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Technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1

Note by the Secretariat

The annex to the present note sets out the revised version of the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 reflecting the outcome of the resumed twelfth meeting of the Open-ended Working Group in tracked changes. The present note, including its annex, has not been formally edited.

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Annex

Technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1

Contents

Glossary

Ash: Non-molten particles from the combustion process.

Best available techniques (BAT): The most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole.

Best environmental practice (BEP): The application of the most appropriate combination of environmental control measures and strategies.

Boiler ash: A solid residue generated during the incineration process, originating from suspended particles in the exhaust gas that is blocked by the boiler tube.

Bottom ash: Solid residues collected under the furnace once wastes have been incinerated.

Calorific value: The amount of energy produced by the complete combustion of a material or fuel.

Emission: Direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into air, water or land; or emissions of pollutants into the environment through any kind of duct, pipe, stack, chimney, funnel, flue, etc.

Excess air: Air above the stoichiometric ratio for complete combustion.

False air: Air that intrudes into the incinerator system without control.

Flue gas: The gaseous product of incineration.

Fly ash: Particles from the combustion chamber or formed within the flue gas stream that are transported in the flue gas.

Selective catalytic reduction: Post combustion flue gas treatment that aims to convert NOx to N_2 using ammonia as reagent and catalysts at ca. 180-240°C.

Selective non-catalytic reduction: Post combustion flue gas treatment that aims to convert NOx to N_2 without a catalyst. Ammonia, urea or isocyanic acid are commonly used as reagents at ca. 850-1000°C.

Slag: Solidified residue formed from inorganic constituents that become molten during high temperature combustion process.

Abbreviations and acronyms

BAT	Best available technique
BEP	Best environmental practices
CEMS[1]	Continuous emission monitoring systems
ESM	Environmentally sound management
MSW	Municipal solid waste
OECD	Organisation for Economic Co-operation and Development
OTNOC	Other than normal operating conditions
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

[1] Referred to as “AMS” (automated measuring systems) in some standards.

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, BC-14/6 and BC-15/[ ] 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, and to incineration as covered by 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.[2]

3. Incineration and co-incineration may be covered by disposal operation D10 and by disposal operation R1.

4. It should be noted that the present technical guidelines do not provide guidance on thermal treatment processes of wastes other than incineration, such as pyrolysis and gasification, and on co-incineration of wastes e.g. in power plants. 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.

5. The term "incinerators for hazardous wastes" is used in the present document to refer to incinerators designed for hazardous wastes. The term "incinerators for household wastes" is used in the present document to refer to incinerators designed for wastes collected from households (i.e. wastes belonging to category Y46 in Annex II to the Convention[3]). When needed, the term "incinerators" is used to encompass both terms. It should be noted that wastes from other sources that are similar to household wastes may also be incinerated in incinerators for household wastes.

6. These guidelines provide:

(a) Overarching and common guidance on incinerators;

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

7. Incineration is a thermal treatment process in which wastes are converted into gases and incombustible solid residues by a combustion process.

8. 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:[4]

(a) Pyrolysis – no oxygen ($\lambda = 0$), typical temperatures ca. 250-700°C;

(b) Gasification – limited oxygen ($\lambda < 0.5$), typical temperatures ca. 500-1600°C;

(c) Incineration – excess oxygen ($\lambda > 1$), typical temperatures ca. 800-1300°C.[5]

9. In addition to the processes referred to in the previous paragraph, there are thermal treatment processes of waste 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).

10. It should be noted that the present technical guidelines do not provide guidance on co-processing of hazardous wastes and other wastes. For guidance on co-processing of hazardous wastes in cement kilns, see the Basel Convention technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP, 2011).

11. For specific guidance on incineration of persistent organic pollutant (POP) wastes, see the General technical guidelines on POPs (UNEP, 2022aXXXX, currently under revision), in particular

[2] Annex IV is currently being reviewed, see decision BC-14/16.

[3] Annex II also covers "Residues arising from the incineration of household wastes" (Y47) which is an output of incinerators for household wastes, and certain plastic wastes (Y48).

[4] The combustion air ratio (λ) is a dimensionless measure; it is usually regarded as the ratio between the air fuel ratio and the ideal (stoichiometric) air fuel ratio.

[5] Federal Environment Agency, 2017. Status of Alternative Techniques for Thermal Waste Treatment.

sections IV.G.2 (b), (e) and (g) that address incineration.

12. 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, XXXX 2022bcurrently under revision).

13. For guidance on the landfilling of hazardous wastes and other wastes, refer to the Technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, XXXX 2022ccurrently under revision).

B. Overview of incineration

14. The purpose of waste incineration is the complete oxidation of all organic compounds contained in the waste. Waste incineration occurs at temperatures of about 800-1300°C, by applying air with sufficient mixing to create conditions with excess 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 wastewater or brine, are treated, auxiliary fuel (gas, oil) might be applied in order to reach sufficient temperatures. Outputs from incineration are flue gas and solid residues (e.g. ash, slag, and other flue gas cleaning residues). Depending on the flue gas treatment, liquids or sludgy wastes may also be an output.

15. Incineration is a rapid oxidation process that generates heat, and converts the organic part of the waste, as well as some metals (e.g. mercury), into the gaseous phase mainly consisting of carbon dioxide (CO_2) and water vapour (H_2O). Carbon monoxide (CO) and some organic compounds (total organic carbon (TOC)) are also present in the gas in at least trace amounts. If air is used as a reactant, the flue gas contains an excess (> 50% vol) of nitrogen (N_2) and the oxygen (O_2) remaining after combustion. Depending on the composition of the waste, other pollutants are also transferred into the gas phase. Typical pollutant groups and specific examples of pollutants that result from waste incineration are presented in Table 1.

Table 1: Typical pollutants groups and specific examples of pollutants from waste incineration

Pollutants Groupings	Example of pollutants
Nitrogen oxides	Nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O)
Acidic hydrogen gases	Hydrogen fluoride (HF), hydrogen chloride (HCl)
Sulphur oxides	Sulfur dioxide (SO_2), sulfur trioxide (SO_3)
Heavy metals	Mercury (Hg), cadmium (Cd), thallium (Tl), copper (Cu), lead (Pb), nickel (Ni), chromium (Cr), antimony (Sb), arsenic (As), cobalt (Co), vanadium (V), manganese (Mn), selenium (Se), and zinc (Zn) Commonly found as metal oxides and chlorides in particulate matter, but can also be emitted as vapour
Toxic organic pollutants	Polycyclic aromatic hydrocarbons Polybrominated dibenzo-p-dioxins and polybrominated dibenzo–furans (PBDD/PBDF
Persistent Organic Pollutants	Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo–furans (PCDD/PCDF), polychlorinated biphenyls (PCB), polychlorinated napthalenes (PCN), and hexachlorobenzene (HCB)
Particulates	Dust, fly ash

16. 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 incinerators for hazardous wastes, the inorganic residue is often (partly) molten and emerges as a slag. The bottom ash from incinerators for household wastes is exposed to lower temperature and therefore only sintered.

17. In general, the requirements for the incineration of hazardous wastes are different than for the incineration of household wastes. For instance, they require higher temperatures and greater effort for logistics and (separate) storage, and apply more sophisticated flue gas treatment methods, such as quench systems. Obtaining energy from incinerators for hazardous wastes may be suitable; attention should however be paid if they have flue gas with high halogen concentrations (see paragraph 83). Incinerators for household wastes commonly obtain energy through the boiler. Nevertheless, some types of hazardous wastes may also be incinerated in incinerators for household wastes.

18. The main goal of waste incineration, when operated in accordance with best available techniques (BAT) and best environmental practices (BEP) are the following:

(a) Permanent destruction of all organic (hazardous) constituents;

(b) Sanitisation of waste;

(c) Minimising emissions to all media;

(d) Complete oxidation of the organic compounds of the waste;

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

(f) Reduction of volume of the waste and preservation of space for other disposal methods (e.g. landfilling or permanent storage);

(g) Possibility to obtain the energy content of the waste;

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

II. Relevant provisions of the Basel Convention, Stockholm and Minamata Conventions

19. The following sections present a brief description of relevant Articles of the Basel Convention and the Stockholm and Minamata Conventions to illustrate their complementarity.

A. Basel Convention

20. 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.

21. 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 22 to 24 below.

22. 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.”

23. 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).”

24. 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

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

26. 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.”

27. According to Article 5 and Annex C of the Stockholm Convention, Parties are required to take measures to reduce total releases derived from anthropogenic sources of unintentionally produced POPs with the goal of their continuing minimization and, where feasible, ultimate elimination. Annex C, Part II, outlines industrial source categories that have the potential for comparatively high formation and release to the environment of POPs listed in Annex C, including “Waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge.” Annex C, Part V outlines general guidance on best available techniques and best environmental practices on preventing or reducing releases of unintentionally produced POPs from the anthropogenic sources, such as incineration.

28. According to Article 10, paragraph 1 (b) of the Stockholm Convention, “each Party shall, within its capabilities, promote and facilitate provision to the public of all available information on persistent organic pollutants, taking into account paragraph 5 of Article 9” of the Stockholm Convention.

C. Minamata Convention on Mercury

29. The objective of the Minamata Convention, which entered into force on 16 August 2017, is, according to Article 1, “to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.”

30. Article 8, paragraph 3, of the Minamata Convention provides that “[a] Party with relevant sources shall take measures to control emissions.” “Relevant source” means a source falling within one of the categories listed in Annex D to the Minamata Convention. Relevant sources listed in Annex D include “Waste incineration facilities” and therefore cover incinerators.

31. Article 8, paragraph 4, provides that “for its new sources, each Party shall require the use of

best available techniques and best environmental practices to control and, where feasible, reduce emissions, as soon as practicable but no later than five years after the date of entry into force of the Convention for that Party."

32. Article 8, paragraph 5, provides that "for its existing sources, each Party shall include in any national plan, and shall implement, one or more of the following measures, taking into account its national circumstances, and the economic and technical feasibility and affordability of the measures, as soon as practicable but no more than ten years after the date of entry into force of the Convention for it:

(a) A quantified goal for controlling and, where feasible, reducing emissions from relevant sources;

(b) Emission limit values for controlling and, where feasible, reducing emissions from relevant sources;

(c) The use of best available techniques and best environmental practices to control emissions from relevant sources;

(d) A multi-pollutant control strategy that would deliver co-benefits for control of mercury emissions; and

(e) Alternative measures to reduce emissions from relevant sources."

III. General considerations on environmentally sound management

33. 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.

34. 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.[6] 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.

35. As presented in paragraph 24 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;

(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.

36. The Organisation for Economic Co-operation and Development (OECD) 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).

37. 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;

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

technologies; and other tools in which all key stakeholders participate and cooperate (UNEP, 2013). The following sections should be taken into account when establishing, implementing or evaluating ESM.

38. 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.

39. 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.[7]

40. The incineration of hazardous wastes and household wastes as per operation D10 is considered final disposal and should therefore be one of the least favoured options. The incineration of hazardous wastes and household wastes as per operation R1 is considered recovery and should therefore be preferred to incineration as per operation D10, when applicable.

IV. General guidance on environmentally sound disposal in incinerators

41. ESM involves the use of facilities operated under quality assured management regimes, according to appropriate BAT and BEP. Planning, designing, building, maintaining, and operating an incinerator requires significant financial investment and skilled professional staff.

42. Guidance on BAT and BEP 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 Stockholm Convention is provided under the Stockholm Convention. 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).

43. Guidance related to BAT/BEP regarding emissions of mercury and mercury compounds to the atmosphere from point sources listed in Annex D to the Minamata Convention, such as "Waste incineration facilities" and therefore incinerators, is provided under the Minamata Convention. Guidance in relation to mercury emissions (Article 8, referred to in paragraphs 8 (a) and 8 (b)) has been adopted by the Conference of the Parties to the Convention at its first meeting, in 2017 (UNEP, 2017).

44. To establish and operate incinerators requires efforts by the responsible authorities and the incinerator operators, including regulatory law, administrative execution, financial instruments (e.g. gate fees) or economic disincentives (e.g. landfill taxes) or subsidies (e.g. to build an incinerator).

45. It should be noted that the establishment and operation of incinerators ~~often~~ requires high construction and operation cost, and professional engineers for a sound operation.

A. Legislative and regulatory framework

46. 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.

47. 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 and monitoring of incinerators as well as regarding enforcement. Examples of national legislation can be found in Annex I.

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

(a) Site selection;

[7] Decision BC-10/2: Strategic framework for the implementation of the Basel Convention for 2012-2021.

(b) Public participation;

(c) Appropriate permits, licenses, or regulatory approvals to operate;

(d) Design standards for facilities;

(e) Provisions for pre-treatment, e.g. for waste mixing or sorting and interim storage, and wastewater management;

(f) Environmental impact assessment;

(g) Operation/discharge standards;

(h) Emergency and contingency plans;

(i) Training of operators of the facility;

(j) Treatment of solid residues (e.g. ash, slag and other flue gas cleaning residues) and if applicable, liquids, or sludgy wastes from the incinerator;

(k) Regulatory oversight;

(l) Monitoring and control, including other than normal operating conditions (OTNOC) (e.g. shutdown, and commissioning);

(m) Measurements and management systems;

(n) Records, record-keeping, and reporting;

(o) Decommission.

B. Location

49. 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.

50. For potential sites, an environmental impact assessment should be done to determine the environmental impacts and the environmental technical, legal, social and economic feasibility of establishing a 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) Distance from areas of food production;

(d) Urbanization of surrounding areas;

(e) Socio-economic aspects (public acceptance), including impacts of transport;

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

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

(h) Symbiosis with industrial clusters.

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

52. Consideration should be given to the general site boundary; 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 site 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

53. 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.

54. Typically, a 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.

55. Household wastes are typically incinerated in grate firing systems or, after pre-processing, as refuse derived fuels (RDF)[8] 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.C of this document.

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

57. Obtaining energy from waste can be an important added value of incinerators, irrespective of whether the incineration falls under the disposal operation D10 or R1. Many iIncinerators for household wastes ~~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 cooling) or is directly delivered to adjacent industrial facilities. Incinerators for hazardous wastes may also be equipped with a boiler for obtaining energy from waste; attention should however be paid if the flue gas has high halogen concentrations (see paragraph 83). Incinerators for hazardous wastes should preferably be located within industrial areas (e.g. chemical parks), so that the produced steam can be utilized in adjacent facilities.

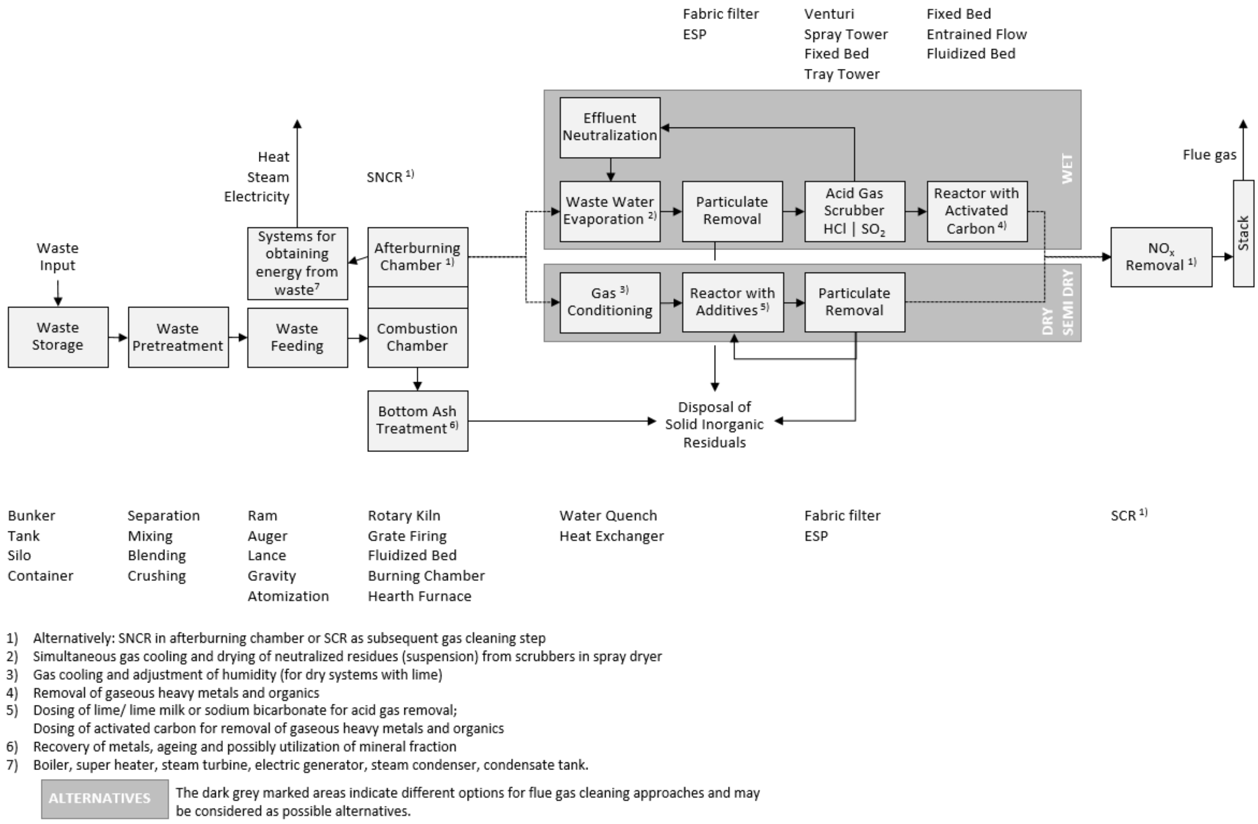
58. The firing equipment of the combustion chamber should be designed, manufactured and placed into service in conformity with relevant guidance or legislation (e.g. the European Machinery Directive (2006/42/EC)) and should comply with common standards, e.g. EN 746-2, EN 12952-8, EN 12953-7. An automatic 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. Auxiliary burners should be designed to start when the temperature in the combustion chambers becomes too low (see Section VI. A). 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.

59. Incinerators consist of components for waste acceptance, potential pre-treatment, temporary storage and feeding, the incineration portion, including obtaining energy from waste where possible, the flue gas treatment system as well as optional installations for bottom ash and wastewater treatment (see Figure 1). Incinerators for hazardous wastes should also be equipped with a laboratory as part of the waste acceptance procedures.

60. The combustion systems and the installations upstream of the furnace vary widely between the different types of incinerators (see Section I). While incinerators for household wastes are typically only equipped with one bunker for the storage of all delivered waste fractions, incinerators for hazardous wastes have a sophisticated infrastructure and the possibility for separate, adequate storage of different types of waste (see Section V).

[8] According to ISO/TR 21916:2021, RDF are solid wastes used as a fuel that do not meet the criteria of ISO 21640 to be classified as “solid recovered fuel”. RDF contains high calorific fractions but has not been processed as extensively as required under ISO 21640 (ISO, 2021 and ISO, 2016).

Figure 1: General overview of components of an incinerator.



1. Types of incinerators

61. In the following paragraphs, the currently relevant furnace systems for waste incineration, designed according to BAT, are described.

(a) Grate incinerators

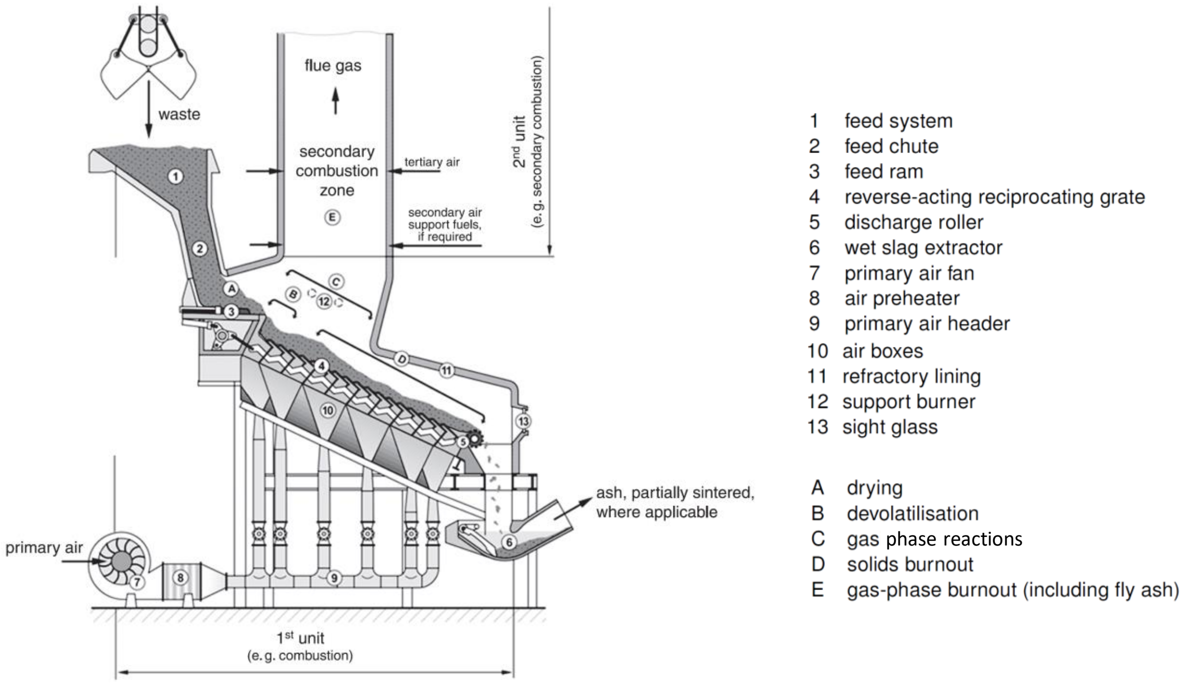
62. Typically, grate incinerators (see Figure 2) are used for the combustion of municipal solid waste (MSW). The waste is usually fed via hopper and stoker onto the cast iron grate, which consists of moving elements (e.g. oscillating steps or rotating drums) for the waste transport. The grate may be horizontal or have a significant decline, depending on the type of the grate.

63. There are forward and reverse (backward) pushing (acting) grates as well as rotating drum grates applied for incinerators for household wastes. Simple traveling grates are only suitable for incineration of homogeneous fuels and therefore not for the treatment of MSW, because satisfactory stoking of the incineration bed is difficult to maintain.

64. 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 2), followed by the devotilisation (B) and finally the burnout of solids (D) takes place. Above the incineration bed gas phase reactions are occurring (C) and the gases are reacting with the oxygen of surplus primary air and 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 of the 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 air sections.

65. After burnout at the end of the grate, the bottom ash falls into a slag discharger (No. 6 in Figure 2). 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 will increase the flue gas flow. Within recent years some incinerators for household wastes were equipped with slag discharges without water filling (dry slag discharge), to improve the quality of the recovered metals.

Figure 2: Scheme of a grate incinerator for MSW (reverse acting grate with counter flow principle; Figure: VDI, 2014).



(b) Rotary kilns

66. A rotary kiln is able 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.

67. Rotary kiln furnaces (cf. Figures 3 and 4) 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 incinerators (see Section IV.C.1 (a)). The typical diameters of rotary kilns for hazardous waste incineration are 3-4m and the length is up to 12m. 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.

68. Figure 3 shows the thermochemical processes (drying (A) – devotilisation (B) – gas phase reactions (C) and burnout (D) of carbonaceous solids) occurring during the treatment.

Figure 3: Scheme of a rotary kiln furnace for hazardous wastes.

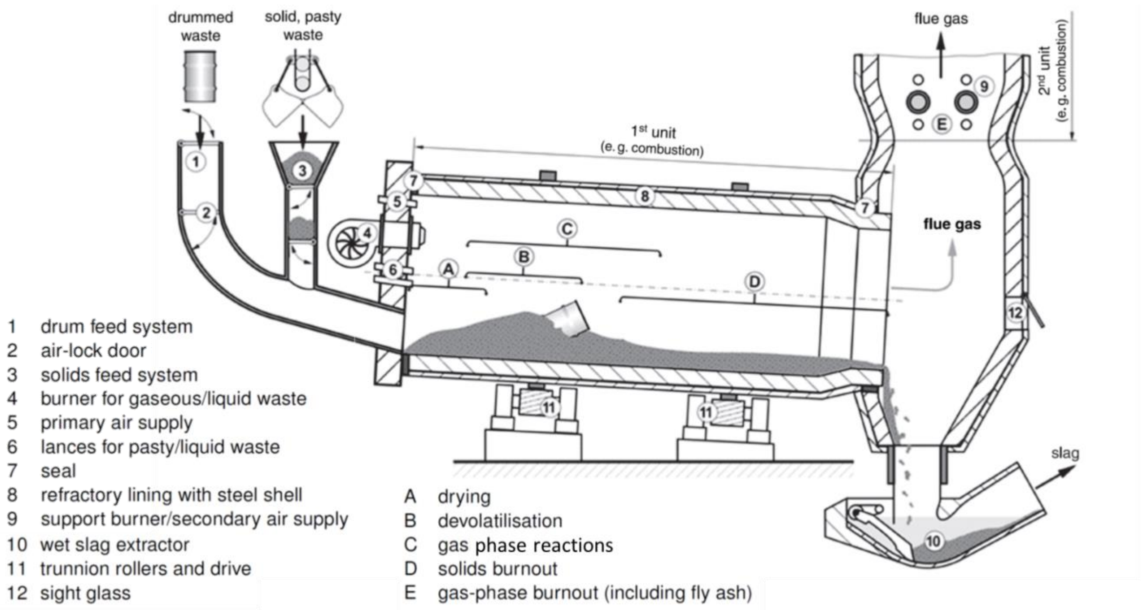
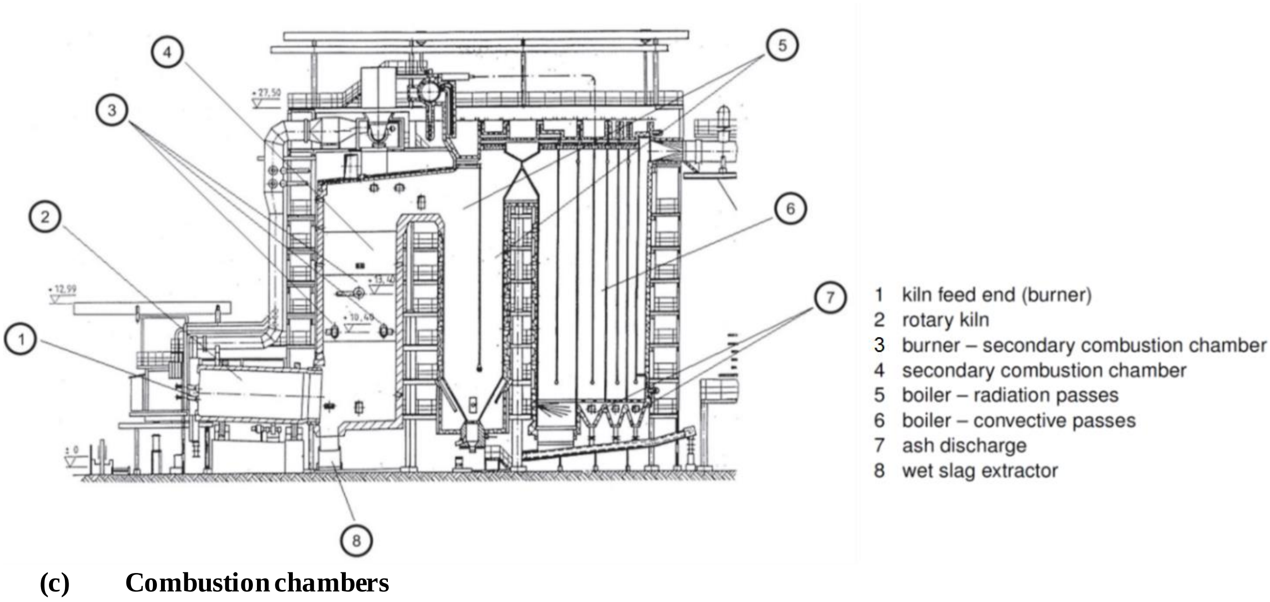


Figure 4: Scheme of a rotary kiln furnace with secondary combustion chamber and heat recovery boiler (VDI, 2014).



(c) Combustion chambers

69. The least complex of all incinerators for hazardous wastes are combustion chambers which are typically used for the incineration of liquid wastes. Usually it is also possible to incinerate gaseous wastes and/or dusts in these devices. 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.

(d) Fluidized bed furnaces

70. Fluidized bed furnaces are normally built as cylindrical (also rectangular geometries are possible), vertically oriented 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 200°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.

71. 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 (typically around 0.5-1m/s), which are sufficient for fluidizing the sand bed, but not high enough to transport it out of the reactor, form a stationary fluidized sand bed with a defined height of approximately 1 to 1.5 meters. Such facilities are called stationary fluidized bed furnaces. The sand bed in these furnaces 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. Fluidised circulating beds operate on a similar principle, but the bed/heat transfer media (sand) is circulated around the system, usually utilising higher air velocities to ensure waste is fully burnt (see paragraph 131).

72. Fluidized bed furnaces can be operated at relatively low temperatures, with the actual bed typically at temperatures as low as 750°C, and the air above the bed generally between 850°C to 950°C. As fluidized bed furnaces are well-mixed systems, they have a uniform distribution of temperature.

73. Advantages offered by fluidized bed furnaces 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 which limits the formation of nitrogen oxides and prevents ash melting in the case problematic (alkaline containing) waste fractions are treated; and

(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.

74. Primary limitations of fluidized bed furnaces are that the waste material must be shredded to a relatively small and uniform particle size and feed materials must not be capable of producing a molten phase in the unit (i.e. they must have low concentrations of alkaline minerals, otherwise the bed has a tendency to clog with slag and subsequently reduce efficiency, and there is a problem of bed entrainment through to the product gas phase). Conventional fluidized bed furnaces are not normally capable of sustaining the temperature required for the efficient destruction of the more thermally stable species of hazardous constituents (i.e. PCBs[9]).

(e) Multiple hearth furnaces

75. 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.

76. Due to the complex construction and the moving parts in multiple hearth furnaces, the maintenance effort and the corresponding costs for such devices are relatively high.

2. Systems for obtaining energy from waste

77. The principal uses of the energy transferred to a boiler are production and supply of heat (as steam or hot water), cooling (via adsorption cooling units), electricity, and/or combination of these.

78. The system for obtaining energy from waste in incinerators may consist of an exhaust heat boiler, a steam turbine, power generator, evaporative condenser and adsorption cooling unit. Additionally, a treatment apparatus for the boiler feed water and deaerators are required as auxiliary equipment. It should be noted that installation of a steam generator for obtaining energy from a small facility whose treatment capacity is approximately below 100 tons per day may be less profitable. In such a case, obtaining energy as hot water may be considered, as production systems for hot water are less complicated and less expensive than for steam. There are several examples of incinerators with capacity lower than 100 tons per day which profitably sell steam to the local heat net or to industrial

[9] For further information, refer to the technical guidelines on PCBs (UNEP, 2017a).

neighbours[10].

79. An exhaust heat boiler is important to obtain combustion heat from waste incineration. It is typically installed at the outlet of the incinerator. In incinerators for household wastes, the boiler and the furnace are usually combined in order to favour the cooling of the furnace and to reduce heat losses. The boiler tubes are continuously exposed to the flue gas with high-temperature and strong acidity, which poses a risk of high-temperature corrosion of the tube. In incinerators for household wastes, it is common to operate at steam parameters of 4 MPa and 400°C when electricity is produced. In the case of heat production, steam with lower parameters or superheated water may be produced (European Commission, 2019a).

80. Flue gas temperatures at the end of the boiler are 180 (to prevent the condensation of sulfuric acid) to 350°C. To reduce, with the aim to prevent the formation of PCDD/PCDF and other unintentional POPs in the flue gas cleaning system, the temperature before the inlet to the dust removal stage may be reduced to below 200°C for example with an appropriate boiler design, a gas/gas heat exchanger, a spray tower to reduce the temperature at the boiler exit or a quenching system.[11] These design options depend on the risk owing to the nature of the waste incinerated.

81. The feeding water for the exhaust heat boiler should be pure water with very low oxygen and carbon dioxide concentrations and also the harness, including calcium carbonate concentration, should be sufficiently low. Thus, water purification systems and deaerators are needed as auxiliary equipment.

82. It should be noted that the adhesion of ash to the boiler may reduce the heat exchange efficiency and/or cause the by-production of PCDD/PCDF. Thus, equipment to remove adhesive materials regularly is necessary. In this context, heat transfer surface cleaning plays an important role. This cleaning can be accomplished manually or automatically with lances (compressed air or water jet), agitators, soot blowers using steam, a hail of pellets (sometimes shot cleaning), sound and shock waves, or with tank cleaning devices. The resulting solid residue is extracted at the bottom of the boiler as boiler ash.

83. For incinerators for hazardous waste, attention should be paid to the halogen content of waste. When the halogen content in waste is high, the high-temperature boiler corrosion can be severe. In order to avoid corrosion of the boiler by halogenated gases, the temperature of the gases in contact with the boiler tubes should not be lower than the dew temperature of these gases. For this purpose, the temperature of the steam in boilers of incinerators for hazardous wastes is generally limited to 233°C – 240°C, which is higher than the dew temperature of gaseous HCl and H_2SO_3.

84. A steam turbine can be used to convert the obtained energy into electricity. The types of steam turbine are categorized as backpressure turbine or condensing turbine, and both usually have one or more bleeder(s) to extract steam at different pressures for internal or external use. It should be noted that the exhaust pressure from the condensing turbine is reduced to vacuum pressure (bound to the cold source), and therefore compared to a backpressure turbine, the generating end-output is higher. Back pressure turbines are used either when middle or low pressure steam is needed for a district heating network or other uses, or electricity is only used locally by the plant and in its surroundings.

85. In introducing a system for obtaining energy from waste, professional engineers should be involved in consideration of the site condition, the local needs for heat (steam and/or superheated water), the purchase price offered by the electricity company for produced electricity, and the profitability, including operational, maintenance, and design costs.

V. Guidance on environmentally sound pre-treatment and acceptance of waste

A. Waste acceptance

86. The operator of a waste incinerator 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

[10] Examples of such facilities include Montgris, Carhaix, Sogad, and Tronville in France, where steam is sold to industry, and TREA I (https://www.swg-konzern.de/ueber-uns/trea-1) and TREA II (https://www.swg-konzern.de/ueber-uns/trea-2) in Germany (both links in German).

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

delivery and acceptance of the wastes.

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

88. Pre-acceptance tests on samples of hazardous wastes prior to the transport of a load of wastes to an incinerator may be conducted by the operator of the incinerator to which the load is planned to be transported. The tests should aim at characterisation of the hazardous wastes samples (e.g. calorific value, viscosity, content of pollutants such as POP content, identification of hazardous characteristics) as well as their treatability. A pre-acceptance test report should be prepared.

1. Household wastes

89. Incinerators for household wastes 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 is 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 above the bunker to prevent odour emissions by adjustment of a slight under pressure.

90. 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 furnaces, often silos with pneumatic or mechanical conveying systems are used for storage and supply to the furnace.

91. For RDF, the risks of self-heating and self-ignition during storage should be minimized. Ignition temperature is predicted to be as low as 40°C to 80°C for stacks of RDF in the 1m to 5m height range (Gao and Hirano, 2006).

2. Hazardous wastes

92. Hazardous waste incineration requires significantly higher efforts 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, if the undesirable reactions mentioned above are prevented, is an appropriate option to fulfil this demand.

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

94. 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.

(a) Specifications for clinical waste

95. For the incineration of clinical waste (which is hazardous waste, cf. entries A4020 and Y1), dedicated burning chambers or incinerators especially equipped for this purpose can be used.

96. The wastes should be incinerated together with the bag/box they were collected in. If any mechanical processing steps need to be taken (e.g. compacting, shredding, etc.), a reliable disinfection treatment (e.g. by the high-pressure saturated steam disinfection method) should be carried out before, and other safety precautions taken.

97. 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.

98. Infectious materials should be collected in secure, 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 incinerator.

99. 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 should be spent on all possible engineering, administrative and protective measures to avoid direct contact with the waste.

B. Reception control

100. 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.). This should include radioactivity detection depending on the risk posed by the incoming waste.

101. Prior to unloading, particularly for hazardous wastes, systematic sampling, analyses of characteristics at the entry laboratory, and checking the compliance with the permit acceptance criteria and any related pre-acceptance test report should be completed. If a specific waste load does not comply with the permit acceptance criteria, the operator should refuse the waste.

102. For incinerators for household wastes, 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.

103. In incinerators for hazardous wastes, the controls should be more stringent than for incinerators for household wastes. Incinerators for hazardous wastes should also be equipped with a laboratory as part of the waste acceptance procedures. 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);

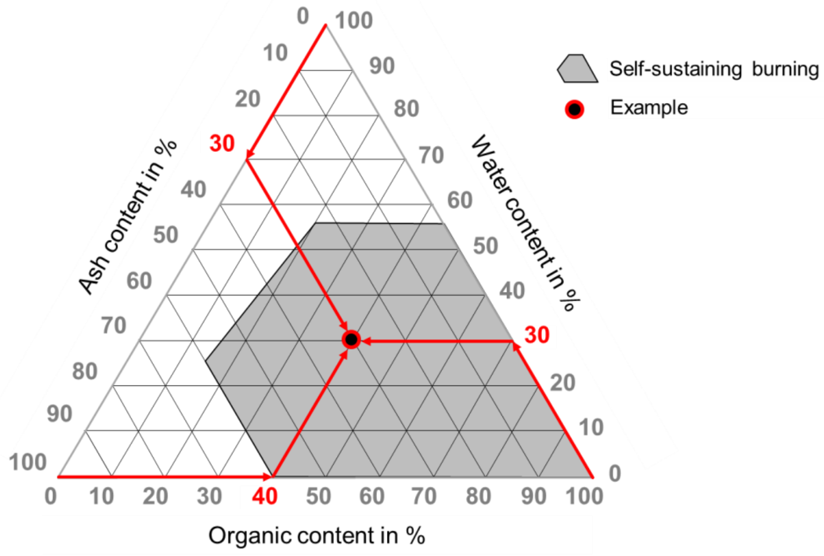
(e) Determination and registration of waste type and mass.

C. Waste selection and pre-treatment

104. 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.

105. All furnaces require the waste to have a sufficient calorific value that allows for combustion. 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 5 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-sustained burning; the example depicts a waste with a composition of 30% water and ash and 40% combustible material.

Figure 5: Fuel triangle for waste combustion.



106. For a stable combustion without auxiliary fuel, a lower calorific value[12] of at least 6 MJ/kg should be steadily sustained, depending on the incineration method.

1. Household wastes

107. Incinerators for household wastes and similar waste from other sources are able to treat a large variety of wastes with different properties and characteristics. Typically wastes that are treated in incinerators for household wastes are household and similar commercial wastes, sorting and treatment residues from other waste treatment facilities and even sludges in moderate amounts. ~~Household waste can potentially contain hazardous constituents, for example POPs and heavy metals.~~

108. Household wastes can contain hazardous constituents due to the potential presence of, for example, POPs and heavy metals, despite best separation efforts. In such instances where household wastes containing hazardous constituents are disposed of in~~. The incineration of hazardous wastes is possible in~~ incinerators for household wastes, ~~if~~ a sufficient destruction of all organic materials ~~is~~ should be achieved.

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

110. 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[13].

111. Household wastes can undergo pre-treatment at mechanical-biological treatment facilities through processes such as shredding and separating metals, and producing RDF. These processes remove some metals and inert materials.

112. While untreated MSW is not used as a supplemental or substitute fuel for industrial applications due to its heterogeneity, the treatment that RDF undergoes may make it suitable for co-processing or co-incineration facilities, though quality can vary. RDF should be processed in such a way to optimise thermal and emission performance for its intended use, which can include as a fuel in

[12] Other terms meaning the same as "lower calorific value" are "lower heating value", "net heating value" and "net calorific value". It is noted that there are different methods for calculating it.

[13] See information on automated crane operations to supplement experienced crane operators: https://www.ebara.co.jp/en/jihou/no/list/detail/258-6.html

cement kilns or wood fired/pulp mill boilers.[14]

2. Hazardous wastes

113. Incinerators for hazardous wastes, according to BAT, are able to treat all kinds of combustible hazardous waste fractions and even accept some incombustible wastes, such as contaminated water and soil. Other incombustible wastes, may enter the kiln as part of an accepted waste type, such as shredded or unshredded metallic drums. Contaminated water will evaporate, and any organic contamination will be oxidised, while metallic drums will become decontaminated during the incineration process. Typically, the energy needed to treat these incombustible waste fractions is provided by the calorific value of the hazardous waste, though in some cases auxiliary fuel may need to be applied.

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

115. 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 fluxing agents and aid the formation of slag that inhibits heat and gas transfer and 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) Drums containing ordinary pasty or viscous wastes may be shredded.

VI. Guidance on environmentally sound incineration operation

116. Main operational costs for an incinerator include staff wages, reagents for air-pollution control, environmentally sound disposal of fly-ash/filter cakes (in case of a wet process), bottom ashes/slags and cleaning residues, maintenance/repair, electricity, auxiliary fuels, storage facilities, and for satisfying ~~stringent~~ health and safety provisions required for daily operation, especially in a hazardous waste incinerator. Other costs include continuous emissions monitoring, operator training, stack testing, and air-pollution control upgrades. The costs may vary depending on the incineration technology being utilized.

A. General aspects

117. 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 vapours 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 chamber, in which the emitted burnable gases are post-combusted.

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

(a) There should be a system to move and/or stoke the solids in the combustion bed to ensure sufficient mixing;

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

(c) The temperature should be high enough to reach the ignition temperature and maintain sufficient reaction temperature for the specified residence time;

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

(e) The gas and secondary air should be efficiently mixed;

[14] See information on the related ISO work in the ISO/TC300 ~~Solid Recovered Fuels~~ Solid recovered materials, including solid recovered fuels at https://www.iso.org/committee/5960430.html.

(f) The velocity of the flue gas should be homogeneous;

(g) The flue gas should be held at a high enough temperature for long enough for sufficient oxidation to occur (residence time).[15]

119. Waste should only be introduced into the combustion chamber when the appropriate temperature is reached. The waste feed rate should be able to be adjusted to prevent waste from entering the combustion chamber when the combustion conditions are not appropriate (e.g. temperature becomes too low).

120. Auxiliary burners should ensure that the combustion chamber reaches the appropriate temperature during start-up and remains ~~is~~ at the appropriate temperature during ~~start-up and~~ shutdown and when the waste is being treated ~~as well as temporarily , when waste is treated in case the temperature drops~~. In case an auxiliary burner (e.g. for rotary kilns) is fired with liquid or sludgy waste, the required operating temperature for that waste in the combustion chamber should be met. For OTNOC, e.g. start up or shut down, the frequency of the occurrence of OTNOC and the emissions during OTNOC should be reduced (see details in paragraph 195).

121. Typical legally required minimum temperature of the gas resulting from the incineration in the post-combustion chamber of the waste furnace 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.[16]

122. In most cases CO and O_2 are required input parameters into the combustion control system. The application of optical and infrared cameras is also helpful for the control of the incineration conditions[17].

B. Operational considerations of different types of incinerators

1. Grate incinerators

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

124. An aim of the incineration grate is to have a good distribution of the incineration air into the furnace, according to combustion requirements. A primary air fan forces incineration air through small grate layer openings into the fuel layer. Secondary air is generally added above the waste bed to complete the combustion of volatile gases.

125. Air entering the grate incinerator can be preheated as required, if it is necessary to pre-dry the waste. The residence time for wastes on the grates generally ~~should~~ may not exceed 60 minutes, but it should be long enough for sufficient oxidation of the waste to occur.

126. It is common for fine materials to fall through the moving parts of the grate before being completely burnt (known as riddlings or siftings). This may be reduced by enhancing the combustion in the grate incinerator. Once collected, this material can be collected in the bottom ash remover and 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.

2. Rotary kilns

127. 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 chamber is necessary to guarantee a complete burnout of the organic components and of the generated 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

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[15] 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*.

[16] Many operators have, based on national legislation, exceptional permissions to run an incinerator 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.

[17] Suitable combustion control systems are also commonly used for enabling stable combustion (European Commission, 2019a; Ding et al., 2021; Kojima et al., 2021).

minimum temperature of 1100°C is required, a burner for a fuel with a high calorific value, e.g. natural gas or waste alcohol, 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.

128. While the solid wastes have a residence time of up to one (or even two) hours in the rotary kiln, the gas produced by the incineration process, such as combustion gases and evaporated liquids leave the rotary kiln after a few seconds. These gases may contain incompletely combusted substances. Therefore, a post-combustion chamber is necessary to guarantee a complete burnout of the residual organic components in a gaseous form and of the generated gases. Further burners for liquid or gaseous waste streams may be placed in the lower part of the post-combustion chamber. In addition, when a minimum temperature of 1100°C is required, a burner for waste or fuel with a high calorific value, e.g. natural gas, may be placed in the post-combustion chamber to ensure a sufficient temperature when needed. Alternatively, the temperature in the post-combustion chamber may be controlled by regulating the calorific value of the waste flow delivered by the front burners. Furthermore, a residence time of at least two seconds after the last air supply of the flue gas in the post combustion chamber at the requested temperature should be guaranteed, as well as a sufficient turbulence of the gases.

3. Combustion chambers

129. One of the key components for efficient operation of combustion chambers, which are dedicated to the incineration of gaseous or liquid hazardous wastes, is the design and the monitoring of the atomization of the burner. Most of the burners introduce air in a vortex section, surrounding the liquid atomizing nozzle. This creates intimate mixing of the vaporized fuel and wastes with the combustion air, yielding uniform flame temperatures and high destruction efficiencies.

4. Fluidized bed furnaces

130. Fluidized bed furnaces are applied for homogeneous fuels with a relatively narrow grain size spectrum, typically up to 50mm in diameter. Thus, in terms of solid waste treatment, the incinerated waste should be pre-processed. The additional treatment of pasty wastes is unproblematic. Therefore, fluidized bed furnaces can predominantly be applied for RDF, pre-processed waste wood or sludges.

131. If higher air velocities (2-5m/s) are applied, the fluidization of the sand is not limited to a certain height (fixed fluidised beds), but the sand bed is expanding over the whole combustion chamber and is carried out together with the flue gas (circulating fluidised beds), which allows for recirculation of the waste until it is fully combusted. In these cases, a cyclone is mounted at the chamber outlet to separate the sand from the flue gas and to return it back to the furnace.

C. Treatment of emissions and residues

132. The main mass stream resulting from the incineration of waste is the flue gas. Depending on the type of waste, solid residues may also be generated, such as bottom ash, slag, boiler ash, fly ash, and other flue gas cleaning residues. The quantities of bottom ash generated depends on the percentage of non-volatile mineral elements, with the quantities of fly-ash and/or filter cakes depend on the level of pollutants in the raw flue gas. For information on typical quantities of residues produced in incinerators for household wastes, see for example European Commission, 2019a or Sabbas et al., 2003.

133. In the case that a wet flue gas cleaning system (scrubber) is used for acid and other pollutant removal, liquid effluents may also arise. These output streams contain pollutants and should be treated before their release to the environment (i.e. surface water) or prior to disposal.

1. Flue gas

134. 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.

135. The control of CO and volatile organic compounds is solely dependent on the proper operation of the furnace. Grate furnaces for household wastes can be controlled by underfired air, the furnace geometry, secondary air injection and gas mixing. Continuously operated incinerators for hazardous wastes normally have low carbon monoxide emissions by ensuring sufficient mixing inside the system, residence time, and excess air levels. If high-calorific wastes are fed in batches, CO peaks may arise.

136. For the treatment of the flue gas several established concepts exist (see Section VI.C). Usually they are categorized according to the treatment step for removing the acid gases: dry – semiwet – wet. Figure 1 shows a principle process schemes for these three options (grey shaded sector; schematic for

dry and semiwet 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 sulphur 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. 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 wet 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.

137. 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

138. The name of the entire flue gas cleaning system stems from the technology applied for reduction of acid gas (HCl, HF, sulfur oxides (SO_X)) emissions. Wet, semiwet and dry methods (cf. Figure 1) are named after the capture process:

(a) Wet: Transfer in a scrubber into water with further chemical treatment;

(b) Semiwet: By firstly a transfer into a liquid, which is typically a lime solution, that is atomized in a reactor and where an acid-base reaction occurs. After, it evaporates in the hot flue gas stream by a direct reaction with the remaining reagent previously in suspension;

(c) Dry: By a direct reaction between the acid gas and the reagent injected as a dry powder (usually sodium bicarbonate or lime).

139. Wet flue gas cleaning systems usually consist of a pre de-duster (electrostatic precipitator or fabric filter) as a first step, to protect the following scrubber. The scrubber may be subdivided into two separate sections with different pH-values. In the first step, at a pH value of <1, predominantly HCl and HF (and HBr, HI) but also mercury salts are absorbed into the liquid. It is possible to reduce hydrochloric acid by refining the flushing liquid. The second scrubber step is operated at a more or less neutral pH-value (about 7), which is maintained by addition of an alkaline neutralization agent (usually $Ca(OH)_2$ or NaOH). If hydrated lime is used, gypsum ($CaSO_4 \cdot 2 H_2O$) may be recovered.

140. Semiwet flue gas cleaning systems are named due to the fact that water should be present in the gas phase to realize a transfer of the acidic gases, especially of sulfur dioxide, into milk droplets. Typically, milk of lime ($Ca(OH)_2$) is used as an additive as a suspension. The water of the suspension improves the capture of acid gases and the reaction with the base being evaporated in the hot flue gas. The reaction continues with the dried reagent but is limited by the deposit of salts (reaction products) onto the reagent grains. The reaction product is a dry powder, containing the halogens and sulfur oxides as calcium salts ($CaCl_2$, Ca(OH)Cl, CaF_2, $CaSO_3$, $CaSO_4$). It is collected below the reactor and in the following de-duster. Most often, the de-duster is a baghouse filter. Precondition for an effective acid gas removal in this operational mode is sufficiently high moisture[18] in the gas, which may be adjusted by water injection and evaporation.

141. Dry flue gas cleaning systems are operated without any water addition. Reagents are injected in a powdery form in the flue gas (e.g. slaked lime). The point of injection is one or two cyclones located between the boiler and the filter. Generally, since the neutralization reaction requires a slaked lime excess, it is recommended to consider recirculating part of the collected filter dust, as it contains a certain percentage of unconsumed reagent so as to reduce the total amount of reagent needed and the amount of filter residues. A good distribution of the additive in the gas is prerequisite for a good functionality of the system. Fluidized bed furnaces are well-suited for the application of this concept. Most often dry flue gas cleaning systems use sodium bicarbonate ($NaHCO_3$, "baking soda"). This offers the advantage that it can be recycled afterwards. The reaction products are collected below the reactor and in the following de-duster. 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. Most recent incinerators in Europe use dry systems.

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

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

142. Typically a process for treatment involves heating to a sufficient temperature (850°C or 1,100°C, if the hazardous waste contains more than 1 per cent of halogenated organic substances expressed as chlorine), with a minimum residence time of 2 seconds under conditions that ensure appropriate mixing.[19,20] The remaining fragments of PCDD/PCDF may be recombined in the temperature range between 200 and 400°C, when the flue gas is cooled down (de-novo synthesis). Typically, this recombination reaction is expected to be supported by longer residence times in this temperature window (< 50 ms prevents recombination), the presence of fly ash and low sulfur dioxide concentrations.[21] Since this de-novo synthesis cannot be entirely prevented, the application of secondary diminishing measures is necessary.

143. The air emissions for PCDD and PCDF should be below 0.1 ng TEQ/Nm^3.[22]

144. De-novo synthesis and assisted catalytic coupling of 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, should be avoided. Input of PCDD/PCDF precursors in wastes, such as chlorinated phenols, PCBs or HCBs, should also be minimised to reduce heterogeneous reactions.

145. Widespread is tThe application of activated coke or activated carbon as an absorbent for gaseous PCDD/PCDF is typically used to reduce such emissions. 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 adsorbers, equipped with activated coke or carbon (particle size 1.25 to 5 mm) are commonly used as a emergency and polishing filter step at the end of flue gas cleaning systems to remove PCDD/PCDF that was not fully destroyed. 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 kPa. The activated carbon can be burnt in the furnace after utilization, which will destroy PCDD/PCDF in the activated carbon that was not fully destroyed in the first instance. However, this practice should only be done where another sink for mercury exists (e.g. a wet scrubbing system), to prevent mercury from accumulating in the incineration process; the used activated carbon may also be regenerated in dedicated installations.

(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 adsorbed 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 3kg additive per ton of wastes may be reached (European Commission, 2019c);

(c) Carbonaceous adsorbents can also be used in wet scrubbers as carbon-impregnated polypropylene packing. Removal efficiencies (example of electrostatic precipitator in combination with a wet scrubber) can be higher than 98% (European Commission, 2019c);. The high loading capacity allows operation times of several years. The loaded packing can be incinerated to destroy the adsorbed PCDD/PCDF that was not fully destroyed in the first instance. 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 can be suitable and effective for the destruction of gaseous PCDD/PCDF by catalytic oxidation. Depending on the number of catalyst layers and activity, removal efficiencies up to 99% can be reached (European Commission, 2019c);;

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[19] See the general technical guidelines on persistent organic pollutants (UNEP, XXXX2022a, currently under revision).

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

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

[22] TEQ as referred to in Annex C, part IV, paragraph 2, to the Stockholm Convention, but only for PCDD and PCDF. Nm^3 refers to dry gas, 101.3 kPa and 273.15 K. Standardization at 11 per cent O_2. Standardization at 10 per cent O_2 for cement kilns co-incineration.

(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

146. 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.

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

148. 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.

149. Only mercury vaporises completely during combustion. A part is subsequently condensing on particles, another part is reacting to form compounds like $HgCl_2$. 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 $HgCl_2$, 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 particulate emissions

150. For the separation of particulates from the flue gases of incinerators, 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 incinerators, 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) 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 incinerators only for pre-separation of coarse particles;

(c) Electrostatic precipitators separate particulates 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 to 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;

(d) Wet scrubbers are applied in incinerators 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.

(e) Techniques to reduce emissions of oxides of nitrogen

151. 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 followed by excess air in the secondary combustion) 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.

152. BAT for the abatement of nitrogen oxides (NO and NO_2) is the application of selective catalytic reaction (SCR) or selective non-catalytic (SNCR) reduction processes[23]. For both of them ammonia (NH_3) or urea ($(NH_2)_2CO$) 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 ($(NH_4)_2SO_4$) and ammonium hydrogensulfate (NH_4HSO_4) may be generated, which tend to form deposits in the flue gas ducts.

153. 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. BAT is the controlled injection in several levels, into areas of optimal temperature, which are determined by acoustical gas temperature measurement.

154. For the SCR process, a catalyst (standard materials include TiO_2, $V2O_5$ and WO_3) is applied to reduce the activation energy and therefore the reaction temperature necessary for the destruction of the nitrogen oxides. Continuous operation temperatures of 180°C - 240°C are common. 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, therefore the catalyst cannot be contaminated. However, using SCR in this configuration reduces energy efficiency of the plant.

2. Wastewater

155. 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.

156. 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.

157. 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 Na_2S 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.

158. The pollutants removed from the exhaust gas by wet treatment methods should not directly be discharged with the wastewater, as, for example, they have a high potential for POPs contamination, but should be processed at the facility site. Any discharge of wastewater from the facility should be subjected to permission by the responsible authority and in compliance with existing standards.

3. Solid residues (bottom ash, fly ash, and flue gas cleaning residues)

159. The solid residue contains non-volatile minerals, metals, and smaller amounts of unburnt material.

160. 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.

161. 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 used reagents and the dust from the furnace. Wet systems (scrubbers) are

[23] Exhaust gas recirculation and low air ratio combustion may be applied to reduce NOx and fly ash generation, and improve heat recovery efficiency (Miyagoshi et al., 2007; European Commission, 2019a; UNEP, 2020).

characterized by separate residues, because the dust is removed from the flue gas before some gaseous pollutants are absorbed in the scrubber liquid.

162. Due to the fact that dry residues from dry and semidry systems contain all pollutants in concentrated form, they usually have hazardous characteristics and should be disposed of accordingly.

163. Since hydrogen chloride (HCl) and the sulfur oxides (SO_2, SO_3) are absorbed in the scrubber unit(s), a selective recovery with production of hydrochloric acid and gypsum is possible.

164. It is possible to regenerate the sodium bicarbonate that is used in dry systems after use. This practice exists in Europe.

165. The treatment of ash/slag and other solid residues discharged from an incinerator should depend inter alia on the concentration of pollutants and whether the residues are hazardous waste (cf. guidance on environmental monitoring in section V.E.2). In case ash/slag and other solid residues are contaminated with POPs (e.g. because of the incinerated wastes), refer to the relevant guidance in the General technical guidelines on POPs to determine how the waste should be managed (UNEP, XXXX2022a).

(a) Incinerators for household wastes

166. Bottom ash/slag and other solid residues discharged from an incinerator for household wastes may or may not be hazardous wastes according to national legislation depending on its concentration of heavy metals and POPs is generally non-hazardous, subject to national/domestic legislation. Fly ash and flue gas cleaning residues discharged from an incinerator for household wastes are typically considered hazardous.

167. Typically, ferrous and non-ferrous metals can be recovered from the bottom ash/slag by mechanical post-treatment and recycled into the metallurgical industry. 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 several applications, such as road construction, depending on the quality (especially the elution of heavy metals and POPs) and if the leaching potential of the material is sufficiently low. However, bottom ashes which do not meet the environmental quality requirements according to national legislation, even after one or more aging phases, are not uncommon, especially in installations unable to guarantee a sufficient level of combustion or which accept waste containing pollutants. These pollutants are transferred to the bottom ashes or their combustion residues affect the environmental quality of the bottom ashes.

168. The mineral fraction from bottom ash is used for different applications, such as for: base layers in road construction (bound and unbound), subbase layers in road construction, secondary raw materials in cement production, bound and unbound construction materials, subgrade filling in industrial and storage buildings, and noise reduction and visual protection barriers (Blasenbauer et al., 2020). If bottom ash is used for building material, an analysis and characterisation should be undertaken to ensure it is appropriate to be used (see section E.2 for further details) (Wang et al., 2010).

169. Where mineral fraction from incinerator bottom ash is utilised, the utilisation rate varies between 20 and 100wt%. Approximately 54wt% of the total amount generated in the EU, Norway and Switzerland has been utilised between 2015 and 2019 (Blasenbauer et al., 2020).

(b) Incinerators for hazardous wastes

170. Ash/slag and other solid residues discharged from an incinerator for hazardous wastes incinerator may be considered hazardous wastes according to national/domestic legislation, and it. They should be disposed as such hazardous wastes unless it can be provend that they are not. Slag from incinerators for hazardous wastes generally contain steel parts, mainly from containers (drums, smaller boxes, etc., shredded or not), which are normally extracted magnetically. As they are decontaminated by the incineration process, they may be recycled.

D. Obtaining energy from waste

171. This section covers both obtaining energy from waste in case of operation D10 (where it is considered as a secondary consequence) and operation R1 (where it is considered the principal result). It should be noted that the operations D10 and R1 refer to waste treatment operations, not to waste treatment facilities. The distinction between disposal operations D10 and R1 could be based on the energy efficiency of a facility designed for a specific waste type. For the calculation of the energy efficiency, the energy output of a facility (e.g. electricity, heat), the energy input into a facility (e.g. the energy contained in the waste and in fuels) and the internal energy losses should be taken into account. The actual energy efficiency depends inter alia on the calorific value of incoming waste.

Examples of pertinent national and regional legislation on the criteria for distinction between disposal operations D10 and R1 can be found in Annex II.

172. Electricity production, supply of district heating (or cooling) networks or the direct delivery of steam are options for obtaining energy from waste in incinerators.

173. Energy obtained from the boiler can be used on site (thus replacing energy delivered) and/or off site. The energy supplied may be used for a wide variety of other processes. Commonly, heat and steam are used for industrial or district heating systems, industrial process heat and steam and occasionally as the driving force for cooling and air conditioning systems. Electricity is often supplied to distribution grids and/or used within the installation.

174. 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.

175. The maintenance of a system for obtaining energy from waste in incinerators should be conducted in compliance with the relevant national and regional legislation. Generally, an exhaust heat boiler requires confirmation of the level of corrosion and exchange of the boiler tube. A steam turbine needs periodic inspection and repair. Certificated specialists should run these operations according to the national and regional legislation.

176. For incinerators for household wastes, Iif electricity is produced, electrical efficiencies can reach up to approximately 30% (European Commission, 2019a), though this excludes the energy used for pre and post processing[24]. 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.

177. Energy obtained from waste can be enhanced, if heat (as hot water or low pressure steam) or (high pressure) steam to industrial customers are delivered.

178. The overall efficiency of a facility is dependent on the possibilities to deliver steam, heat or cooling. 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.

179. For the effective use of energy from waste, long-term contracts for the supply of electricity, heat and/or cooling should be in place and coordination with the contractor of the energy is essential. With electricity contractors, it is desirable to agree on the fluctuation of power transmission capacity, including the interruption period of power transmission during the system maintenance. With heat or cooling contractors, in addition to agreeing on the fluctuation of heat or cooling supply, further consultation should be done regarding the potential of periodical and seasonal variation of heat or cooling demands, and the alternative means to use the heat or cooling upon such cases. Therefore, it is essential to understand the calorific value of incoming wastes, including its seasonal change.

180. For example in Scandinavia, where incinerators for household wastes are usually integrated in district heating systems, even the condensation heat of the water contained in the flue gas is applied for heating purposes. Such concepts lead to the highest overall efficiencies.

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

E. Monitoring

182. In Article 10 (“International Cooperation”), paragraph 2 (b), the Basel Convention requires Parties to “cooperate in monitoring the effects of the management of hazardous wastes on human health and the environment.” In Article 11, paragraph 1, the Stockholm Convention requires Parties, within their capabilities, at the national and international levels, to encourage and/or undertake

[24] Further information on the power generation efficiency corresponding to various conditions including the treatment capacity is available at Takaoka, 2019.

appropriate monitoring pertaining to POPs.

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

184. All parameters relevant for the operation of incinerators should be continuously monitored and controlled. The monitoring of environment and human health can help to determine the impact of the incinerator on the ambience.

1. Technology monitoring

185. The monitoring of crucial performance indicators and emission parameters should be state-of-the-art and BAT. The parameters that should be monitored are listed and explained in Section I.B.

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

187. Prior to initial operation of an incinerator, temperature investigations should be done under normal and licensed worst-case conditions to ensure they can meet temperature and residence time requirements for environmentally sound incineration (see paragraph 1424 above).

2. Environmental monitoring

188. 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.

189. 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 an incinerator and should be monitored by the responsible authority:

(a) 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. Best Available Techniques Reference Document for waste incineration (European Commission, 2019a).[25] This includes the measurement of all auxiliary parameters (O_2 and H_2O concentration and temperature and pressure), necessary for the standardization of the measured values.

(b) A reliable measurement (with sufficient redundancy) 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 (see paragraph 1424 above).[26]

(c) 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.

190. 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 if appropriate facilitate the operation of the facility or prevent disturbances or accidents:

(a) The continuous measurement of mercury concentration in the raw gas in order to detect unwanted mercury emissions at an early stage and/or the measurement of mercury concentration in the flue gas after the cleaning system in order to check adherence to limit values. The injection rate of the mercury sorbent and, if necessary, oxidizing reagents in order to transform Hg° in Hg^{2+}, should be controlled instantly by the continuously measured concentration in the cleaned flue gas. The system may be refined by adding a second continuous monitoring device in the raw gas. This allows to detect earlier mercury peaks and better adapt the extra mercury sorbent to inject. 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 wastes, which may occur from time to time. If no such device is installed, these incidents cannot be detected and no countermeasures taken;

[25] As published by the European Integrated Pollution Prevention and Control Bureau on waste incineration (https://eippcb.jrc.ec.europa.eu/reference/waste-incineration).

[26] 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.

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

(c) Temperature along the entire flue gas path for an optimized control and operation of the system, particularly in relation to the recombination of PCDD/PCDF between 200°C - 400°C. Temperature measurement also helps to detect disruptions in the operation (e.g. intrusion of false air, failure in additive dosing);

(d) 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 in the facility;

(e) 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.

191. Continuous monitoring of pollutants in the flue gas (CO, TOC, HCl, SOx, NOx, NH_3, dust, Hg and HF) should be done in accordance with national legislation or national or international standards such as ISO where appropriate.[27] To allow further data processing and analysis (e.g. standardization), it is also necessary to measure the auxiliary variables exhaust gas flow rate, oxygen, 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 (e.g. BS EN 14181, JIS B7996).

192. Metals (Cd, Tl, As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V, and Hg if not continuous) and their compounds should be monitored periodically in accordance with national legislation or national or international standards such as ISO.

193. The channelled emissions to the air of PCDD/PCDF and dioxin-like PCBs from incineration of waste should be monitored with at least the frequency of once every six months for short-term sampling and of once every month for long-term sampling if the emission levels are not proven to be sufficiently stable (European Commission, 2019b; European Commission, 2019c).

194. Solid residues should be monitored and periodically analyzed in a representative and reproducible way, including in relation to heavy metals and, where appropriate, the POP content ~~where appropriate~~ in order to determine whether relevant guidance in the General technical guidelines on POPs (UNEP, ~~XXXX~~2022a) applies. In order to judge the environmental impact, not only 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 building material in construction) or disposal of the materials.

195. 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. For OTNOC, e.g. start up or shut down, the frequency of the occurrence of OTNOC and the emissions during OTNOC should be reduced, including through implementing a risk-based OTNOC management plan because the emissions of pollutants such as POPs during OTNOC may be considerably higher than under normal operating conditions due to unstable combustion conditions (Tejima et al., 2007, UNEP, 2007). Such a plan should inter alia include monitoring and recording of emissions during OTNOC, when such monitoring and recording is possible, notably when waste is being treated (European Commission, 2019b).

196. The environmental impact from the facility may require the implementation of an ambient air-

[27] Further information on monitoring is available in the Reference Report on Monitoring of Emissions to Air and Water from IED Installations, Joint Research Centre, 2018. (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-12/ROM_2018_08_20.pdf) and Waste to Energy: A Technical Review of Municipal Solid Waste Thermal Treatment Practices, B.C Ministry of the Environment, 2011 (https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/bcmoewteemmissionsrevmar2011.pdf).

monitoring programme (e.g. depending on robust air quality modelling scenarios). 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.

197. Soil monitoring of specific pollutants (e.g. PCDD/PCDF and heavy metals) may also be required upstream and downstream of the prevailing wind direction and at the point of maximum impact and/or key receptors. Before starting the operation of an incinerator, the background concentration of such specific pollutants should be determined.

3. Medical monitoring

198. 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 monitors may facilitate the detection of diffuse emissions of pollutants (see section I.B).

F. Record keeping and reporting

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

200. 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; and

(l) Miscellaneous.

201. 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.

202. Reports should be made on a frequent basis to the competent authorities on the activities at the incinerator. 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[28].

[28] The public disclosure of the real-time monitoring data is also effective to enhance transparency and public acceptance. See reference for an example (Clean Authority of TOKYO, 2018).

G. Health and Safety

1. General rules

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

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

205. A health and safety program should be designed to identify, evaluate, and control safety and health hazards. A globally recognised formal method for health and safety risk assessment should be used as a basis for effective risk management.[29]

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

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

2. Technical and organizational measures

208. 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.

209. 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, and due to possible self-ignition during storage.

210. In incinerators for household wastes, the waste bunker should be operated under minimal sub-atmospheric pressure to ensure this requirement, depending on location. 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 incinerators for hazardous wastes.

211. 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 where appropriate, in particular when engineering or administrative controls are not feasible or do not totally eliminate the risk.

212. 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.

213. 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.

214. When silos or waste bunkers are utilised (most often in fluidised bed furnaces), fire prevention or monitoring systems should be installed.

VII. Guidance on emergency response and spill handling

215. An environmental insurance should be in place in order to finance the consequences of environmentally relevant accidents linked to incinerators. In preparing such insurances, it should be taken into account that such accidents may have huge impacts and cause significant costs, with the

[29] For examples of globally recognised formal methods for health and safety, refer to relevant International Labour Organisation occupational health and safety instruments at https://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm.

risk of existential impact even on medium sized companies.

A. Emergency preparedness and response

216. Emergency preparedness and response plans and procedures should be established for the protection of the workforce and public before operations begin based on a formally recognised environmental risk assessment method or combination of methods, and be made available to all staff. An emergency preparedness and response plan, ensuring appropriate measures to handle possible on-site emergencies and coordinate off-site response, should be in place. This emergency and preparedness response plan should, at a minimum, 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, water curtain system for gas releases, 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;

(o) Emergency site drainage control system, including flooding events.

B. Spill handling

217. A spill handling plan for incinerators for hazardous wastes 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.

218. 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, appropriate for the site;

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

VIII. Guidance on public participation

219. Public participation should be organised in all the phases of the incinerator 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.

220. Public participation should be organised as soon as the preparatory design phase and before an ~~of the~~ incinerator is approved by the authorities. 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.

221. 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 incinerator, according to environmental, social and economic criteria.

222. 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 national legislation and regulatory frameworks related to incineration

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

Country	Legislation and link	Brief description
Argentina	National Law 24051 https://www.boletinoficial.gob.ar/detalleAviso/primera/7126669/19920117?busqueda=1 Decree 831/93 https://www.boletinoficial.gob.ar/detalleAviso/primera/7134717/19930503?busqueda=1	Addresses hazardous waste management and contains definitions and minimal requirements for incineration.
Canada	Nova Scotia Solid Waste-Resource Management Regulation https://www.novascotia.ca/Just/Regulations/regs/envsolid.htm	Requires all incinerators in the province of Nova Scotia to adhere to the Canadian Council of Ministers for the Environment's "Operating and Emission Guidelines for Municipal Solid Waste Incinerators"
	Ontario Environmental Protection Act, regulation 347 https://www.ontario.ca/laws/regulation/900347	Defines terms related to incineration (such as fly ash) and sets emission limits for incinerators operated in the province of Ontario.
	Ontario Guideline A-7: Air Pollution Control, Design and Operation Guidelines for Municipal Waste Thermal https://www.ontario.ca/page/guideline-7-air-pollution-control-design-and-operation-guidelines-municipal-waste-thermal	Provides guidelines and minimum expected requirements for incinerators for household wastes under the Environmental Protection Act, including requirements for monitoring, performance testing, emission limits, and air pollution control systems.
Chile	Norma de emission para la incineración, co-incineración y coprocesamiento, DTO 29-2013 (Emission standard for incineration, co-incineration and co-processing) https://www.bcn.cl/leychile/navegar?idNorma=1054148 (in Spanish only)	Establishes the emission standards and operation requirements of incinerators.
China	National Standard 18484: Pollution control standard for hazardous waste incineration https://english.mee.gov.cn/Resources/standards/Solid_Waste/SW_control/200710/t20071024_111901.shtml	The standard covers the pollution control in the whole process of hazardous wastes incineration and requires to considering the comprehensive use of heat energy for incineration disposal facilities that have conditions to recover the heat energy.~~To be added~~
	National Standard 18485: Standard for pollution control on the municipal solid waste incineration https://english.mee.gov.cn/Resources/standards/Solid_Waste/SW_control/201603/t20160303_331143.shtml	The current standard specifies the contents such as site selection and technical requirement for garbage incinerating plants, waste feed requirement, operation requirement, emission control requirement, monitoring requirement, implementation and supervision.~~To be added~~
European Union	Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control)	This Directive lays down rules on integrated prevention and control of pollution arising from industrial activities. It also lays down rules designed to prevent or, where that is not practicable, to reduce emissions into air, water and land and to

	https://eur-lex.europa.eu/eli/dir/2010/75/2011-01-06 Commission Implementing Decision (EU) 2019/2010 of 12 November 2019 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for waste incineration http://data.europa.eu/eli/dec_impl/2019/2010/oj	prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole. Annex VI of this Directive contains specific technical provisions relating to incinerators. Best available techniques (BAT) conclusions are the reference for setting permit conditions for installations covered by Chapter II of Directive 2010/75/EU. According to Article 15 of this Directive, competent authorities should set emission limit values which ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the BAT conclusions.
Japan	The Waste Management and Public Cleansing Act (Translated as of 2001) http://www.env.go.jp/en/laws/recycle/01.pdf Regulations of the Waste Management and Public Cleansing Law http://www.env.go.jp/en/laws/recycle/03.pdf Act on Special Measures against Dioxins (Translated as of 2011) http://www.japaneselawtranslation.go.jp/law/detail/?id=2566&vm=04&re=02 Air Pollution Control Act (Translated as of 2010) http://www.japaneselawtranslation.go.jp/law/detail/?id=2146&re=02	The Waste Management and Public Cleansing Act stipulates the environmentally sound management of waste and the definition of relevant terms in Japan. Under this Act, waste is categorized into municipal solid waste discharged mainly from households and industrial waste. They are managed as specially-controlled wastes (similar to hazardous wastes) depending on their types, the hazardousness, and/or the concentration of certain chemical substances contained in the waste. The Act and Regulations also lay down the structural, operational, and maintenance standards for waste incineration facilities, e.g. requirements for mixing waste in a pit for complete combustion, waste feeder (to isolate waste from outside air), combustion chamber (temperature, detention period, ignition loss and its measurement standards), measurement/monitoring/recording system, cooling facilities, exhaust gas treatment system. In addition, emission standards are stipulated by the Act on Special Measures against Dioxins, the Air Pollution Control Act, and others.
United States	Clean Air Act https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=caf26f4022eea7ae1550271911e5e11e&mc=true&tpl=/ecfrbrowse/Title40/40CIsubchapC.tpl	This act authorizes EPA to set mobile source limits, ambient air quality standards, hazardous air pollutant emission standards, standards for new pollution sources, and significant deterioration requirements; to identify areas that do not attain federal ambient air quality standards set under the act; to administer a cap-and-trade program to reduce acid rain; and to phase out substances that deplete the Earth's stratospheric ozone layer.
	Solid Waste Disposal Act and Resource Conservation and Recovery Act https://www.ecfr.gov/cgi-bin/text-idx?SID=38c3c0155a36e4965d20f1f66668d02c&mc=true&tpl=/ecfrbrowse/Title40/40CIsubchapI.tpl	This act governs the regulation of solid and hazardous wastes, and corrective actions to address improper waste management practices.

Annex II to the technical guidelines

Examples of national legislation on the criteria for distinction between disposal operations D10 and R1

Examples of national ~~and regional~~ legislation on the criteria for distinction between disposal operations D10 and R1 are outlined below.

Country	Legislation and link	Brief description
Canada	Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations https://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-149/page-1.html	Schedule 2 of the Regulations contains operation R1, which in addition to requiring recovery of energy from a material, establishes a minimum heating value for materials to be considered as fuel for operation R1.
European Union	Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives http://data.europa.eu/eli/dir/2008/98/2018-07-05	This Directive contains a definition for recovery in Art. 3(15), which is further specified for incinerators dedicated to the processing of municipal solid waste in a footnote to operation R1 in Annex II to this Directive. In addition, guidelines on the interpretation of this footnote has been developed by the European Commission (see https://ec.europa.eu/environment/waste/framework/pdf/guidance.pdf).

Annex III to the technical guidelines

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