums) for the waste transport. The grate may be horizontal or have a significant decline, depending on the type of the grate.

50. There are forward and reverse (backward) pushing (acting) grates as well as rotating drum grates applied for MSWI. Simple traveling grates are only suitable for incineration of homogeneous fuels and therefore not for the treatment of municipal solid waste, because the stoking of the incineration bed is almost not possible.

51. As explained before (see Section IV.A), solid waste incineration is a process taking place in subsequent steps. Since the waste is moved over a grate during this process, these steps are located in defined sectors of the grate: first the waste is dried (section (A) in Figure 3), followed by the degasification or pyrolysis (B) and finally the burnout of solids (D) takes place. Above the incineration bed gas phase reactions are occurring (C) and the pyrolysis gases are reacting with the oxygen of the secondary air (E). Since the different reaction steps require different amounts of air/oxygen, the grate should be equipped with independently controllable under-grate air sections, which allow the selective local adjustment and control the of primary air stream. Also, the adjustment of different temperatures (up to 200 °C) should be possible (e.g. application of high pre-heated air in the drying zone and of cool air in the burnout sector). Larger grates may be equipped with up to 20 separately controllable under-grate air sections.

52. After burnout at the end of the grate, the bottom ash falls into a slag discharger (No. 6 in Figure 3). As state-of-the-art, these devices are operated with a water filling for rapid cooling of the slag (wet slag discharge). The water bath in the discharger also seals the furnace against the ambience, to prevent the intrusion of false air into the furnace, which may disturb the combustion process. Within the last years some MSWI facilities were equipped with slag discharges without water filling (dry slag discharge), to improve the quality of the recovered metals.

Figure 3: Scheme of a grate incinerator for MSW (reverse acting grate with counter flow principle; Figure: VDI 3460) (Source TBC).



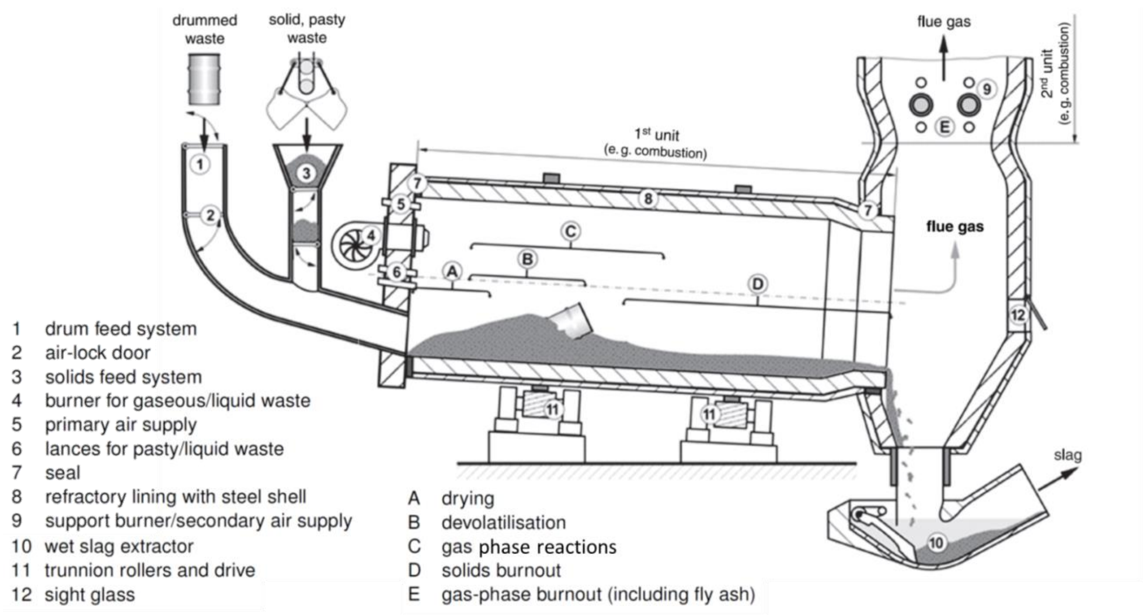
Rotary kilns

53. The major advantage of the rotary kiln is its ability to handle a variety of different waste types in different aggregate states: solid wastes of widely varying sizes, liquid (and in some facilities also gaseous) wastes, using atomizing burners centrally located at the inlet end of the kiln, high moisture content wastes and sludge-like materials, and materials which form molten slags, whilst ensuring good mixing and break-up of the material.

54. Rotary kiln furnaces (cf. Figures 4 and 5) consist of a refractory lined steel cylinder, which rotates at a very low speed, typically 0.05-2 revolutions per minute, and is mounted on a slight incline of 1-3° so that solid materials introduced at one end will move through the kiln (with a maximum feeding degree of 20 %) and be discharged at the other end. The slag discharge takes place with wet operated slag discharging devices similar to those described for grate furnaces (see Section IV.B.1). The typical diameters of rotary kilns for hazardous waste incineration are 3-4 m and the length is up to 12 m. At least one burner is mounted at the same end of the kiln as the solid feed mechanism. The auxiliary burner can be fired with fossil fuels like natural gas and oil or liquid and pasty wastes.

55. Figure 4 shows the thermochemical processes (drying (A) – pyrolysis (B) – gas phase reactions (C) and gasification/burnout (D) of carbonaceous solids) occurring during the treatment.

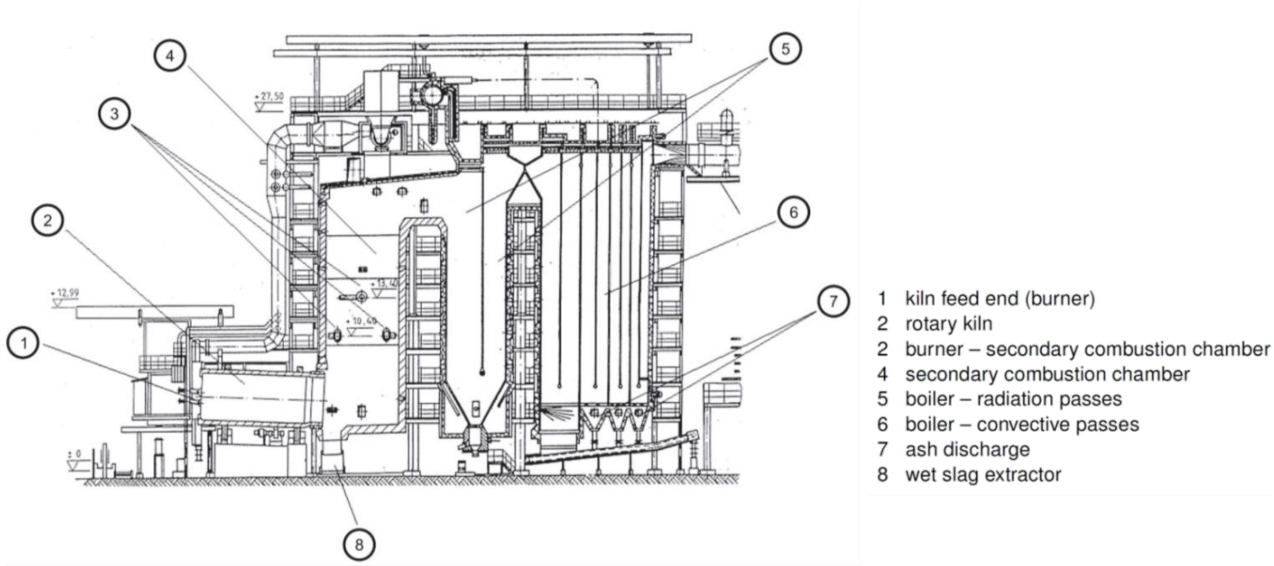
Figure 4: Scheme of a Rotary Kiln Furnace for Hazardous Waste



Combustion chamber

56. The least complex of all hazardous waste incinerators are combustion chambers for the incineration of liquid wastes. Usually it is also possible to incinerate gaseous wastes and/or dusts in these devices. The liquid wastes are normally introduced through atomizing burners where they are intimately mixed with combustion air, elevated in temperature to about 1100 °C, maintained in contact with excess air for between 1.5 and 2 seconds. Firing can be axial or tangential into one or more combustion chambers, which can be arranged in series or in parallel configuration. Frequently, only a single refractory lined chamber is used for the entire combustion process with no afterburner being required. Supplementary fuel can be mixed with the waste or can be introduced through a separate orifice in the burner to maintain the required temperature for complete destruction of the waste components

Figure 5: Scheme of a Rotary Kiln Furnace with Secondary Combustion Chamber and Heat Recovery Boiler (Figure: VDI 3460) (Source TBC).



Fluidized bed

57. Fluidized bed reactors are normally built as cylindrical (also rectangular geometries are possible) burning chambers, equipped with a (closed or open) nozzle floor that is supplied by a wind box. Air (which can be pre-heated up to 500 °C and mixed with recirculated flue gas for adjustment of the desired oxygen concentration) is injected via the nozzles into the burning chamber, to fluidize a filling of quartz sand, which has the function to achieve an optimal mixture and heat transfer into the fuel.

58. According to the gas velocities applied for the fluidization of the sand bed, two different types of fluidized bed furnaces can be distinguished. Lower velocities (1-2 m/s) , which are sufficient for fluidizing the sand bed, but not high enough to transport it out of the reactor, are forming a stationary fluidized sand bed with a defined height of approximately 1 to 1.5 meters. Such facilities are called stationary fluidized bed incinerators. The sand bed in these reactors has a density similar to water. Therefore, lighter fuel particles tend to swim on the surface of the sand bed, heavier elements may sink down to the floor.

59. Advantages offered by fluidized bed incinerators are the following:

(a) They have a high thermal inertia, which provides a close control of the operating temperature;

(b) The operation at relatively low temperatures (around 850 °C and sometimes even lower) is limiting the formation of nitrogen oxides and prevents ash melting in the case problematic (alkaline containing) waste fractions are treated;

(c) The intense mixture allows the introduction of solid absorbent materials (e.g. limestone) simultaneously with the waste feed to absorb acid gases during the combustion process, rather than after the combustion process.

60. Primary limitations of fluid bed units are that the waste material must be of relatively uniform particle size and feed materials must not be capable of producing a molten phase in the unit. Conventional fluidized bed incinerators are not normally capable of sustaining the temperature required for the efficient destruction of the more thermally stable species of hazardous wastes (i.e. PCB wastes).

Multiple hearth furnaces

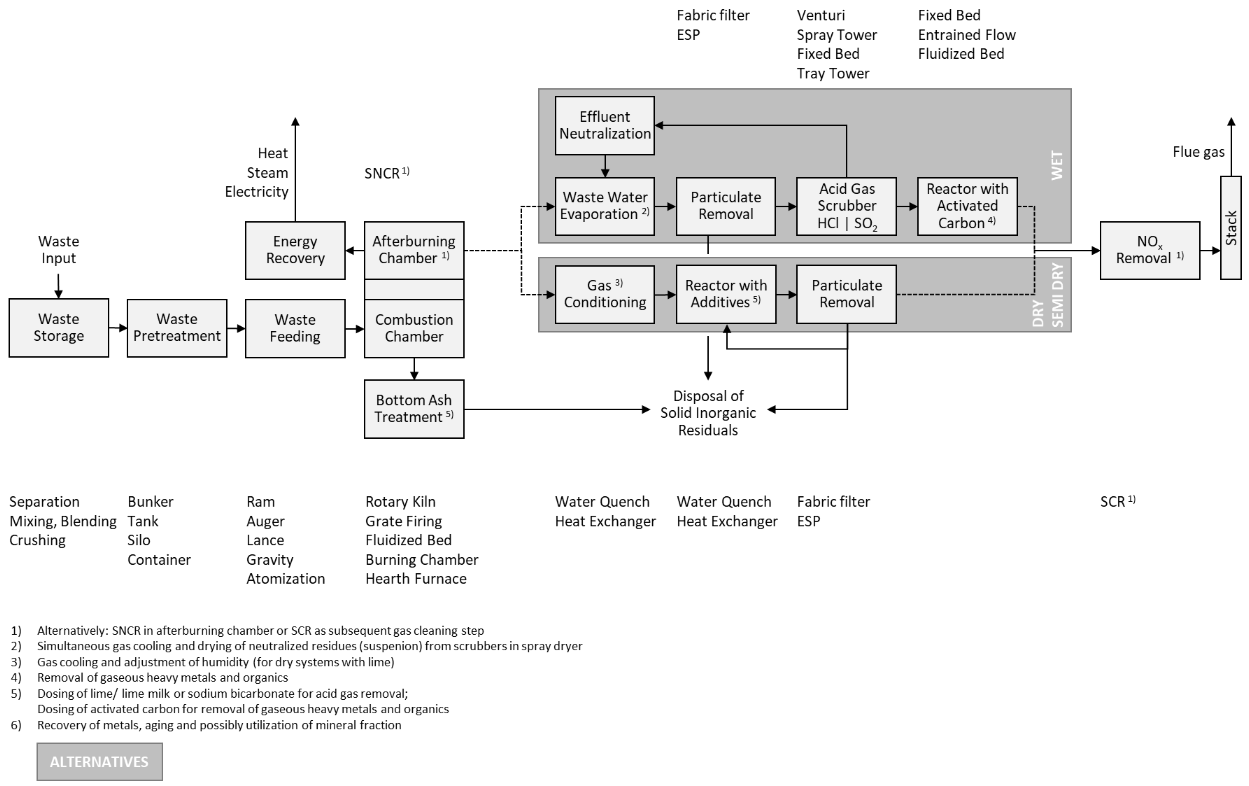
61. Multiple hearth furnaces can be used for solids containing a very high moisture content or for sewage materials which should be dried before. Combustion gases are discharged to air pollution control systems while the solids are discharged through ash hoppers at the bottom of the furnace.

62. Due to the complex construction and the moving parts in the furnace, the maintenance effort and the corresponding costs for such devices are relatively high.

D. Facility components

63. Waste incineration facilities consist of components for waste acceptance, pre-treatment, storage and feeding, the actual incineration part, including the possibility for energy recovery, the flue gas treatment system as well as optional installations for bottom ash and wastewater treatment. The incineration facilities should also be equipped with a laboratory as part of the waste acceptance procedures. (cf. Figure 1):

Figure 1: General overview of components of incineration facilities. The dark grey marked areas indicate different options for flue gas cleaning approaches and may be considered as possible alternatives.



64. Especially the combustion systems (see Section IV.B) and the installations upstream of the furnace vary widely between the different types of waste incineration facilities. While household waste incineration facilities are typically only equipped with one bunker for the storage of all delivered waste fractions, those for hazardous wastes have a sophisticated infrastructure and the possibility for separate, adequate storage of different types of waste (see Section III.A).

65. For the treatment of the flue gas several established concepts exist (see Section IV.C). Usually they are categorized according to the treatment step for removing the acid gases: dry – semidry – wet. Figure 1 shows a principle process schemes for these three options (grey shaded sector; schematic for dry and semidry is the same). For higher requirements or lower emission values, respectively, these concepts can be combined in multistage approaches (e.g. a dry system can be supplemented with a scrubber for lower sulfur oxide emissions). Furthermore, the order of the flue gas treatment steps may deviate from the schematic. In some facilities for example, the selective catalytic reduction (SCR) catalyst is located downstream of the dust filter or directly behind the boiler. Beyond that, also multifunctional treatment components are applied, which combine more than one step of emission reduction in one reactor. Examples are the simultaneous separation of dust and acid components in Venturi scrubbers, the PCDD/PCDF adsorption on activated carbon doped carrier material in packed column scrubbers or the application of flocculation agents for mercury in the sump of washing towers.

E. Controls and enforcement

66. The primary method of controlling air pollution is the use of a well-designed, constructed, managed, operated, monitored and maintained incineration facility appropriate to the waste being burned.

67. For a proper operation of the whole facility a high degree of measurement instrumentation and automatic control of important parameters is necessary. The measurement of the following parameters is necessary for the proper operation of a waste incineration facility and should be monitored by the responsible authority:

(a) All relevant pollutants in the flue gas emitted in the environment (as specified in Section I.B) should be measured at the stack (if possible continuously) on a transparent and reproducible way in order to guarantee an efficient enforcement of emission limits, including legally binding limits as defined in national legislation (e.g. in the reference document on best available techniques on waste incineration).[5] This includes the measurement of all auxiliary parameters (like O_2 and H_2O concentration or temperature), necessary for the standardization of the measured values;

(b) A reliable and redundant measurement of the temperature in the post-combustion chamber of waste furnaces is necessary, since a sufficiently high temperature is crucial for the safe destruction of toxic organic pollutants.[6] Typical legally required minimum temperature is 850 °C or, if hazardous waste contains more than 1 percent of halogenated organic substances in the kiln expressed as chlorine, 1100 °C, with a minimum residence time of 2 seconds.[7] These temperatures also mark the limit, which should be reached before waste is allowed to be fed into the furnace.

68. In addition to the parameters mentioned above, which can be regarded as necessary for a reasonable performance of the facility, the measurement of the following parameters may facilitate the operation of the facility or prevent disturbances or accidents:

(a) CO and oxygen O_2, in order to optimize the operation of the furnace. In most cases CO and O_2 are required input parameters into the combustion control system. Helpful for the control of the incineration conditions is also the application of optical and infrared cameras;

(b) The continuous measurement of mercury concentration in the (preferably raw) flue gas. Due to the complex measurement and harsh environment, certain devices will in fact not show the true concentration. Nevertheless, they are very helpful to immediately realize and react on incidents by illegal mercury discharge, disposed of in the household waste, which occurs from time to time. If no such device is installed, these incidents cannot be detected and no countermeasures taken;

(c) Acid gas concentrations (SO_2 and HCl) in the raw gas, if dry flue gas cleaning systems (especially with lime as adsorbent) are applied;

(d) Temperature and mass flow along the entire flue gas path for an optimized control and operation of the system. The measurement of these parameters also helps also to detect disruptions in the operation (e.g. intrusion of false air, failure in additive dosing);

(e) Carbon monoxide in the downstream gas due to the high tendency of activated carbon to self-ignite, if an activated carbon adsorption bed is used as a final police filter in the facility;

(f) Further measurements and controls are necessary for the proper operation of the machinery and (auxiliary) equipment, for example of the following parameters:

(i) Pressure in the furnace and the gas ducts, in order to prevent the outlet of flue gas;

(ii) Fluid levels and flow rates for transport and storage of liquids;

(iii) pH-value, density and/or conductibility in scrubbers;

(iv) Pressure for atomization.

69. The firing equipment of the combustion chamber should be designed, manufactured and placed into service in conformity with relevant guidance or legislation (e.g. the European Machinery Directive (2006/42/EC)) and should comply with common standards, e.g. EN 746-2, EN 12952-8, EN 12953-7. An automatic burner control system should be installed, which serves to monitor burner operation. Automatic burner control units and flame-failure monitors should be type-examined and approved for continuous operation. Emergency tripping should also be an integral function of the burner control system. It should be physically located in a safe place that is easily accessible;

70. Solid residues should be monitored and periodically analyzed in a representative and reproducible way. In order to judge the environmental impact, not the concentration in the solid itself is relevant but the leaching behaviour of toxic components. To judge this behaviour, standardized leaching tests can be applied. The results of these measurements should be controlled by the responsible public administration and be the basis for a subsequent utilization (e.g., bottom ash as a

[5] As published by the European Integrated Pollution Prevention and Control Bureau on waste incineration (http://eippcb.jrc.ec.europa.eu/reference/wi.html).

[6] Thermocouples, mounted inside the combustion chamber, are influenced by radiation from hot solid surfaces and the combustion bed, which may result in an adulteration of the measured values. This is not the case for suction pyrometers, which are measuring the temperature within a protection pipe in the hot gas stream, sucked out of the combustion chamber.

[7] Many operators have exceptional permissions to run a facility at lower temperatures or shorter residence times without any negative effect on the emissions. This fact of course should be proven, before the permission is given.

building material in construction) or disposal of the materials. If the solid residues of waste incineration are hazardous and are to be landfilled, then they should be disposed of in an engineered landfill for hazardous waste.

71. The pollutants removed from the exhaust gas by wet treatment methods should not directly be discharged with the waste water, but be processed at the facility site. Any discharge of waste water from the facility should be subjected to permission by the responsible authority and in compliance with existing standards.

V. Environmentally Sound Pre-treatment and Acceptance of Waste

A. Waste acceptance

72. The operator of a waste incineration facility should take all precautionary measures necessary to avoid or reduce, as far as possible, the pollution of air, soil, surface water and groundwater, other environmental harm, odour and noise pollution as well as direct hazards to human health by the delivery and acceptance of the wastes.

73. Operators should only accept waste from trustworthy sources, especially for hazardous and clinical waste, and refuse the delivery of unsuitable waste. Consideration should be given to whether to waste is collected directly from generators or from intermediaries.

1. Household waste

74. MSWI for household waste should usually be equipped with an underground bunker for waste storage. The waste should be tipped through dumping openings/chutes directly from the delivering trucks, were it usually was compacted by a hydraulic press. Orange-peel grabs are used for mixing and conveying the waste into the feed hopper and a ram is applied to dose it from the hopper onto the grate. The combustion air for the furnace is sucked from bunker to prevent odour emissions by adjustment of a slight under pressure.

75. There are also facilities designed for the incineration of pre-processed household and similar waste of defined particle size and relatively homogeneous properties, such as RDF. In facilities with fluidized bed incinerators, often silos with pneumatic or mechanical conveying systems are used for storage and supply to the furnace. Due to the sophisticated and sensible fluidized bed technology, grate incinerators are increasingly used also for RDF combustion. If this is the case, the same storage and feeding devices as for MSWI facilities are used.

2. Hazardous waste

76. Hazardous waste incineration requires significantly higher effort for logistics, pre-treatment and storage than for household waste incineration. One reason is that hazardous waste fractions should be stored separately, according to their chemical character, to prevent the danger of undesirable reactions (e.g., polymerization, explosions, self-ignition, formation of toxic fumes, pressure increase etc.) by mixing them with other substances. Another reason is the adjustment of an appropriate calorific value for the furnace, to prevent excessive combustion temperatures on the one hand and excessive need for auxiliary fuel on the other hand. Blending of compatible waste fractions of different calorific value is an appropriate option to fulfil this demand, but legal regulations, regarding the prohibition of mixing different waste streams, should be taken into account.

77. The different properties of hazardous wastes, for instance their aggregate state, corrosiveness, toxicity, inflammability etc., require specifically designed solutions for storage and safety installations (e.g., inertization with nitrogen, special coatings for vessels, temperature control etc.).

78. Liquid wastes should be stored in closed, pressure-safe containers. The gases emitted during filling of these containers and also contaminated exhaust air from other waste handling areas should be captured and treated (as combustion air) in the furnace.

3. Clinical waste

79. For the incineration of clinical waste, dedicated burning chambers or MSWI or hazardous waste incineration facilities especially equipped for this purpose can be used.

80. Infectious materials should be collected in stable, odour tight and moisture-impervious bags or boxes, directly at the place of generation, which in turn are stored in (favourably returnable) tight and clearly labelled containers for transport to the incineration facility.

81. Clinical wastes from hospitals may be infectious and therefore contact with the waste during collection and transport should be avoided. Therefore, the wastes should not be removed from the

bags/boxes before entering the furnace, and should be mechanically loaded directly into the furnace. The size of the storage containers should be compatible with the feeder system. During storage, measures should be taken to avoid gas formation.

82. The wastes should be incinerated together with the bag/box they were collected in and no mechanical processing steps (compacting, shredding etc.) should be applied before, unless a reliable disinfection treatment (e.g. by the high-pressure saturated steam disinfection method) has been carried out before.

83. Facilities treating infectious clinical wastes should be taking the following aspects into account:

(a) No mixing of separately collected waste types;

(b) Provision of cooled and refrigerated storage facilities;

(c) Establishment of a system to monitor and register storage times;

(d) Installations of container disinfection facilities;

(e) If possible, build-up of systems for automated transfer;

(f) If people are involved in the handling of clinical waste, special accuracy has to be spend on all possible engineering, administrative and protective measures to avoid direct contact with the waste.

B. Reception control

84. Waste acceptance should include a quality control of incoming wastes, to prevent the insertion of waste fractions that are inappropriate for combustion, disturb the process or may even damage the facility (explosives, pressurized gas bottles etc.).

85. Prior to unloading, particularly for hazardous waste and clinical waste, systematic sampling, analyses of characteristics, and checking the compliance with the permit acceptance criteria should be completed at the entry laboratory. If a specific waste load does not comply with the permit acceptance criteria, the operator should refuse the waste.

86. In MSWI facilities, a reception control of the whole incoming waste is not performed, due to the large mass streams (several 100,000 tons/year) and the kind of delivery, compacted in big trucks. It should be taken into account that the risk of receiving undisclosed waste from commercial sources is usually greater than from households. Suppliers should be controlled by random sampling. Adequate facilities to unload the trucks and visually control the content should be foreseen.

87. In hazardous waste incineration facilities, the controls should be more stringent than for incineration facilities for other wastes. Operators should take the following measures before accepting hazardous wastes:

(a) Inspection of the accompanying documents;

(b) Inquiry of relevant information about the waste:

(i) Origin and generation of the waste;

(ii) Physical properties and chemical composition of the waste;

(iii) Special information about specific hazards and precaution measures;

(c) Control of regulatory compliance of the delivered waste;

(d) Sampling according to a risk management plan (e.g. with special focus on new/unknown sources or on peculiarities);

(e) Determination and registration of waste type and mass.

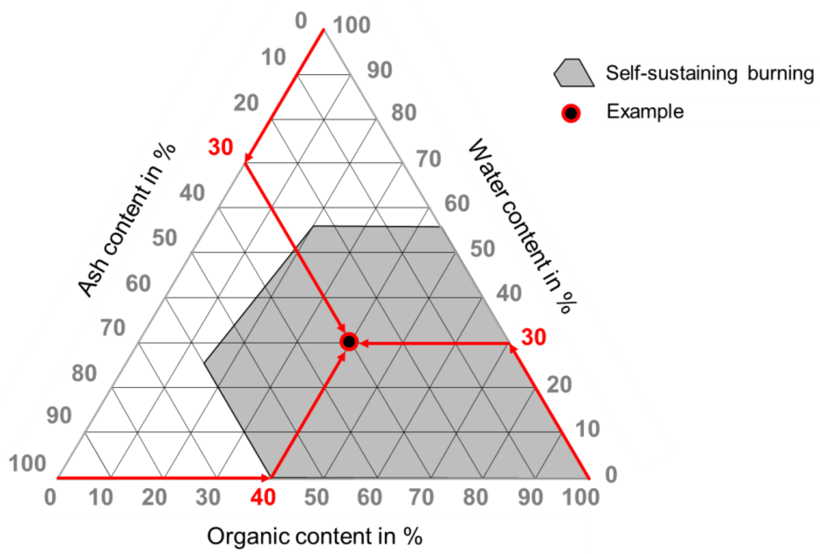
C. Waste selection and pre-treatment

88. The type of furnace (amongst other influencing parameters) defines the treatable types of wastes and the necessary pre-treatment. Significant differences between different facility types can be found.

89. All furnaces require the waste to have a sufficient calorific value that allows for incineration. This means that the content of inorganic material (ashes) and water should be limited (otherwise the application of an auxiliary fuel is necessary to adjust the sufficient incineration temperature). Since these two fuel characteristics have both impacts on the combustibility, no generally valid maximum

values can be given. Figure 2 shows the so-called fuel or combustion triangle, which allows to plot the correlation between the three fuel characterizing parameters ash, water and organic material content. The grey shaded area indicates the composition that wastes require for self-sustainingly burning.

Figure 2: Fuel Triangle for Waste Combustion (The grey shaded area indicates the range within the waste is burning self-sustainingly; the example depicts a waste with a composition of 30 % water and ash and 40 % combustible material) (Source TBC).



1. Household Waste

90. MSWI facilities for household and similar wastes are able to treat a large variety of wastes with different properties and characteristics. Typically wastes that are treated in MSWI facilities are household and similar commercial wastes, sorting and treatment residues from other waste treatment facilities and even sludges in moderate amounts. Also, the incineration of hazardous wastes is possible, if a sufficient destruction of all organic materials is achieved.

91. If a grate-system is used, pre-sorting or classical pre-treatment of the waste is not necessary. For bulky waste, a shredder for size reduction may be available at one tipping point of the bunker.

92. Usually, the only – but important – pre-treatment step is the mixing of the waste by the crane operator. During this procedure, a homogenization of the delivered wastes is carried out and a preferably constant calorific value of the mixture is adjusted. The quality of this treatment step is highly dependent to the crane operator’s experience.

93. Besides the direct incineration of MSW in the grate firings of MSWI facilities, it is possible to pre-process household waste in mechanical-biological treatment facilities, where metals and inert materials are sorted out and RDF, predominately generated from the plastic fraction in the waste, is produced.

2. Hazardous waste

94. Hazardous waste incineration facilities according to BAT are able to treat all kinds of combustible hazardous waste fractions. Also, the treatment of incombustible fractions is possible, if sufficient amounts of auxiliary fuel are applied.

95. Hazardous waste should be collected separately at the location of generation and not be mixed with wastes of other characteristics.

96. The (pre-) treatment of the accepted waste strongly depends on its characteristics and is always an individual decision. Some examples may show the significant differences:

(a) Liquid wastes with similar properties may be pre-mixed for a homogenization of the feeds calorific value;

(b) Wastes containing higher amounts of fluorine or alkalis can only be fed in small concentrations, because they are forming liquid slag that may damage the refractory material in the furnace;

(c) Reactive or corrosive wastes with particular hazard potential are fed by single dosing (direct injection) or as single drum;

(d) Infectious waste could be fed in small hermetical boxes (max [30] [60] liters and [120] liters for clinical waste) by a special introduction point;

(e) Drums containing ordinary pasty or viscous wastes may be shredded.

VI. Environmentally Sound Incineration Operation

97. Operational costs for an incineration facility may vary depending on the incineration technology being utilized. These costs may include continuous monitoring, operator training, maintenance and repair, and stack testing. Additional costs should be taken into account if treatment of the residues on site is necessary, and for satisfying stringent health and safety provisions required for daily operation, especially in a hazardous waste incineration facility.

A. General aspects

98. The addition of the combustion air should be adapted to the fact that the incineration process of solid fuels takes place in subsequent steps – the drying of the fuel, the degassing of volatile vapors (pyrolysis) and the final combustion of both the emitted burnable gases and the remaining solid. Therefore, the supply of combustion air should take place at two different positions in the furnace: the primary air should be fed into the main combustion chamber, where the solids are treated/transported and secondary air should be supplied in an adjacent afterburning chamber, in which the emitted burnable gases are post-combusted.

99. The following conditions should be applied in a furnace in order to assure a proper, smooth and undisturbed operation:

(a) There should be a possibility to move and/or stoke the solids in the combustion bed (if fixed bed furnaces like great firing systems or rotary kilns are used);

(b) The furnace design should assure a sufficient contact between the solids and the (pre-heated) primary combustion air;

(c) The temperature must should be high enough to reach the ignition temperature;

(d) There should be enough oxidant (air) for thorough oxidation to occur;

(e) The vapor and air should be efficiently mixed in the gas phase;

(f) The vapor/air mixture should be held at a high enough temperature for long enough for complete oxidation to occur (residence time).[8]

B. Operational considerations of different types of incinerators (*information still under development*)

1. Grate incinerator

100. While it is common for fine materials to fall through the grate, this material can be recovered in the bottom ash remover. Once collected, this material can undergo additional incineration cycles in the grate, though care should be taken to ensure that existing waste in the hopper is not ignited. Alternatively, the material can be removed and disposed of separately.

101. Air entering the grate incinerator can be preheated as required, if it is necessary to pre-dry to waste. The residence time for wastes on the grates generally should not exceed 60 minutes.

2. Rotary kiln furnace

102. While the solid wastes have a residence time of up to one (or even two) hours in the rotary kiln, the gaseous components produced by the incineration process and the non-burned portion of the evaporated liquid wastes will leave the rotary kiln after some seconds. Therefore, an afterburning

[8] The requirements regarding the gas phase are often referred to as 3T-rule: the *Temperature* should be high enough, there should be enough *Turbulence* in the combustion gas mixture and it should be held at these conditions for a long enough *Time*.

chamber is necessary to guarantee a complete burnout of the organic components (E) and of the generated pyrolysis gases, like carbon monoxide, methane and hydrogen. It is common practice to implement further burners for liquid or gaseous waste streams in the post-combustion chamber. In addition, when a minimum temperature of 1100°C is required, a burner for natural gas should be placed in the post-combustion chamber to ensure a sufficient temperature. Furthermore, a residence time of at least two seconds after the last air supply of the flue gas in the post combustion chamber should be guaranteed.

3. Combustion chamber

103. One of the key components for efficient operation of these systems is the design and the monitoring of the atomization of the burner. Most of the burners, which have been designed especially for waste materials, introduce air in a vortex section, surrounding the liquid atomizing nozzle. This creates intimate mixing of the vaporized fuel and waste materials and the combustion air, yielding uniform flame temperatures and high destruction efficiencies.

4. Fluidized bed incinerator

104. Fluidized bed combustion (FBC) systems all applied for homogeneous fuels with a relatively narrow grain size spectrum. Thus, in terms of solid waste treatment, a pre-processing of the incinerated materials is mandatory. The additional treatment of liquid or pasty substances is unproblematic. Therefore, FBC systems are predominantly applied for RDF, pre-processed waste wood or sludges.

105. If higher air velocities (2-5 metres/second) are applied, the fluidization of the sand is not limited to a certain height, but the sand bed is expanding over the whole reactor and is carried out together with the flue gas. Therefore, a cyclone is mounted at the reactor outlet, to separate the sand from the flue gas and to return it back to the furnace.

5. Multiple hearth furnaces (*still under development*)

C. Treatment of emissions and residues

106. The main mass stream, resulting from the incineration of waste is the flue gas. Depending on the type of waste, also relevant amounts of solid residues are generated. These are bottom ash (MSWI) or slag (hazardous-waste incineration), boiler ash and the flue gas cleaning residues. In the case that a wet flue gas cleaning system (scrubber) is used for acid gas removal, also liquid effluents may arise. All these output streams are contaminated with harmful pollutants and should be treated before the release to environment.

1. Gas Emissions [air emissions control] [Flue gas treatment]

107. The primary method of minimizing air pollution should be to use a well-designed, constructed, managed, operated, monitored and maintained incinerator appropriate to the waste being burned.

108. In fact, the control of CO and volatile organic compounds is solely dependent on the proper operation of the furnace. Grate furnaces for household waste can be controlled by underfired air, the furnace geometry, secondary air injection and gas mixing. Continuously operated hazardous waste incinerators normally have low carbon monoxide emissions. If high-calorific wastes are fed in batches, CO peaks may arise.

109. For all other pollutants listed in Section I.B additional diminution measures should be applied downstream of the furnace. The so-called secondary measures are described in the following paragraphs. The combination of all applied treatment steps results in flue gas cleaning system that should be able to reduce all pollutant concentrations below their individual legal limits. Typical configurations of widespread flue gas cleaning systems are depicted in Figure 1.

(a) Techniques to reduce acid gas emission

110. The name of the entire flue gas cleaning system stems from the technology applied for reduction of acid gas (HCl, HF, sulfur oxides (SOX)) emissions. Wet, semi-dry and dry methods (cf. Figure 1) are named after the way of additive addition: into a liquid, as or together with a liquid that is atomized and evaporated in the hot flue gas stream or as a dry powder.

111. Wet flue gas cleaning systems usually consist of a dust removing unit (electrostatic precipitator or fabric filter) as a first step, to protect the following scrubber. The scrubber is usually subdivided into two separate sections with different pH-values. In the first step, at a pH value of 0.8-1.5, predominantly HCl and HF (HBr, HI) but also mercury salts are absorbed in the liquid. It is possible to produce hydrochloric acid by refining the flushing liquid. The second scrubber step is operated at a neutral pH-value of about 7, which is kept stable by addition of an alkaline neutralization

agent (usually Ca(OH)2 or NaOH). If hydrated lime is used, gypsum (Ca[SO4]·2 H2O) may be recovered.

112. Semi-dry flue gas cleaning systems are named due to the fact that water steam should be present in the gas phase to realize an efficient removal of the acidic gases, especially of sulfur dioxide, out of the gas. Typically, milk of lime (Ca(OH)2) is used as an additive in liquid form or as a suspension. The water of the suspension is evaporated during reaction with the acidic gases in the hot flue gas. Therefore, the reaction product is a dry powder, containing the halogens and sulfur oxides as calcium salts (CaCl2, Ca(OH)Cl, CaF2, CaSO3, CaSO4). It is also possible and common to use dry Ca(OH)2 instead milk of lime as additive. Precondition for an effective acid gas removal in this operational mode is sufficiently high moisture[9] in the gas, which may be adjusted by water injection and evaporation.

113. Dry flue gas cleaning systems are operated without any water addition. If lime-based adsorbents are used, an efficient operation without water addition is only possible at very high reaction temperatures. Therefore, this approach is realized by limestone[10] addition into the furnace. Due to the fact that a good distribution of the additive in the gas is prerequisite for a good functionality of the system, FBC systems are predestined for the application of this concept. Another additive for dry flue gas cleaning is sodium bicarbonate (NaHCO3, “baking soda”). The operational temperature should be above 180 °C, but no special humidity should be adjusted. Therefore, the additive can be directly injected into the hot flue gas after the boiler, without any conditioning.

(b) Techniques to reduce organic compounds including PCDD/PCDF

114. Typically, a process for treatment involves heating to a temperature greater than 850°C or, if the waste contains more than 1 per cent of halogenated organic substances in the kiln expressed as chlorine, to a temperature greater than 1,100°C, with a residence time greater than two seconds under conditions that ensure appropriate mixing.[11] However, the remaining fragments may be recombined in the temperature range between 200 and 400°C, when the flue gas is cooled down (de-novo synthesis). This recombination reaction is supported by longer residence times in this temperature window (< 50 ms prevents recombination), the presence of dust (fly ash) and low sulfur dioxide concentrations.[12] Since this de-novo synthesis cannot be (entirely) prevented, the application of secondary diminishing measures is necessary.

115. De-novo synthesis and assisted catalytic coupling of the precursors are heterogeneous reactions accounting for PCDD/PCDF formation post-combustion. The presence of catalysts known to increase the formation of PCDD/PCDF, such as copper or iron, should be diminished. [Input of PCDD/PCDF precursors in wastes, such as chlorine, should also be controlled to reduce heterogeneous reactions.]

116. Widespread is the application of activated coke or activated carbon as an absorbent for gaseous PCDD/PCDF. These carbonaceous adsorbents show a significant affinity for adsorption of organic pollutants and may be applied in fixed bed reactors, in entrained flow processes and even in wet scrubbers. These may include:

(a) Fixed-bed absorbers, equipped with activated coke or carbon (particle size 1.25 to 5 mm) are commonly used as emergency and polishing filter step at the end of flue gas cleaning systems to remove remaining PCDD/PCDF. Due to the tendency to self-ignition, such devices need major safety precautions (CO and/or temperature measurement in the off-gas, possibility for inert gas purging). Fixed-bed absorbers show high pressures losses of 25 to 40 mbar. The activated carbon can be burnt in the furnace after utilization;

(b) In entrained flow processes, the activated carbon or coke is injected into the flue gas, in a reactor or just in the flue gas duct. The PCDD/PCDF molecules are adsorbing on the activated carbon particles’ surface and can be removed together with those particles by means of a dust filter. Removal efficiencies of more than 99 % by application of 0.35 to 3 kg additive per ton of wastes may be reached;

(c) Carbonaceous adsorbents can also be used in wet scrubbers as carbon-impregnated polypropylene packing (ADIOX). Removal efficiencies (example of electrostatic precipitator in

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[9] It is assumed that especially SO_2 needs a “coating” of water molecules on the additive particles, to realize a good adsorption affinity.

[10] Calcination to the more reactive burnt lime occurs in situ by the high furnace temperatures.

[11] See the technical guidelines on persistent organic pollutants (UNEP/CHW.13/6/Add.1/Rev.1).

[12] SO_2 supports sulfating reactions which reduce the chloride content in the fly ash and therefore the PCDD/PCDF de-novo synthesis.

combination with a wet scrubber) are higher than 98 %. The high loading capacity allows operation times of several years. The loaded packing can be incinerated to destroy the adsorbed PCDD/PCDF. PCDD/PCDF can also be removed in scrubbers by using a suspension of activated carbon in water (up to 50 g/l) as a scrubbing medium. However, this may be associated with coke deposits in the system;

(d) SCR catalysts for the destruction of nitrogen oxides are also suitable and effective for the destruction of gaseous PCDD/PCDFs by catalytic oxidation. Depending on the number of catalyst layers and activity, removal efficiencies up to 99 % can be reached;

(e) Since dioxins and furans tend to adsorb on the fly ash particles, dust precipitation is also an effective measure for reduction of PCDD/PCDF.

(c) Techniques to reduce heavy metals

117. Due to their different chemical and physical properties, heavy metals may be present in the flue gas in gaseous, liquid or solid form, elemental or as a compound.

118. Semi-volatile elements (chromium, copper, cobalt, nickel etc.) are significantly reduced by the dust removal with a fabric filter or electrostatic precipitator.

119. Other metals, like arsenic, lead or cadmium are more volatile and are partly vaporised during incineration. After condensation (on the particles in the flue gas), they can also be removed by particle precipitation. An efficient reduction of those elements therefore requires sufficient residence time at lower temperatures to allow for condensation.

120. Only mercury vaporises completely during combustion. A part is subsequently condensing on particles, another part is reacting to compounds, like HgCl2. Gaseous metallic mercury can be captured by adsorption onto carbonaceous adsorbents, like activated carbon, together with PCDD/PCDF (entrained flow and fixed bed reactor, wet scrubber). Mercury in the form of compounds, predominantly as HgCl2, can be absorbed within the acid stage of wet scrubbers. This may be supported by the utilization of sulphur-impregnated clay minerals or sulphur-impregnated activated carbon, which can remove elemental and oxidised mercury. By adding oxidants, like sodium hypochlorite or hydrogen peroxide, to the scrubbing fluid, it is possible to convert elemental mercury to its oxidised form, which dissolves in both scrubbing stages. If reducing compounds are present, oxidised mercury absorbed in the scrubbing liquid may be converted to elemental mercury and re-emitted to the gas. By complexing agents (halide ions) in the scrubbing liquid, this can be prevented.

(d) Techniques to reduce dust emissions

121. For the separation of particles from the flue gases of waste incineration facilities, fabric filters, electrostatic precipitators, wet scrubbers and cyclones are applied. These devices are used to retain the fly ash from the furnace and also the spent additives, which were injected upstream for abatement of gaseous pollutants:

(a) Fabric filters (usually in the form of long cylindrical filter bags mounted on metal cages) achieve the highest dust collection efficiencies of all regarded systems, independently of the particle size. The flue gas passes through a semi-permeable surface, on which the particles are retained. In waste incineration facilities, fabric filters are commonly applied as combined dust and sorption filters. This means that injected sorbent materials (e.g. lime, activated carbon) are forming a thin layer on the filters surface, in which gaseous pollutants are adsorbed. The filter cake of retained dust and spent adsorbents should be removed from the filter surface periodically. Therefore, time or pressure drop controlled filter cleaning cycles are carried out: The dust cake on the outside of the filter element is removed either by vibration or by a compressed air impulse. Applied filter media (e.g. Teflon coated needle felt) should be robust and should be thermally resistant at least up to 220 °C;

(b) Electrostatic precipitators realize the dust separation from the flue gas by charging the dust particles with a negative load. Discharge electrodes (e.g. wires or ribbons, with about 20 to 100 kV) are emitting electrons, which load and ionize surrounding gas molecules. These ionized molecules adsorb on dust particles and move together with them to the collecting electrode. At the positively charged anode, the molecules and dust particles are discharged and the dust particles are retained at the electrode, from where they have two be removed from time to time, e.g. by knocking with automated hammers. In wet operated electrostatic precipitators, the deposited particles are rinsed off by water flushing. The efficiency of electrostatic precipitator systems is almost as high as that of fabric filters;

(c) Wet scrubbers are applied in waste incineration facilities primarily to reduce the concentration of acidic gases in the flue gas. At the same time, the intensive mixing of the flue gas with the scrubber liquid leads to a precipitation of particles. The separation efficiency of scrubbers, especially for smaller particles, is lower compared to fabric filter and electrostatic precipitator. A separation limit can be determined between 0.5 and 1 µm. Smaller particles cannot be transferred from the gas to liquid phase and therefore not retained by scrubber systems;

(d) In cyclones, particle separation is realized by centrifugal forces. Through a tangential feed of the flue gas into the cylindrical separation chamber, a cycloidal fluid flow is adjusted, which leads to separation of the particles. Regarding the retainable particle sizes, cyclones are significantly restricted. The separation limit of cyclones can be assigned between 2 and 10 µm. Therefore, cyclones are used in waste incineration facilities only for pre-separation of coarse particles.

(e) Techniques to reduce emissions of oxides of nitrogen

122. Principally, the generation of nitrogen oxides can be influenced by measures of fuelling. The so-called staged or starved air combustion (primary combustion zone is run with a shortage of oxygen) is an appropriate method to reduce the formation of nitrogen oxides and state-of-the-art for gas burners, coal power plants and some biomass furnaces. For waste incineration, such approaches could only be successfully applied for fluidized bed incinerators (sewage sludge combustion). Trials in other waste furnace types showed a significant reduction of nitrogen oxides, but the measure alone was not sufficient to reach the legal emission limits.

123. State-of-the-art (BAT) for the abatement of nitrogen oxides (NO and NO2) is the application of SCR or selective non-catalytic (SNCR) reduction processes. For both of them ammonia (NH3) or urea ((NH2)2CO) are applied as additives. These substances react with the nitrogen oxides in the flue gas to elemental nitrogen, water (in the case of ammonia) and also carbon dioxide, if urea is applied. If sulfur oxides are present in the gas, the undesired by-products ammonium sulfate ((NH4)2SO4) and ammonium hydrogensulfate (NH4HSO4) may be generated, which tend to form deposits in the flue gas ducts.

124. The SNCR process requires temperatures between 850 and 1000 °C and is therefore applied directly in the boiler, downstream of the afterburning zone. The additives are injected via nozzles. State-of-the-art (BAT) is the controlled injection in several levels, into areas of optimal temperature, which are determined by acoustical gas temperature measurement. Optimized systems are able to operate stable at NOx-levels significantly below 100 mg/m³ under normative conditions (exhaust gas in the standard state (273.15 K, 101.3 kPa) after correction of the water vapour content.

125. For the SCR process, a catalyst (standard materials include TiO2, V2O5 and WO3) is applied to reduce the activation energy and therefore the reaction temperature necessary for the destruction of the nitrogen oxides. Operation temperatures for SCR processes were significantly reduced within the last years. Continuous operation temperatures of 180 °C are common, a further reduction to 140 °C could be shown. The low temperature operation makes it necessary to heat the catalysts periodically up to temperatures of several hundred degrees in order to eliminate deposited salts. The catalyst can be arranged at different positions in the gas path. Figure 1 shows the so-called tail end configuration, which is very common because all other pollutants are eliminated before and the catalyst can therefore not be contaminated. Nevertheless, it is also possible to locate the catalyst directly after the boiler (high dust configuration), to benefit from the higher temperature.

2. Liquid waste

126. Many air pollution control devices use water for gas cleaning (quenching and scrubbing), thus creating wastewaters containing the pollutants that have been removed from the gases. In the first instance, the facility should be designed so as to minimize the discharge of process wastewater, where this is compatible with atmospheric emissions.

127. There should be requirements for wastewater discharges placing limits on temperature, pH-value, quantity of suspended solids, and pollutant levels need to be legally fixed.

128. Any wastewater from the incinerator should be treated before being disposed of or released to a water or sewer system. Possible treatments include neutralization and settling (precipitation) of metals, e.g. with lime, dolomite, soda, NaOH and especially mercury with Na2S or poly-organosulfides. Sulfates can be precipitated by lime. The emerging solids can be removed from the liquids by sedimentation, flotation, filtration or possibly membrane technologies for removal of finest particles.

3. Disposal of solid residues (bottom ash and flue gas cleaning residues)

129. Waste streams from gas cleaning and ash/slag from the combustion chamber should be properly controlled and disposed of, to prevent harm for the environment.

130. Ash/slag and other solid residue discharged from a hazardous waste incineration facility may

be considered hazardous in national/domestic legislation and it would be prudent to manage them as such, unless it can be proved that they are not. In particular, landfilling of residues from incineration requires special attention because of their potential for leaching.

131. Iron and non-ferrous metals can be recovered from the bottom ash/slag by mechanical post-treatment. These extracted metals parts are usually not hazardous. After separation of the metals, further mechanical processing and an aging phase (regularly three months), the mineral bottom ash fraction from household waste incineration may be used as a building material in road construction, if the leaching potential of the material is sufficiently low.

132. The character and composition of flue gas cleaning residues is dependent on the type of gas cleaning system applied. In dry and semi-dry systems, all pollutants are concentrated in a solid residue, which contains the additives applied and the dust from the furnace. Wet systems (scrubbers) are characterized by separate residues, because the dust is removed from the flue gas before the gaseous components are absorbed in the scrubber liquid.

133. Due to the fact that the dry residue from dry and semidry systems contains all pollutants in concentrated form, and usually has hazardous character and should be disposed of correspondingly.

134. Since hydrogen chloride (HCl) and the sulfur oxides (SO2, SO3) are absorbed in different scrubber units, a selective recovery with production of hydrochloric acid and gypsum is possible. This approach is state-of-the-art (BAT) and practiced in several facilities.

D. [Recovery of energy

135. Electricity production, supply of district heating (or cooling) networks or the direct delivery of steam are common options for energy recovery from waste incineration facilities.

136. The recovery of the heat from combustion is usually realized by steam boilers, which are directly connected to the furnace. In fact, the walls of the furnace afterburning chamber are built from water containing tubes that are part (usually the evaporator, heated by radiation) of the water-steam-cycle (cf. Figure 5).[13] A steam boiler consists of several passes/drafts (i.e. rectangular gas ducts), which are also built of water pipes. In the rear section of the boiler, where the flue gas temperature is sufficiently low, tube bundles are also installed across the gas ducts as convective heat exchangers. Typical flue gas temperatures at the end of the boiler are 180 (to prevent the condensation of sulfuric acid) to 350 °C.[14] A quench system can be used to rapidly cool flue gases to minimize formation of PCDD/PCDF and other UPOPs. Operation of the quench system precludes the utilization of a boiler to generate steam and energy.

137. The quality of the feed water is decisive for the long-term operations of the steam boiler. Typical damage images with poor water quality are deposits and corrosion caused by an unsupervised pH-value for unalloyed or low alloyed boiler steels, especially in saline waters. The required pH-value can be adjusted in the boiler feed water by solid alkalizing (e.g. sodium hydroxide and trisodium phosphate) and in the condensate by volatile alkalizing (e.g. ammonia and hydrazine). As far as possible, the combined use should be pursued under continuous dosing. Other parameters such as chloride or oxygen content in the boiler feed water should be agreed with the supplier.

138. If electricity is produced, electrical efficiencies can reach up to 30%. Higher values are not practicable, due to the risk of corrosion of the boiler that is induced by the higher steam parameters (pressure and especially temperature), which would be necessary for this purpose.

139. Energy recovery can be enhanced, if heat (as hot water all low pressure steam) or (high pressure) steam to industrial customers are delivered.

140. The overall efficiency of a facility is dependent on the possibilities to deliver steam or heat. Besides these location-related facts, the efficiency is also limited by the relatively high internal consumption for flue gas cleaning and the – especially in countries closer to the equator – limited possibility to utilize the low temperature heat from steam condensation and in the flue gas. Therefore, methods to enhance the efficiencies should reduce the internal consumption and find consumers for the low temperature heat.

141. For example in Scandinavia, where MSWI facilities are usually integrated in district heating

[13] In hazardous waste incineration plants also afterburning chambers with no heat exchanger pipes are applied, to reduce the maintenance effort.

[14] For the incineration of (hazardous) wastes with low ash content (e.g. liquids) in smaller installations up to 30 MW thermal power, fire-tube smoke boilers may be applied. These devices consist of a big water tank with crossing pipes for the hot flue gas.

systems, even the condensation heat of the water contained in the flue gas is applied for heating purposes. Such concepts lead to very high overall efficiencies. |

142. In countries, where especially in the summer months no heat is needed, the application of adsorption cooling units is an appropriate option to optimize the overall efficiencies.]

E. Monitoring

143. All parameters relevant for the operation of incineration facilities should be continuously monitored and controlled. The monitoring of environment and human health can help to determine the impact of the incineration facility on the ambience.

1. Technology monitoring

144. The monitoring of crucial performance indicators and emission parameters are state-of-the-art and BAT for a smart facility operation. The parameters that should be monitored are listed and explained in Section II.D.

145. Another important part of technology monitoring is regular inspection, to determine signs of corrosion, wear, blockages or other damages in the facility.

2. Environmental monitoring

146. The most important way of environmental monitoring is the stringent and steady control of the output of the facility: the flue gas, the ash/slag and possibly arising liquids.

147. Continuous monitoring of pollutants in the flue gas (CO, TOC, HCl, SOx, NOx, NH3, dust, Hg and HF) should be done when technically possible. To allow further data processing and analysis (e.g. standardization), it is also necessary to measure the auxiliary variables exhaust gas flow rate, moisture (humidity) and temperature. The operator should assure proper calibration, maintenance, and operation of the continuous emission monitoring systems (CEMS). A quality assurance programme should be established to evaluate and monitor CEMS performance on a continual basis.

148. Continuous monitoring of metals (Cd, Tl, As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V) and their compounds as well as PCDD/PCDF should be done if technically possible. Otherwise, periodic sampling and analysis in the laboratory should be done.

149. Performance tests should be conducted to demonstrate compliance with the emission limits and performance specifications for continuous monitoring systems, when the facility is operating under normal conditions.

150. The environmental impact from the facility may require the implementation of an ambient air-monitoring programme. This should assess levels of key pollutants identified as a priority for environmental control. The arrangements should include control and downwind locations, including the area of maximum ground level deposition from stack emissions. A meteorological station should be provided for the duration of the ambient sampling exercise in a location free from significant interference from buildings or other structures.

3. Medical monitoring

151. A medical monitoring programme should be implemented to assess and monitor employee health both prior and during employment. An effective programme should consider the following components as a minimum:

(a) Pre-employment screening, to determine fitness-for-duty, including the ability to work while wearing personal protective equipment (PPE), and provide baseline data for future exposures;

(b) Periodic medical monitoring examinations (the content and frequency of which depend on the nature of the work and exposure), to determine biological trends that may mark early signs of chronic adverse health effects;

(c) Provisions for emergency and acute non-emergency treatments;

(d) The auxiliary utilization of portable sensor stickers may facilitate the detection of diffuse emissions of defined pollutants.

F. Record keeping and reporting

152. Reporting of monitoring results involves summarising and presenting results, related information and compliance findings in an effective way.

153. Records of the activities on the site should be kept, including but not limited to:

(a) Type and quantity of waste being incinerated;

(b) Movements of waste from acceptance to incineration;

(c) Parameters analysis of waste samples at the time of acceptance;

(d) Pre-treatments and/or treatments of wastes;

(e) Maintenance, construction or improvement activities;

(f) Staff responsible for each task on the site on a specific date;

(g) Equipment used;

(h) Equipment failure;

(i) Monitoring parameters and the results of the monitoring tests;

(j) Visitors and inspections;

(k) Weather conditions;

(l) Miscellaneous.

154. In order for monitoring reports to be used in decision making processes, they should be readily available, accurate (to within stated uncertainties). Copies of the records should be kept in a way to prevent their loss in the event of an accident.

155. Reports should be made on a frequent basis to the competent authorities on the activities at the incineration facility. Moreover, public participation should be encouraged, therefore reports should be made available to the general public and contain information sufficient both quantitatively and qualitatively to ensure a good understanding of the activities at the facility. Comments by the different stakeholders on the reports should be taken into account in the improvement process of the reporting obligations.

G. Health and Safety

1. General rules

156. Modern incinerators are large-scale processes, which require high safety measures.

157. Health and safety should be a conscious priority and integrated into all aspects of the operation of an incineration facility. Overall and specific personnel requirements, the chain of command, and individual roles and responsibilities, should be clearly established.

158. A health and safety program should be designed to identify, evaluate, and control safety and health hazards.

159. Adequate documentation and information on safe waste handling, operating procedures and contingency measures should be available.

160. Easily understandable safety instructions should be provided to employees and visitors in advance.

2. Technical and organizational measures

161. The best management practices in terms of design, construction and maintenance are necessary to minimize both the potential for air emission particulates and trace metal migration into the environment, contamination of wastewaters and the exposure of workers to materials that may endanger their health.

162. Measures should be taken to ensure that the facility used for temporary storage and pre-processing of wastes prior to incineration be designed and managed in such a way as to avoid or minimize contamination of the environment through emission of dust, volatile substances and odours. In MSWI facilities the waste bunker should be operated under minimal sub-atmospheric pressure to ensure this requirement. Hazardous waste fractions that could cause any harm or nuisance may be left in the vessels they are delivered in or transferred to airtight storage installations under hermetic conditions in hazardous waste incineration facilities.

163. In order to eliminate or control employees' exposure to hazards, all possible engineering, administrative and protective measures should be taken:

(a) Engineering controls to preclude worker exposure by removing or isolating the hazard. For example, ventilation or use of remotely operated material handling equipment;

(b) Administrative controls to manage worker access to hazards and establish safe working procedures; for example, security measures to prevent unauthorized or unprotected access to hazardous wastes on-site;

(c) PPE when engineering or administrative controls are not feasible or do not totally eliminate the risk.

164. Employees should be effectively trained to a level determined by their job function and responsibility. This should be carried out prior to them being permitted to engaging in hazardous waste operations that could expose them to hazardous substances, safety, or health hazards.

165. The training should cover safety, health and other hazards present on the facility; use of PPE; work practices to minimize risks from hazards; safe use of engineering controls and equipment on the site; medical surveillance, including recognition of symptoms and signs that could indicate exposure to hazards. Those engaged in hazardous emergency response should also be appropriately trained.

VII. Emergency Response and spill handling

A. Emergency response

166. Emergency plans and procedures should be established for the protection of the workforce and public before operations begin. An Emergency Response Plan, ensuring appropriate measures to handle possible on-site emergencies and coordinate off-site response, should be in place. As a minimum, this plan should address the following:

(a) Pre-emergency planning and coordination with outside emergency responders;

(b) Personnel roles, lines of authority, training and communication procedures;

(c) Emergency recognition and prevention procedures;

(d) Safe distances and places of refuge;

(e) Site security and control procedures;

(f) Evacuation routes and procedures;

(g) Site mapping highlighting hazardous areas, site terrain, site accessibility and off-site;

(h) Populations or environments at potential risk;

(i) Decontamination procedures;

(j) Emergency medical treatment and first aid procedures;

(k) Emergency equipment (e.g., fire extinguishers, self-contained breathing apparatus, sorbents and spill kits, shower/eye wash stations) at the facility;

(l) Emergency alerting and response procedures;

(m) Documenting and reporting to local authorities;

(n) Critique of response and follow-up procedures.

B. Spill handling

167. A spill handling plan for hazardous waste facilities should be developed to adequately deal with spills or other discharges that may occur on site. The spill handling plan should include at least the following information:

(a) Monitoring and reporting procedures for all possible spills of materials;

(b) Identification of all facility equipment and contents;

(c) A description of the hazards of materials that could be involved in potential spills;

(d) Emergency shutdown procedures;

(e) The chain of command designation during a spill incident;

(f) Emergency contact list with telephone numbers;

(g) Specification of equipment available for containment and clean-up procedures;

(h) Options available for the ultimate disposal of materials involved in a spill.

168. In the case an accidental spill occurs, transfer and storage areas should be designed to handle this accident by the following measures:

(a) Storage areas should have adequate boundaries and be adequately sealed, impermeable and resistant to the stored waste materials;

(b) Incompatible wastes should be prevented from mixing;

(c) All connections between tanks should be capable of being closed by valves;

(d) Overflow pipes should be directed to a contained drainage system such as a bounded area or another vessel;

(e) Measures to detect leaks and appropriate corrective action should be provided;

(f) Contaminated runoff should be prevented from entering storm drains and watercourses;

(g) Any runoff should be collected and stored for disposal in the kiln;

(h) Adequate alarms for abnormal conditions should be provided.

C. Financial considerations

169. In order to finance the consequences of environmentally relevant accidents, it is advised to sign an environmental insurance. It should be taken into account, when the scope and extend of the insurance is defined, that such accidents may have huge impacts and cause enormous costs, with existential impact even on medium sized companies.

VIII. Public Participation

170. Public participation should be encouraged in all the phases of the incineration facility lifespan. Public outreach, meaningful consultation and engagement and open dialogue are important because they build the different stakeholders’ appreciation of the needs and concerns of the community as a whole. Moreover, over the years this can lead to strong partnerships that help in problem-solving by reducing miscommunication issues and lead to better decision-making for all the stakeholders involved.

171. Public participation should be encouraged as soon as the design phase of the incineration facility. Communities should be involved in the choice of the location of a site as this could greatly reduce frictions and the chances of making a poor decision.

172. The different stakeholders should meet on a regular basis to express their needs and concerns during the active operations phase of the incinerator. This can lead to the identification of issues before they become a major problem and thus lead to better management of the engineered landfill, according to environmental, social and economic criteria.

173. A communications plan should be made and updated on a regular basis. This plan should aim to keep all stakeholders informed of new information as soon as possible and should value a transparent and direct communications approach.

Annex I to the technical guidelines

Examples of pertinent national legislation

Examples of national legislation containing provisions related to the incineration of hazardous waste and household wastes are outlined below

Country	**Legislation**	**Brief description**
Argentina	**National Law 24051 and Decree 831/93**	**Hazardous Waste management at national level. Contain definition and Minimal requirements for incineration.**
Canada	Nova Scotia Solid Waste-Resource Management Regulation Ontario Environmental Protection Act, regulation 347	Requires all incinerators in the province to adhere to the Canadian Council of Ministers for the Environment's "Operating and Emission Guidelines for Municipal Solid Waste Incinerators" Defines terms related to incineration (such as fly ash) and sets emission limits for incinerators operated within Ontario.
European Union	Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control	

Annex II to the technical guidelines

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