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Section I

Introduction

Contents

I.A Purpose

Under the Stockholm Convention on Persistent Organic Pollutants, Parties shall promote in some cases and require in others the use of best available techniques, and promote the application of best environmental practices. In short, each Party shall:

- Develop, within two years of the date of entry into force of the Convention for it, an action plan (national or regional) where releases of chemicals listed in Annex C of the Convention are identified, characterized and addressed; the plan shall include source inventories and take into consideration the source categories listed in Parts II and III of Annex C (subparagraph (a) of Article 5);
- For **new sources**:
    - Promote and, in accordance with the implementation schedule of its action plan, require the use of best available techniques within source categories identified as warranting such action, with particular initial focus on source categories identified in Part II of Annex C; the requirement to use best available techniques for Part II source categories shall be phased in as soon as practicable, but no later than four years after entry into force of the Convention for the Party (subparagraph (d) of Article 5);
    - Promote, for those categories identified above, the use of best environmental practices (subparagraph (d) of Article 5);
    - Promote, in accordance with its action plan, best available techniques and best environmental practices within source categories such as those listed in Part III of Annex C which a Party has not addressed above (subparagraph (e) (ii) of Article 5);
- For **existing sources**:
    - Promote, in accordance with its action plan, the use of best available techniques and best environmental practices for source categories listed in Part II of Annex C and such sources as those in Part III of the Annex (subparagraph (e) (i) of Article 5).

When applying best available techniques and best environmental practices for the above, Parties should take into consideration the general guidance on prevention and release reduction measures in Annex C and guidelines on best available techniques and best environmental practices to be adopted by decision of the Conference of the Parties (see subparagraphs (d) and (e) of Article 5).

The Conference of the Parties to the Stockholm Convention, at its first meeting held in Punta del Este, Uruguay, 2–6 May 2005, in its decision SC-1/19, established an Expert Group on Best Available Techniques and Best Environmental Practices with a mandate to complete further work on the enhancement and strengthening where need be of the “draft guidelines on best available techniques and guidance on best environmental practices relevant to Article 5 and Annex C of the Convention”[1] as contained in document UNEP/POPS/COP.1/INF/7.

The Conference of the Parties to the Stockholm Convention, at its third meeting held in Dakar, Senegal, 30 April to 4 May 2007, in its decision SC-3/5 adopted the present revised draft guidelines on best available techniques and provisional guidance on best environmental practices, and invited Parties and others to provide to the Secretariat comments on their experience in implementing the above-mentioned revised guidelines. In accordance with Article 5 of the Convention, the guidelines and guidance, upon adoption by decision of the Conference of the Parties, should be taken into consideration when applying best available techniques and best environmental practices pursuant to

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[1] The draft guidelines on best available techniques and guidance on best environmental practices relevant to Article 5 and Annex C of the Convention were developed by the Expert Group on Best Available Techniques and Best Environmental Practices established for this purpose by the sixth session of the Intergovernmental Negotiating Committee for an International Legally Binding Instrument for Implementing International Action on Certain Persistent Organic Pollutants (see UNEP/POPS/INC.6/22, paragraph 75).

subparagraphs (d) and (e) of Article 5. They may also be used to assist decision-making at the country level in the implementation of action plans and other actions related to the obligations under Article 5 and Annex C.

I.B Structure of document and using guidelines and guidance

Section I of this document is an introduction and includes the purpose and structure of the document; a brief description of the characteristics and risks of chemicals listed in Annex C of the Stockholm Convention; directly relevant provisions of the Stockholm Convention, Article 5 and Annex C; a summary of required measures under these provisions; and an explanation of the relationship of these provisions to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

Section II provides guidance on consideration of alternatives, including a checklist that may be used in applying best available techniques to new sources, and information on other considerations of the Stockholm Convention.

Section III includes general guidance, applicable principles and descriptions of considerations that cut across multiple source categories.

Section IV is a compilation of the summaries provided for each category source in sections V and VI.

Sections V and VI contain specific guidelines for each source category listed in Part II and Part III of Annex C of the Stockholm Convention. For each of the source-specific guidelines, the following information is provided:

- Process description;
- Sources of chemicals listed in Annex C;
- Primary and secondary measures;
- Performance levels;
- Performance reporting;
- Case studies.

References and bibliographic information are provided for each of the guidelines.

I.C Chemicals listed in Annex C: Definition, risks, toxicity

1. What are the chemicals listed in Annex C?

1.1 Definition

The chemicals listed in Annex C of the Stockholm Convention include polychlorinated dibenzo-*p*-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB).

1.2 Characteristics

The chemicals listed in Annex C, in addition to their documented toxicity, are persistent and bioaccumulative and undergo long-range transport. Persistent chemicals do not easily degrade in the environment. Bioaccumulative chemicals are usually fat soluble and build up in higher trophic levels, including in humans. The chemicals listed in Annex C, as semi-volatile compounds, undergo a series of evaporations and condensations in the environment, making them mobile.

1.3 Uses

PCDD and PCDF have never been used as commercial products nor were they intentionally manufactured for any reason other than laboratory purposes.

PCB have been used as coolants and lubricants in transformers, capacitors and other electrical equipment because they do not burn easily and are good insulators. Among other things, products that may contain PCB include old fluorescent lighting fixtures and electrical devices containing PCB capacitors.

HCB has been widely used as a pesticide to protect the seeds of onions and sorghum, wheat and other grains against fungus. It has also been used to make fireworks, ammunition and synthetic rubber. It is also used as a solvent in the production of pesticide.

The following guidelines and guidance, however, do not apply to the commercial production of PCB and HCB, but rather to those processes that inadvertently lead to their formation and release.

2. What are the risks to humans of chemicals listed in Annex C?

2.1 Exposure

Because these chemicals exist throughout the environment, almost all living creatures, including humans, have been exposed to the chemicals listed in Annex C. Exposure arises mainly through fatty foods, including breast milk, but can also arise from accidental or occupational situations. The health effects that have been associated with these exposures depend on a variety of factors, including the level of exposure and the duration and frequency of exposure.

2.2 PCDD and PCDF

Much of the information on the toxicity of these chemicals is based on extensive studies of the most toxic member of the family, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in experimental animals. TCDD and related compounds can produce a wide variety of effects in animals and might produce many of the same effects in humans.

The International Agency for Research on Cancer (IARC) under the World Health Organization (WHO) identified 2,3,7,8-TCDD as the most toxic of all dioxin compounds, and as carcinogenic to humans, based mainly on studies of cases involving accidental or occupational heavy exposure. Animal studies have also shown an increased risk of cancer from long-term exposure to PCDD/PCDF.

TCDD exposure results in a wide variety of reproductive and developmental effects in a number of species of experimental animals, including reduced viability, structural alterations, growth retardation and functional alterations. There is also evidence of neurobehavioural effects and effects on immune and various endocrine functions, including those of the thyroid. Because of this evidence in animals, particularly at high doses but in some cases at doses close to those with relevance for human beings, scientists are concerned about the potential for these same effects to occur in humans, especially the effects of prenatal exposure on developing children.

2.3 PCB

The most commonly observed health effects in people exposed to large amounts of PCB are skin conditions. Studies in exposed workers have shown changes in blood and urine that may indicate liver damage. In the Yusho and Yucheng incidents, each involving about 2,000 cases, Japanese and Taiwanese people were exposed to high concentrations of PCB and PCDF through consumption of contaminated rice oil. Fatal liver disease (among other indicators) was found to be 2–3 times more frequent than national rates in both cohorts (IARC)**.** PCB exposures in the general population are not likely to result in skin and liver effects. Most of the studies of health effects of PCB in the general population examined children of mothers who were exposed to PCB.

IARC has determined that PCB are probably carcinogenic to humans. A few studies of workers indicated that PCB were associated with certain kinds of cancer in humans, such as cancer of the liver and biliary tract. Rats that ate food containing high levels of PCB for two years developed liver cancer.

PCB may be associated with developmental or endocrine effects. Women who were exposed to relatively high levels of PCB in the workplace or ate large amounts of fish contaminated with PCB had babies that weighed slightly less than babies of women who did not have these exposures. Babies born to women who ate PCB-contaminated fish also showed abnormal responses in tests of infant behaviour. Some of these behaviours, such as problems with motor skills and a decrease in short-term memory, lasted for several years.

2.4 HCB

The United States Department of Health and Human Services has determined that HCB may reasonably be expected to be a carcinogen. Studies in animals show that long-term ingestion of large amounts of HCB can damage the liver, thyroid, nervous system, bones, kidneys, blood, and immune and endocrine systems.

3. How is the toxicity of chemicals listed in Annex C measured?

3.1 Toxic equivalency

For PCDD/PCDF the most toxic compounds have chlorines in the 2, 3, 7 and 8 positions. For PCB, the highest toxicity is with compounds where the molecule can assume a planar conformation, analogous to that of the PCDD/PCDF. Toxicity of mixtures of these materials is evaluated as a single number called the toxic equivalent (TEQ).

To determine the TEQ of a mixture, the amount of each of the toxic members of the family is multiplied by a weighting factor relative to the most toxic chemical, 2,3,7,8-TCDD. This weighting factor is called a toxic equivalency factor (TEF). The first scheme, derived by the Committee on the Challenges of Modern Society of the North Atlantic Treaty Organization in 1988 and called I-TEFs, covered 17 PCDD/PCDF. Twenty-nine of the 419 individual PCDD, PCDF and PCB have TEFs assigned by WHO in 1997 and revised in 2005 (Table 1). HCB does not have a TEF.

3.2 Tolerable intakes

The tolerable daily intake (TDI) is the amount of intake per kg of body weight per day of a chemical substance judged not to give rise to manifestations of health effects if such an amount is taken every day for an entire lifetime. The TDI established by WHO in 1998 for chemicals contributing to TEQ was set at 1–4 pg/kg body weight/day.[2] In 2001, the Joint FAO/WHO Expert Committee on Food Additives set a provisional tolerable monthly intake (PTMI) of 70 pg/kg body weight/month, which approximates to 2.3 pg/kg body weight/day.

Table 1. Toxic equivalency factors

Congener	WHO/1997 Mammalian TEFs	I-TEFs	WHO/2005 Mammalian TEFs
PCDD			
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PeCDD	1	0.5	1
1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.01
1,2,3,4,6,7,8,9-OCDD	0.0001	0.001	0.0003
PCDF			
2,3,7,8-TCDF	0.1	0.1	0.1
1,2,3,7,8-PeCDF	0.05	0.05	0.03
2,3,4,7,8-PeCDF	0.5	0.5	0.3
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
1,2,3,4,6,7,8,9-OCDF	0.0001	0.001	0.0003

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[2] 1 pg (picogram) = 1 × 10^{-15} kilogram (1 × 10^{-12} gram).

Congener		WHO/1997 Mammalian TEFs	I-TEFs	WHO/2005 Mammalian TEFs
PCB				
IUPAC No.	**Structure**			
non-*ortho* substituted				
77	3,3',4,4'-TCB	0.0001	n.a.	0.0001
81	3,4,4',5-TCB	0.0001		0.0003
126	3,3',4,4',5-PeCB	0.1		0.1
169	3,3',4,4',5,5'-HxCB	0.01		0.03
mono-ortho substituted				
105	2,3,3',4,4'-PeCB	0.0001		0.00003
114	2,3,4,4',5-PeCB	0.0005		0.00003
118	2,3',4,4',5-PeCB	0.0001		0.00003
123	2',3,4,4',5-PeCB	0.0001		0.00003
156	2,3,3',4,4',5-HxCB	0.0005		0.00003
157	2,3,3',4,4',5'-HxCB	0.0005		0.00003
167	2,3',4,4',5,5'-HxCB	0.00001		0.00003
189	2,3,3',4,4',5,5'-HpCB	0.0001		0.00003

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I.D Article 5 and Annex C of the Stockholm Convention

Box 1. Article 5 of the Stockholm Convention

ARTICLE 5

Measures to reduce or eliminate releases from unintentional production

Each Party shall at a minimum take the following measures to reduce the total releases derived from anthropogenic sources of each of the chemicals listed in Annex C, with the goal of their continuing minimization and, where feasible, ultimate elimination:

a) Develop an action plan or, where appropriate, a regional or subregional action plan within two years of the date of entry into force of this Convention for it, and subsequently implement it as part of its implementation plan specified in Article 7, designed to identify, characterize and address the release of the chemicals listed in Annex C and to facilitate implementation of subparagraphs (b) to (e). The action plan shall include the following elements:

   (i) An evaluation of current and projected releases, including the development and maintenance of source inventories and release estimates, taking into consideration the source categories identified in Annex C;

   (ii) An evaluation of the efficacy of the laws and policies of the Party relating to the management of such releases;

   (iii) Strategies to meet the obligations of this paragraph, taking into account the evaluations in (i) and (ii);

   (iv) Steps to promote education and training with regard to, and awareness of, those strategies;

   (v) A review every five years of those strategies and of their success in meeting the obligations of this paragraph; such reviews shall be included in reports submitted pursuant to Article 15;

   (vi) A schedule for implementation of the action plan, including for the strategies and measures identified therein;

b) Promote the application of available, feasible and practical measures that can expeditiously achieve a realistic and meaningful level of release reduction or source elimination;

c) Promote the development and, where it deems appropriate, require the use of substitute or modified materials, products and processes to prevent the formation and release of the chemicals listed in Annex C, taking into consideration the general guidance on prevention and release reduction measures in Annex C and guidelines to be adopted by decision of the Conference of the Parties;

d) Promote and, in accordance with the implementation schedule of its action plan, require the use of best available techniques for new sources within source categories which a Party has identified as warranting such action in its action plan, with a particular initial focus on source categories identified in Part II of Annex C. In any case, the requirement to use best available techniques for new sources in the categories listed in Part II of that Annex shall be phased in as soon as practicable but no later than four years after the entry into force of the Convention for that Party. For the identified categories, Parties shall promote the use of best environmental practices. When applying best available techniques and best environmental practices, Parties should take into consideration the general guidance on prevention and release reduction measures in that Annex and guidelines on best available techniques and best environmental practices to be adopted by decision of the Conference of the Parties;

e) Promote, in accordance with its action plan, the use of best available techniques and best environmental practices:

   (i) For existing sources, within the source categories listed in Part II of Annex C and within source categories such as those in Part III of that Annex; and

   (ii) For new sources, within source categories such as those listed in Part III of Annex C which a Party has not addressed under subparagraph (d).

When applying best available techniques and best environmental practices, Parties should take into consideration the general guidance on prevention and release reduction measures in Annex C and guidelines on best available techniques and best environmental practices to be adopted by decision of the Conference of the Parties;

f) For the purposes of this paragraph and Annex C:

   (i) "Best available techniques" means 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 in principle the basis for release limitations designed to prevent and, where that is not practicable, generally to reduce releases of chemicals listed in Part I of Annex C and their impact on the environment as a whole. In this regard:

   (ii) “Techniques” includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

   (iii) “Available” techniques means those techniques that are accessible to the operator and that are developed on a scale that allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages; and

   (iv) “Best” means most effective in achieving a high general level of protection of the environment as a whole;

   (v) "Best environmental practices" means the application of the most appropriate combination of environmental control measures and strategies;

   (vi) “New source” means any source of which the construction or substantial modification is commenced at least one year after the date of:

      a. Entry into force of this Convention for the Party concerned; or

      b. Entry into force for the Party concerned of an amendment to Annex C where the source becomes subject to the provisions of this Convention only by virtue of that amendment.

g) Release limit values or performance standards may be used by a party to fulfil its commitments for best available techniques under this paragraph.

Box 2. Annex C of the Stockholm Convention

Annex C

UNINTENTIONAL PRODUCTION

Part I: Persistent organic pollutants subject to the requirements of Article 5

This Annex applies to the following persistent organic pollutants when formed and released unintentionally from anthropogenic sources:

Chemical
Polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/PCDF) Hexachlorobenzene (HCB) (CAS No: 118-74-1) Polychlorinated biphenyls (PCB)

Part II: Source categories

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, hexachlorobenzene and polychlorinated biphenyls are unintentionally formed and released from thermal processes involving organic matter and chlorine as a result of incomplete combustion or chemical reactions. The following industrial source categories have the potential for comparatively high formation and release of these chemicals to the environment:

a) Waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge;

b) Cement kilns firing hazardous waste;

c) Production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching;

d) The following thermal processes in the metallurgical industry:

   (i) Secondary copper production;

   (ii) Sinter plants in the iron and steel industry;

   (iii) Secondary aluminium production;

   (iv) Secondary zinc production.

Part III: Source categories

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, hexachlorobenzene and polychlorinated biphenyls may also be unintentionally formed and released from the following source categories, including:

a) Open burning of waste, including burning of landfill sites;

b) Thermal processes in the metallurgical industry not mentioned in Part II;

c) Residential combustion sources;

d) Fossil fuel-fired utility and industrial boilers;

e) Firing installations for wood and other biomass fuels;

f) Specific chemical production processes releasing unintentionally formed persistent organic pollutants, especially production of chlorophenols and chloranil;

g) Crematoria;

h) Motor vehicles, particularly those burning leaded gasoline;

i) Destruction of animal carcasses;

j) Textile and leather dyeing (with chloranil) and finishing (with alkaline extraction);

k) Shredder plants for the treatment of end of life vehicles;

l) Smouldering of copper cables;

m) Waste oil refineries.

Part IV: Definitions

1. For the purposes of this Annex:

a) "Polychlorinated biphenyls" means aromatic compounds formed in such a manner that the hydrogen atoms on the biphenyl molecule (two benzene rings bonded together by a single carbon-carbon bond) may be replaced by up to ten chlorine atoms; and

b) “Polychlorinated dibenzo-*p*-dioxins” and “polychlorinated dibenzofurans” are tricyclic, aromatic compounds formed by two benzene rings connected by two oxygen atoms in polychlorinated dibenzo-*p*-dioxins and by one oxygen atom and one carbon-carbon bond in polychlorinated dibenzofurans and the hydrogen atoms of which may be replaced by up to eight chlorine atoms.

2. In this Annex, the toxicity of polychlorinated dibenzo-*p*-dioxins and dibenzofurans is expressed using the concept of toxic equivalency which measures the relative dioxin-like toxic activity of different congeners of polychlorinated dibenzo-*p*-dioxins and dibenzofurans and coplanar polychlorinated biphenyls in comparison to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. The toxic equivalent factor values to be used for the purposes of this Convention shall be consistent with accepted international standards, commencing with the World Health Organization 1998 mammalian toxic equivalent factor values for polychlorinated dibenzo-*p*-dioxins and dibenzofurans and coplanar polychlorinated biphenyls. Concentrations are expressed in toxic equivalents.

Part V: General guidance on best available techniques and best environmental practices

This Part provides general guidance to Parties on preventing or reducing releases of the chemicals listed in Part I.

A. General prevention measures relating to both best available techniques and best environmental practices

Priority should be given to the consideration of approaches to prevent the formation and release of the chemicals listed in Part I. Useful measures could include:

a) The use of low-waste technology;

b) The use of less hazardous substances;

c) The promotion of the recovery and recycling of waste and of substances generated and used in a process;

d) Replacement of feed materials which are persistent organic pollutants or where there is a direct link between the materials and releases of persistent organic pollutants from the source;

e) Good housekeeping and preventive maintenance programmes;

f) Improvements in waste management with the aim of the cessation of open and other uncontrolled burning of wastes, including the burning of landfill sites. When considering proposals to construct new waste disposal facilities, consideration should be given to alternatives such as activities to minimize the generation of municipal and medical waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste. Under this approach, public health concerns should be carefully considered;

g) Minimization of these chemicals as contaminants in products;

h) Avoiding elemental chlorine or chemicals generating elemental chlorine for bleaching.

B. Best available techniques

The concept of best available techniques is not aimed at the prescription of any specific technique or technology, but at taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. Appropriate control techniques to reduce releases of the chemicals listed in Part I are in general the same. In determining best available techniques, special consideration should be given, generally or in specific cases, to the following factors, bearing in mind the likely costs and benefits of a measure and consideration of precaution and prevention:

a) General considerations:

   (i) The nature, effects and mass of the releases concerned: techniques may vary depending on source size;

   (ii) The commissioning dates for new or existing installations;

   (iii) The time needed to introduce the best available technique;

   (iv) The consumption and nature of raw materials used in the process and its energy efficiency;

   (v) The need to prevent or reduce to a minimum the overall impact of the releases to the environment and the risks to it;

   (vi) The need to prevent accidents and to minimize their consequences for the environment;

   (vii) The need to ensure occupational health and safety at workplaces;

   (viii) Comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;

   (ix) Technological advances and changes in scientific knowledge and understanding.

b) General release reduction measures: When considering proposals to construct new facilities or significantly modify existing facilities using processes that release chemicals listed in this Annex, priority consideration should be given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of such chemicals. In cases where such facilities will be constructed or significantly modified, in addition to the prevention measures outlined in section A of Part V the following reduction measures could also be considered in determining best available techniques:

   (i) Use of improved methods for flue-gas cleaning such as thermal or catalytic oxidation, dust precipitation, or adsorption;

   (ii) Treatment of residuals, wastewater, wastes and sewage sludge by, for example, thermal treatment or rendering them inert or chemical processes that detoxify them;

   (iii) Process changes that lead to the reduction or elimination of releases, such as moving to closed systems;

   (iv) Modification of process designs to improve combustion and prevent formation of the chemicals listed in this Annex, through the control of parameters such as incineration temperature or residence time.

C. Best environmental practices

The Conference of the Parties may develop guidance with regard to best environmental practices.

I.E Relationship to the Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was adopted in 1989 and entered into force in 1992. The Basel Convention is the one other global agreement, besides the Stockholm Convention, directly relevant to the application of best available techniques and best environmental practices to the control of chemicals listed in Annex C of the Stockholm Convention. The Convention places obligations on countries that are Parties to, inter alia: minimize generation of hazardous waste; ensure that adequate disposal facilities are available; and ensure environmentally sound management of wastes.

Paragraph 2 of Article 6 of the Stockholm Convention, which addresses measures to reduce or eliminate releases from stockpiles and wastes, contains the following provisions:

> "The Conference of the Parties shall cooperate closely with the appropriate bodies of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal to, inter alia:
>
> (a) Establish levels of destruction and irreversible transformation necessary to ensure that the characteristics of persistent organic pollutants are not exhibited;
>
> (b) Determine what they consider to be the methods that constitute environmentally sound disposal referred to above; and
>
> (c) Work to establish, as appropriate, the concentration levels of the chemicals listed in Annexes A, B and C in order to define the low persistent organic pollutant content referred to in paragraph 1 (d) (ii)."[3]

The Conference of the Parties to the Basel Convention, at its eighth meeting in December 2006 adopted updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants and updated guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls, polychlorinated terphenyls or polybrominated biphenyls. The general technical guidelines developed under the Basel Convention address matters related to all three of the outstanding definitional issues raised in paragraph 2 of Article 6 of the Stockholm Convention.

In addition the eighth meeting of the Conference of the Parties to the Basel Convention also adopted the following three new specific technical guidelines: Technical guidelines for the environmentally sound management of wastes consisting of, containing off contaminated with the pesticides aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex or toxaphene or with hexachlorobenezene as an industrial chemical; Technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with 1,1,1-trichloro-2,2-bis (chlorophenyl)ethane (DDT); and Technical guidelines for the environmentally sound management of wastes containing or contaminated with unintentionally produced polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), hexachlorobenzene or polychorinated biphenyls.

I.F Relationship to other environmental concerns

There has been global recognition of the adverse impacts of mercury and its compounds. This has resulted in decisions on the need for further international action and measures which will reduce or

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[3] Article 6, paragraph 1 (d) (ii) of the Stockholm Convention states that each party shall: "(d) Take appropriate measures so that such wastes, including products and articles upon becoming wastes, are … (ii) Disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the persistent organic pollutant content is low, taking into account international rules, standards, and guidelines, including those that may be developed pursuant to paragraph 2, and relevant global and regional regimes governing the management of hazardous wastes."

eliminate releases of mercury and its compounds into the environment. A number of the sources of release of the persistent organic pollutants listed in Annex C to the Stockholm Convention may also release high levels of mercury into the environment. Releases of other environmental pollutants or greenhouse gases are also possible. In recognition of these effects, when applying the best available techniques and best environmental practices set out in the present guidelines in relation to the release of persistent organic pollutants, Parties should consider also applying appropriate measures to ensure that releases of mercury and other pollutants are minimized at the same time.

Under the definitions in the Stockholm Convention, specifically in relation to Article 5 and Annex C, the term “best environmental practices” means the application of the most appropriate combination of environmental control measures and strategies, while the term “best” is defined as being the most effective in achieving a high general level of protection of the environment as a whole.

Efforts should be made to avoid increasing the release of other pollutants while decreasing the release of persistent organic pollutants.

Section II

Consideration of Alternatives in the Application of Best Available Techniques

Contents

II.A Consideration of alternatives in the Stockholm Convention

The Stockholm Convention provides general guidance on best available techniques and best environmental practices in which Parties are encouraged to give priority to the consideration of approaches that prevent the formation and release of the chemicals listed in Part I of Annex C of the Convention.[1] The Convention addresses the "consideration of alternatives" with specific reference to best available techniques as follows:

> "When considering proposals to construct new facilities or significantly modify existing facilities using processes that release chemicals listed in this Annex, priority consideration should be given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of such chemicals."[2]

II.B The Stockholm Convention and new sources

Parties are obliged to require the use of best available techniques for new sources within source categories that a Party has identified as warranting such action in its action plan. Initial focus should be given to the source categories identified in Part II of Annex C of the Convention.[3]

When a Party implements this obligation, it should assure that priority consideration is given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of chemicals listed in Part I of Annex C.

In this regard, the Stockholm Convention is ambitious. It encourages a search for processes, techniques and practices that avoid generation and release of persistent organic pollutants and it encourages Parties to give them priority consideration. This encouragement should not be interpreted to mean that facilities that have the potential to form and release to the environment chemicals listed in Part I of Annex C should always be avoided. Complete elimination may not be practical or feasible. Sources that are listed in Parts II and III of Annex C have useful purposes despite the potential to form and release persistent organic pollutants.

A key factor in deciding when it is best to avoid a Part II source, a Part III source or some other prioritized source is a consideration of both the originally proposed new facility as well as the possible alternatives, taking into account the feasibility of the various options under consideration.

II.C An approach to consideration of alternatives

When a Party requires the application of best available techniques for a proposed new source of chemicals listed in Annex C, decision makers are encouraged to assure that consideration is also given to alternatives that avoid the formation and release of such chemicals. In doing this, they should undertake a comparison of the proposed process, the available alternatives and the applicable legislation using what might be termed a "checklist approach", keeping in mind the overall sustainable development context and taking fully into account environmental, health, safety and socio-economic factors.

The following are elements of such an approach:

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[1] See Stockholm Convention, Annex C, Part V, section A, chapeau.

[2] See Stockholm Convention, Annex C, Part V, section B, subparagraph (b).

[3] See Stockholm Convention, Article 5 (d).

1. Review the proposed new facility in the context of sustainable development

Decision makers should carry out a review of both the originally proposed new facility and of possible alternatives in the context of the country's plans for sustainable development. The purpose of such a review is to enable decision makers to understand better the proposed facility and its intended usefulness in relation to social, economic and environmental considerations, and its potential contribution to sustainable development. They should also review the availability of and the practicality of implementing general measures to reduce releases of chemicals listed in Annex C, such as those measures listed in Annex C, Part V, section B, subparagraph (b), points (i) through (iv).

2. Identify possible and available alternatives

An effort should be made to identify available alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of chemicals listed in Annex C. Available guidance comprising options for those processes, techniques and practices should be taken into account (for example, guidance from the Basel Convention, the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), other intergovernmental bodies and governments).

In order to assist Parties to identify possible available and appropriate alternatives, the Convention Secretariat will, in its role as clearing-house mechanism for information mandated under Article 9, produce, manage and facilitate a compendium of available processes, techniques or practices that avoid the generation and release to the environment of chemicals listed in Annex C, and that may be utilized as appropriate alternatives to facilities and processes that do generate and release such chemicals. The development and maintenance of this element of the clearing-house mechanism must:

- Be done in a transparent manner;
- Be kept up to date;
- Provide information that Parties can use in ways that take fully into account the particular circumstances of developing countries and some countries with economies in transition;
- Provide information that Parties can use to give consideration to regional differences and to help them to focus on sustainable development, taking into account environmental, health, safety and socio-economic factors.

3. Undertake a comparative evaluation of both the proposed and identified possible and available alternatives

After possible and available alternatives have been identified, decision makers should undertake comparative evaluations of the various options, namely the originally proposed new facility and all possible alternatives that may be under consideration. In some cases, and for some kinds of facilities, it may be most appropriate for this comparative evaluation to be done by local or district authorities. However, in many cases, it may be more appropriate, from a sustainable development perspective, for the comparative evaluation to be made at some other strategic or policy level. In carrying out the comparative evaluation, consideration should be given to appropriate items of the indicative list contained in Annex F[4], Information on Socio-Economic Considerations; and also relevant criteria from Annex C, Part V, sections A and B.

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[4] The list of items provided in Annex F to the Convention for chemicals being assessed under Article 8 (listing of chemicals in Annexes A, B and C) is also relevant to the comparative evaluation.

4. Priority consideration

A proposed alternative should be given priority consideration over other options, including the originally proposed facility, if, based on the comparative evaluation described in subsection 3 above, and using relevant considerations and criteria from Convention Annex F and Annex C, an identified, available alternative is determined to:

- Avoid the formation and release of chemicals listed in Annex C;
- Have similar usefulness;
- Fit comparatively well within a country's sustainable development plans, taking into account effective integration of social, economic, environmental, health and safety factors.

II.D Other considerations of the Stockholm Convention

1. Health, safety and environmental considerations

Article 1 of the Convention states that "the objective of this Convention is to protect human health and the environment from persistent organic pollutants". In carrying out comparative evaluations of originally proposed facilities and possible and available alternatives (as in section II.C, subsection 3 of the present guidelines), health, safety and environmental considerations should be taken into account.

Health, safety and environmental impacts of proposed alternatives should be compared with the corresponding impacts of the originally proposed facility. The outcome of this comparison should constitute an important component in the consideration of "similar usefulness" and in a determination of practicality and feasibility.

2. Social and economic considerations

Annex F of the Stockholm Convention addresses relevant information relating to socio-economic considerations associated with possible control measures to enable decisions by the Conference of the Parties. However, it is also a starting point for a useful list of social and economic considerations and criteria that can be used by authorities in carrying out comparative evaluations of originally proposed facilities and identifying possible and available alternatives. The creation of a country-specific checklist is strongly recommended; it should include the following items, many of which are included in Annex F of the Convention:

- Technical feasibility;
- Costs, including environmental and health cost;
- Cost efficiency;
- Efficacy (infrastructural capacity, including availability of well-trained staff);
- Risk;
- Availability;
- Accessibility;
- Operator friendliness (ease of use);
- Positive or negative impacts on society, including health (public, environmental and occupational health); agriculture (including aquaculture and forestry); local and traditional techniques and/or knowledge; biodiversity; economic aspects; movement towards sustainable development; and social costs.

In many cases, a proposed new facility may have the potential to contribute to a country's economic development and poverty reduction plans. Proper implementation of the Stockholm Convention should not significantly interfere with this potential. Rather, if properly implemented, the Stockholm Convention should contribute positively to sustainable development and poverty reduction.

The Convention[5] provides that developing country Parties and Parties with economies in transition will have access to new and additional financial resources to enable them to meet the agreed full incremental costs of implementing measures that fulfill their Convention obligations. Therefore, insofar as a Party is obliged to require best available techniques under the well-defined circumstances specified in the Convention, the Party should receive access to the agreed full incremental costs of implementing this obligation.

In some cases, appropriate alternatives to proposed sources of chemicals listed in Annex C require less expenditure on imported capital goods, relying rather on locally available labour sources and building on local knowledge. Such alternatives may avoid formation and release of chemicals listed in Annex C; fit well into a country's sustainable development plans; and provide usefulness that is as good as or better than the originally proposed facility.

Finally, all obligations under the Convention contribute to the Convention's objective to protect human health and the environment from chemicals listed in Annex C.[6]The Convention recognizes in its preamble[7] "health concerns, especially in developing countries, resulting from local exposure to persistent organic pollutants, in particular impacts upon women and, through them, upon future generations". By minimizing releases of chemicals listed in Annex C, as part of a robust and balanced sustainable development process, proper implementation of the Stockholm Convention can reduce the burdens of disease and health deficits that undermine efforts aimed at sustainable development and poverty reduction.

3. Annex C considerations

All relevant sections of Annex C, Part V, sections A and B should be taken into consideration in applying the present guidelines.

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[5] See Stockholm Convention, Article 13.2.

[6] See Stockholm Convention, Article 1.

[7] See Stockholm Convention, second paragraph.

Section III

Best available techniques and best environmental practices: Guidance, principles and cross-cutting considerations

Contents

III.A Guidance

1. General considerations

Article 5 of the Stockholm Convention requires Parties to develop, within two years of entry into force for them, an action plan to identify, characterize and address the release of chemicals listed in Annex C. Currently listed are polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF), as well as hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) when produced unintentionally.

The action plan, which is also to be a component of a Party's national implementation plan to be developed pursuant to Article 7 of the Convention, will include strategies for meeting obligations to reduce or eliminate releases of chemicals listed in Annex C of the Stockholm Convention, and a schedule for the action plan. The plan will identify priorities for action, including for those source categories that provide the most cost-effective opportunities for release reduction or elimination. It will also include an inventory of releases of chemicals listed in Annex C.

In accordance with the implementation schedule of its action plan and taking into account the guidelines to be adopted by the Conference of the Parties, Parties are to promote and in some cases require the use of best available techniques and to promote the use of best environmental practices by identified sources of release. Parties are also to promote the development of and, where appropriate, require the use of substitute materials or processes to prevent the formation and release of chemicals listed in Annex C.

2. Policy, legal and governance issues

Just how a government promotes or requires the use of best available techniques and best environmental practices will vary from country to country, depending on its legal structure and socio-economic conditions. Possible implementation strategies would include release estimate reporting, public information and education programmes, voluntary industry programmes, economic instruments and regulation. These issues should be addressed in the Party's national action plan.

The types of measures that may be promoted or required as best available techniques to reduce or eliminate the release of Annex C chemicals can be categorized as follows: shifting to alternative processes; primary measures that prevent the formulation of chemicals listed in Annex C; and secondary measures that control and reduce the release of those chemicals.

3. Scientific and technical issues

The state of the science with regard to both the measurement of releases and levels present in the environment of chemicals listed in Annex C and what is considered "best" available techniques and "best" environmental practices will advance with time. This guidance will be periodically updated to keep up with these changes.

The Convention identifies the term "best" as "most effective in achieving a high general level of protection of the environment as a whole" (see subparagraph (f) (iv) of Article 5).

Consistent with decision SC-1/15 of the Conference of the Parties of the Stockholm Convention efforts should be made to ensure that mechanisms are set in place for providing technical assistance and promoting transfer of technology. A particular case is that of Parties that currently do not have access to those techniques that are subject to intellectual property rights.

These guidelines should be taken into consideration, and the performance levels associated with best available techniques and best environmental practices for PCDD/PCDF releases, may be used by a Party in fulfilling its commitments to apply best available techniques. It is within the jurisdiction of each Party to establish its regulatory release limits based on such guidance.

4. Economic and social implications

Depending on the process that is a source of chemicals listed in Annex C, economic and social conditions in a country are a factor in determining what are “best” available techniques and “best” environmental practices. Where processes are relatively large scale, capital intensive and involve large and continuous throughputs (e.g. cement kilns firing hazardous wastes, sinter plans in the iron and steel industry, fossil fuel-fired utilities, large waste incinerators) the technologies and practices used and enterprises that manage them are rather similar worldwide. In such cases, best available techniques and best environmental practices can be applied in much the same way in all countries. Where processes are relatively smaller in scale (crematoria, home heating and cooking, industrial boilers, motor vehicles) or involve smaller scale management of wastes (waste incineration, open burning), the technologies and practices available may vary greatly from country to country. In these cases, determining what are best available techniques and best environmental practices will need to include an analysis of economic feasibility of the various options available. As such, “best” may mean best option that is economically feasible under the socio-economic conditions present.

5. New versus existing sources

For new sources of chemicals within source categories that warrant the use of best available techniques, as identified in their national action plans, Parties are to focus initially on source categories identified in Part II of Annex C. Parties shall phase in requirements for best available techniques for new sources in the categories in Part II of Annex C as soon as practicable, but no later than four years after entry into force of the Convention for the Party. For existing source categories, identified in the action plans as warranting the use of best available techniques, best available techniques are to be promoted. The use of best available techniques and best environmental practices are to be promoted for those new sources that do not warrant action in a Party’s action plan.

The use of best available techniques and best environmental practices for new sources ensures that releases of chemicals listed in Annex C are minimized to the greatest extent possible. It also allows such techniques and practices to be considered in the design and operation of the facility at a stage when they can be incorporated cost-effectively. Given the range of industrial and other activities involved, national sustainable development strategy should take into account the need to ensure that the investments into the national economy comply with this guidance and guidelines.

The use of best available techniques and best environmental practices for existing sources identified in a Party’s national action plan are to be promoted in accordance with the Party’s action plan.

Addressing existing sources is a good opportunity for a Party to reduce overall releases. In considering priority existing sources identified in its national action plan, a Party will need to consider measures to encourage necessary changes to the process or management practices that could lead to eventual attainment of best available techniques and best environmental practices. Such modifications could be phased in over time and could be part of plans to modernize a facility.

III.B General principles and approaches

When applying these guidelines and guidance to sources of chemicals listed in Annex C of the Stockholm Convention, Parties may find it useful to consider some general environmental management principles and approaches that may be supportive of the Convention. The following is indicative of some of these general environmental management principles and approaches.

1. **Sustainable development.** “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”[1]
2. **Sustainable consumption.** “The use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources

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[1] World Commission on Environment and Development. 1987. www.un.org/documents/ga/res/42/ares42-187.htm.

and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations."[2]

3. **Development and implementation of environmental management systems.** "A structured approach for determining, implementing and reviewing environmental policy through the use of a system which includes organizational structure, responsibilities, practices, procedures, processes and resources."[3]

4. **Use of science, technology and indigenous knowledge to inform environmental decisions.** "Increase the use of scientific knowledge and technology and increase the beneficial use of local and indigenous knowledge in a manner respectful of the holders of that knowledge and consistent with national law;" and "Establish partnerships between scientific, public and private institutions, including by integrating the advice of scientists into decision-making bodies to ensure a greater role for science, technology, development and engineering sectors."[4]

5. **Precautionary approach.** "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[5]

6. **Internalizing environmental costs and polluter pays.** "National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."[6]

7. **Pollution prevention.** "The use of processes, practices, materials, products or energy that avoid or minimize the creation of pollutants and waste, and reduce overall risk to human health or the environment."[7]

8. **Integrated pollution prevention and control.** "This principle aims to achieve integrated prevention and control of pollution arising from large-scale industrial activities. It lays down measures designed to prevent or, where that is not practicable, to reduce emissions in the air, water and land from these activities, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole."[8]

9. **Co-benefits of controlling other pollutants.** For instance, pollution prevention and control of other contaminants may also contribute to the reduction and elimination of chemicals listed in Annex C.

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[2] UNEP (United Nations Environment Programme). 1994. Oslo Symposium: Sustainable Consumption. Oslo, Norway, January 1994. www.iisd.org/susprod/principles.htm.

[3] UNEP (United Nations Environment Programme). 2002. Environmental Impact Assessment Training Resource Manual. Page 558. www.iaia.org/Non_Members/EIA/ManualContents/Vol1_EIA_Manual.pdf.

[4] UN DESA (United Nations Department of Economic and Social Affairs) 2002 Plan of Implementation of the World Summit on Sustainable Development, page 50. http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf

[5] UNEP (United Nations Environment Programme). 1992. Rio Declaration on Environment and Development. Principle 15. Rio de Janeiro, Brazil, 1992. www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163.

[6] Preamble to Stockholm Convention and Principle 16 of the Rio Declaration on Environment and Development.

[7] Environment Canada. 1995. Pollution Prevention – A Federal Strategy for Action. www.ec.gc.ca/cppic/aboutp2/en/glossary.cfm.

[8] European Commission. 1996. Integrated Pollution Prevention and Control Directive. 96/61/EC. europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31996L0061&model=guichet.

10. **Cleaner production.** “The continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency and reduce risks to humans and the environment. Cleaner production can be applied to the processes used in any industry, to products themselves and to various services provided in society.”[9]

11. **Life cycle analysis.** “A system-oriented approach estimating the environmental inventories (i.e. waste generation, emissions and discharges) and energy and resource usage associated with a product, process or operation throughout all stages of the life cycle.”[10]

12. **Life cycle management.** “An integrated concept for managing the total life cycle of goods and services towards more sustainable production and consumption, building on the existing procedural and analytical environmental assessment tools and integrating economic, social and environmental aspects.”[11]

13. **Virtual elimination.** “The ultimate reduction of the quantity or concentration of the toxic substance in an emission, effluent, or waste released to the environment below a specified level of quantification. The ‘level of quantification’ means, in respect of a substance, the lowest concentration that can be accurately measured using sensitive but routine sampling and analytical methods.”[12]

14. **Community Right to Know.** “In the field of environment, improved access to information and public participation in decision-making enhance the quality and the implementation of decisions, contribute to public awareness of environmental issues, give the public the opportunity to express its concerns and enable public authorities to take due account of such concerns.”[13]

III.C Cross-cutting considerations

(i) Chemicals listed in Annex C: Formation mechanisms

1. Formation of chemicals listed in Annex C: An overview

Polychlorinated dibenzo-*p*-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB) are unintentionally formed in industrial-chemical processes, such as chemical manufacture, and thermal processes, such as waste incineration. PCDD/PCDF are the only by-product persistent organic pollutants whose mechanism of formation has been studied extensively in combustion-related processes and to a lesser extent in non-combustion-related chemical processes; even so, the mechanisms and exact formation conditions are not fully resolved. It is clear that the predominant mechanism or pathway can vary from process to process so that different factors become controlling and there is no universal controlling factor.

There is far less information as to the formation of PCB and HCB, especially in combustion processes. Since there are similarities in the structure and occurrence of PCDD/PCDF, PCB and HCB,

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[9] UNEPTIE. www.uneptie.org/pc/cp/understanding_cp/home.htm.

[10] European Environment Agency. glossary.eea.eu.int/EEAGlossary.

[11] UNEPTIE. www.uneptie.org/pc/sustain/reports/lcini/lc-initiative-barcelona-workshop.pdf.

[12] Environment Canada. 1999. Canadian Environmental Protection Act, 1999. Section 65. www.ec.gc.ca/CEPARegistry/the_act/.

[13] Aarhus Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters, United Nations Economic Commission for Europe, www.unece.org/env/pp

it is usually assumed that, with the exception of oxygen-containing species, those parameters and factors that favour formation of PCDD/PCDF also generate PCB and HCB.

On the other hand, in some industrial processes HCB is formed to a greater extent than PCDD/PCDF or PCB. The guidance sections V and VI on various types of incineration and chemical processes contain more specific process and by-product information.

2. Formation of PCDD/PCDF

2.1 Thermal processes[14]

Carbon, oxygen, hydrogen and chlorine, whether in elemental, organic or inorganic form, are needed. At some point in the synthesis process, whether present in a precursor or generated by a chemical reaction, the carbon must assume an aromatic structure.

There are two main pathways by which these compounds can be synthesized: from precursors such as chlorinated phenols or de novo from carbonaceous structures in fly ash, activated carbon, soot or smaller molecule products of incomplete combustion. Under conditions of poor combustion, PCDD/PCDF can be formed in the burning process itself.

The mechanism associated with this synthesis can be homogeneous (molecules react all in the gas phase or all in the solid phase) or heterogeneous (involving reactions between gas phase molecules and surfaces).

PCDD/PCDF can also be destroyed when incinerated at sufficient temperature with adequate residence time and mixing of combustion gases and waste or fuel feed. Good combustion practices include management of the “3 Ts” – time of residence, temperature and turbulence, and sufficient excess oxygen to allow complete oxidation. Use of a fast temperature quench and other known processes are necessary to prevent reformation.

Variables known to impact the thermal formation of PCDD/PCDF include:

- Technology: PCDD/PCDF formation can occur either in poor combustion or in poorly managed post-combustion chambers and air pollution control devices. Combustion techniques vary from the very simple and very poor, such as open burning, to the very complex and greatly improved, such as incineration using best available techniques;
- Temperature: PCDD/PCDF formation in the post-combustion zone or air pollution control devices has been reported to range between 200 °C and 650 °C; the range of greatest formation is generally agreed to be 200 – 450 °C, with a maximum of about 300 °C;
- Metals: Copper, iron, zinc, aluminium, chromium and manganese are known to catalyse PCDD/PCDF formation, chlorination and dechlorination;
- Sulphur and nitrogen: Sulphur and some nitrogen-containing chemicals inhibit the formation of PCDD/PCDF, but may give rise to other unintended products;
- Chlorine must be present in organic, inorganic or elemental form. Its presence in fly ash or in the elemental form in the gas phase may be especially important;
- PCB are also precursors for the formation of PCDF.

Research has shown that other variables and combinations of conditions are also important.

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[14] PCDD/PCDF may also be introduced as contaminants in raw materials or wastes and may therefore appear in processes in which PCDD/PCDF formation does not occur.

2.2 Industrial-chemical processes

As with thermal processes, carbon, hydrogen, oxygen and chlorine are needed. PCDD/PCDF formation in chemical processes is thought to be favoured by one or more of the following conditions:

- Elevated temperatures (> 150 °C);
- Alkaline conditions;
- Metal catalysts;
- Ultraviolet (UV) radiation or other radical starters.

In the manufacture of chlorine-containing chemicals, the propensity for PCDD/PCDF formation has been reported as follows:

Chlorophenols > chlorobenzenes > chlorinated aliphatics > chlorinated inorganics

(ii) Waste management considerations

1. Summary

Burning of waste has the potential for comparatively high unintentional formation and release of persistent organic pollutants to the environment. Waste incinerators are therefore listed as Part II source categories in Annex C of the Stockholm Convention. Open burning of waste, including burning of landfill sites, can also lead to the unintentional formation and release of persistent organic pollutants, and is listed as a Part III source category in Annex C. The application of best available techniques and best environmental practices to these sources should take into consideration environmentally sound waste management practices. Environmentally sound waste management reduces the release of persistent organic pollutants and is also an important factor in avoiding health problems and in promoting sustainable use of resources.

Important principles applicable to the prevention and reduction of waste include the source reduction principle; the integrated life cycle principle; and the principle of recovery of reusable and recyclable components, to the greatest possible extent. In many cases, this will be facilitated by separating at the source those wastes that can be composted, reused or recycled. The remaining waste should be treated and disposed of in an environmentally sound way. Reliable solutions for all steps – the collection system, the recycling actions, and the final disposal – should be adapted to the local circumstances, taking into account such factors as opportunities for waste prevention, the composition of waste, the available recycling processes, the existing structures, and financial, economic and social aspects.

In general priority should be given to approaches that prevent the formation and release of chemicals listed in Annex C of the Convention. Improved waste management approaches should be employed with the aim of avoiding open and other uncontrolled burning of wastes, including burning of landfill sites. When considering proposals to construct new waste disposal facilities, consideration should be given to alternatives such as activities to minimize the generation of municipal and medical waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste. Under this approach, public health concerns should be carefully considered.

The present section deals with these issues but it cannot replace a comprehensive examination of all the specific questions related to waste management.

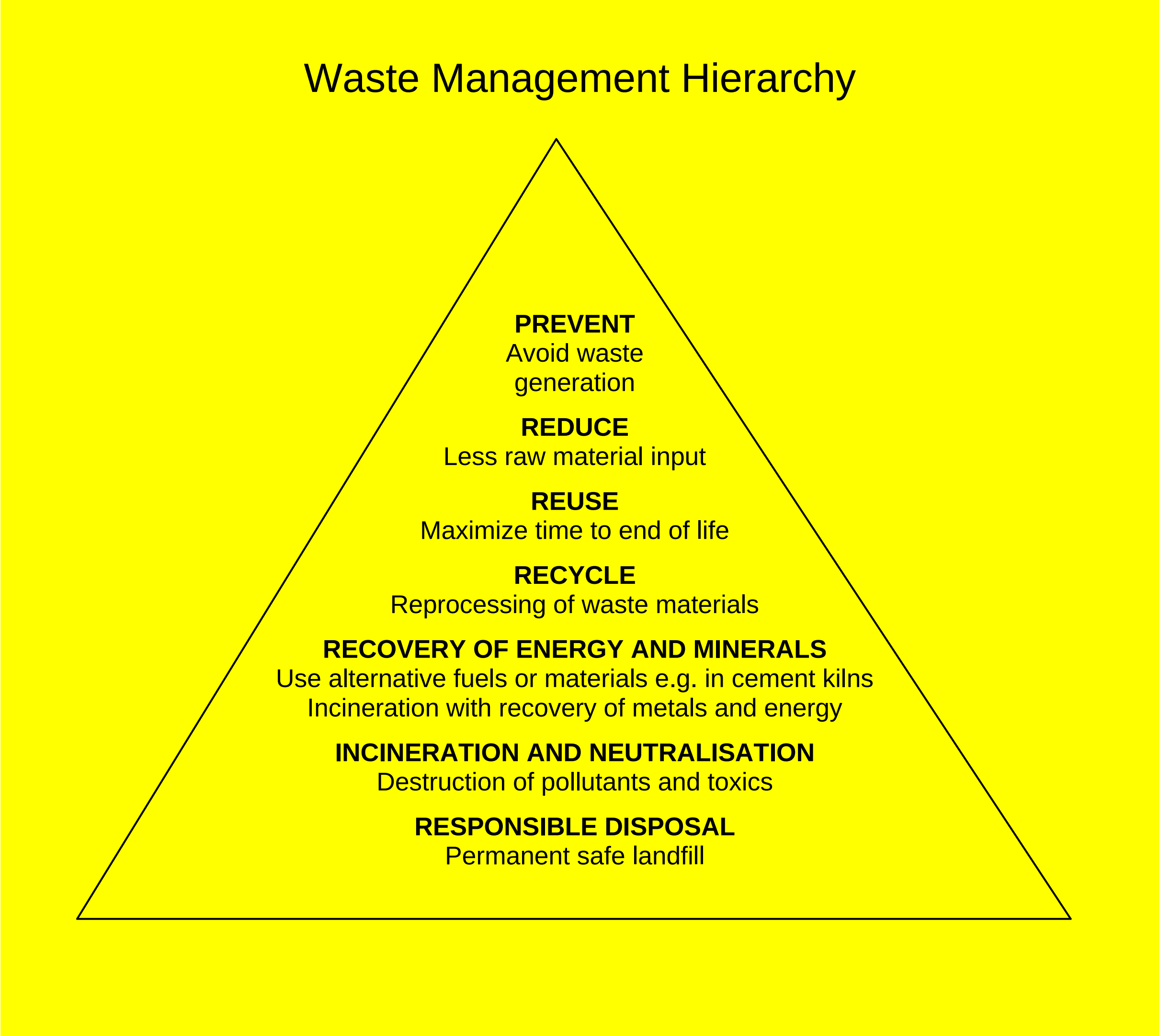
2. Introduction

2.1 The importance of waste management to the environment and health

Sound waste management is an important element in the protection of human health and the protection of the environment. It also helps to avoid the loss of resources. Careless landfilling may pollute water bodies; burning of waste on landfills or in inappropriate incinerators or open burning can release high levels of chemicals listed in Annex C and other toxic substances such as polycyclic aromatic hydrocarbons, heavy metals and particulate matter. For this reason a holistic approach to improving the waste management system will have positive effects in a number of areas.

Waste management consists of many different areas of intervention. As a first step waste prevention and reduction can help reduce the generation of waste, and its hazard potential, to a minimum. In industrial processes the development and use of low-waste and non-waste technologies have had a positive effect in decreasing the amount of waste requiring treatment. Greater emphasis on producer responsibility may also help to solve or at least reduce waste management problems. (see figure 1)

Figure 1: Waste management hierarchy



2.2 Definitions

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal gives the following definition for wastes in general:

> "Wastes are 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."

The Basel Convention defines "disposal" as operations which may or may not lead to the possibility of "resource recovery, recycling, reclamation, direct re-use or alternative uses."

Annex I of the Basel Convention lists 45 categories of hazardous wastes subject to transboundary movement requiring control, unless they do not fall into any of the following categories, the characteristics of which are listed in Annex III of the Basel Convention:

- Explosives;
- Flammable liquids;
- Flammable solids;
- Substances or wastes liable to spontaneous combustion;
- Substances or wastes which, in contact with water, emit flammable gases;
- Oxidizing substances;
- Organic peroxides;
- Poisonous (acute) substances;
- Infectious substances;
- Corrosives;
- Substances that liberate toxic gases in contact with air or water;
- Toxic (delayed or chronic) substances;
- Ecotoxic substances;
- Substances capable, by any means, after disposal, of yielding another material, e.g. leachate, which possesses any of the characteristics listed above.

2.3 The importance of developing national waste management strategies

Waste management influences all parts of society and of its economy. It concerns local, regional and national authorities; it requires a legal base, a financial mechanism, and a great deal of coordination between citizens and authorities at all levels. Furthermore, good waste management is not feasible without a minimal level of investment. To ensure a coherent waste management system, all the actions at different levels should follow a commonly agreed strategy; it is therefore necessary or at least useful to discuss and decide upon a national waste management strategy. The successful implementation of any waste management system, particularly in developing countries, may require the transfer of appropriate technologies and capacity building in accordance with article 12 of the Convention (see also section III.A, subsection 3, on scientific and technical issues).

2.4 Some principles to be applied

Basel Convention guidance to be considered in the development of waste and hazardous waste strategies (Basel Convention Secretariat 1993) includes:

- The source reduction principle, "by which the generation of waste should be minimized in terms of its quantity and its potential to cause pollution. This may be achieved by using appropriate plant and process designs";

- The integrated life cycle principle, “by which substances and products should be designed and managed such that minimum environmental impact is caused during their generation, use, recovery and disposal”.

Discards with the potential for reuse or recycling should be recovered for those purposes to the greatest extent possible.

2.5 Approach proposed in the WSSD Plan of Implementation

The 2002 Johannesburg World Summit on Sustainable Development (WSSD) Plan of Implementation, paragraph 22, states:

> “Prevent and minimize waste and maximize reuse, recycling and use of environmentally friendly alternative materials, with the participation of government authorities, and all stakeholders, in order to minimize adverse effects on the environment and improve resource efficiency, with financial, technical and other assistance for developing countries.
>
> This would include actions at all levels to:
>
> (a) Develop waste management systems with the highest priority placed on waste prevention and reduction, reuse and recycling, and environmentally sound disposal facilities, including technology to recapture the energy contained in waste, and encourage small-scale waste-recycling initiatives that support urban and rural waste management and provide income-generating opportunities with international support for developing countries;
>
> (b) Promote waste prevention and reduction by encouraging production of reusable consumer goods and biodegradable products and developing the infrastructure required.”

2.6 The importance of public education

Successful implementation of a general waste management plan needs the assistance of different actors: consumers, authorities, waste management operators. All these stakeholders have to be informed about coherent waste management and have to be convinced to contribute to its successful implementation. There is a clear need for awareness building at all levels: for example, consumers should be informed about strategies for avoiding waste and the advantages of using recycling opportunities; and information about the health hazards of open burning of waste and promotion of better alternatives are necessary if this way of disposal is to be reduced and eventually stopped.

2.7 The importance of training of personnel

In order to manage wastes effectively, it is important that adequate training is provided to decision makers and technical personnel (refer to section III.C (v)).

3. Influencing production and products

All industrial or artisanal products will at some point become waste. Hence, the quality and especially the technical lifetime of products have a crucial impact on the quantities of waste that have to be eliminated.

National authorities are limited in their ability to directly prescribe the general life cycle quality of products and encourage the production of long-life products. There are however several quite efficient indirect ways to influence these aspects of production.

In many countries public procurement is an important part of the overall market. By defining quality standards and minimum requirements, public procurement allows the quality of the products offered to be influenced. As a follow-up to the World Summit on Sustainable Development, several nations are developing toolkits for sustainable procurement following the definition developed by the

Sustainable Procurement Task Force set up by the Government of the United Kingdom: "Sustainable procurement is a process whereby organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole life basis in terms of generating benefits to society and the economy, whilst minimizing damage to the environment" (Sustainable Procurement Task Force 2006).

In general it is useful to avoid unnecessary packaging, to promote durable and reusable products, and to utilize materials and product designs that avoid toxicity and other hazard characteristics and that enable end-of-life remanufacture, material recovery and recycling.

Labelling is another powerful instrument: it enables the consumers to select products based on environmental performance, price and quality, thus directing their demand towards goods produced with respect for the principles of sustainable development.

3.1 Product warranties

Products become wastes at the end of their life. If the use of a product is limited by careless design or production, this may lead to an unnecessarily short technical lifetime. Electronic appliances or tyres of low quality may become waste after a comparatively short period of use, thereby increasing the amount of waste. One possible way of influencing quality is by legally defining a minimum period of warranty for products.

3.2 Encourage companies to use environmental management systems

The use of environmental management systems (for example those developed by the International Standards Organization and the European Union Eco-Management and Audit Scheme, or EMAS) leads to better knowledge about industrial processes and their influence on the environment. This may also help to reduce the amount of waste and its hazardous characteristics. The responsible management of products and processes from an environmental point of view can stimulate greater awareness throughout a company, improve corporate credibility and reputation, enhance business development opportunities and facilitate dialogue and partnership with key stakeholders.

3.3 Producer responsibility

Producers and other stakeholders have responsibilities that can be established through approaches such as the European Union's draft Integrated Product Policy and forthcoming thematic strategy on the prevention and recycling of waste, the Extended Producer Responsibility programme of the Organisation for Economic Co-operation and Development (OECD 2000), the concept of product stewardship, or through other means. In some cases it may be useful to oblige producers to take back certain end-of-life products and to assure their environmentally sound treatment.

4. Source reduction as a priority

In general, a society should give careful consideration to the full range of waste management options and considerations before reaching a decision to make a large-scale investment in the construction of any new incinerator, a new sanitary landfill, mechanical or biological treatment, or other similar investments, or to retrofit an existing facility for these purposes.

The first priority among waste management options is source reduction – minimization of the quantity of waste, alongside the reduction of its toxicity and other hazard characteristics. This is a responsibility shared by all sectors of society. One measure of success is the percentage of discards that can be diverted from landfills and incinerators, but this should always be considered in the context of total waste generated.

In some situations, the decision to construct a new large-scale waste treatment facility can undermine efforts at waste reduction and waste-derived resource recovery. Those who invest in these new facilities will often face pressures to assure sufficient incoming waste in order to recover their investments. When this happens, the new facility can sometimes serve as a counterforce and as a disincentive to effective waste reduction efforts. Therefore, any such consideration should take place in the framework of holistic waste management policies.

5. Collection

Households usually keep waste to be discarded in designated containers. These may be metal or plastic dustbins or plastic and paper bags. In large buildings and apartment blocks, centralized containers are sometimes provided into which occupants place their waste. In most developed countries, it is usual for household waste to be collected from premises on a regular basis since food waste, in particular, decays rapidly. In cities and urban areas, waste is collected for disposal in specially designated vehicles fitted with compaction equipment to increase the payload that can be transported, often over significant distances, to sanitary landfill sites. In large conurbations, studies show that transferring the collected waste to railway containers for transport to a landfill site is economically viable; large barges are also used for transport. In some instances, waste is baled to facilitate mechanical handling.

Even though there exist quite efficient mechanical sorting systems for mixed waste, source separation and collection of recyclable goods is in many cases cheaper and will provide cleaner products for recycling. This is particularly true when, without source separation, paper and cardboard would be mixed up with wet waste from the kitchen, or when vegetable waste, designed to be composted or fermented, is at risk of being mixed with hazardous waste from small industries.

6. Recycling

Generally a large proportion of municipal solid waste can be composted, reused or recycled. In several industrial countries more than 50% of municipal solid waste is recycled. Some regions achieve even higher recycling rates. NGOs such as Zero Waste International Alliance are following such ambitious goals for the diversion of wastes from landfills or incinerators in a number of countries. Zero waste means designing and managing products and processes to reduce the volume and the toxicity of waste and materials, conserve and recover all resources and not to burn or bury them. Zero waste programmes have been implemented in many countries, for example in Palarikovo, Slovakia and in Canberra, Australia – refer to the web-sites reference for further information.

The sound disposal of mixed waste is in most cases more expensive than source reduction through the use of long-life products, repairing goods and efficient recycling. The possibilities of composting, reuse and recycling have to be examined and developed taking into account the composition of the waste, the existing collection and recycling systems and the economic possibilities

As an example, the recycling of paper and cardboard, metals and glass in many cases creates a positive revenue or is at least cheaper than the transportation and elimination of these materials together with other wastes. Similarly, collection and recycling of polyethylene terephthalate (PET) bottles or other plastic containers can produce a feedstock for the plastic recycling industry.

In many developing countries, waste-derived resources can provide important raw materials for small-scale resource recovery and remanufacturing activities. These small-scale activities can be encouraged. When this is done, efforts should also be made to promote improvements in the health and safety of this sector, which in many countries is presently an informal sector.

The collection of recyclable goods may be done by source separation followed by collection of the recyclable goods by either public authorities or private companies. In many cases the informal sector has also built up quite efficient structures for the collection of those wastes. The use and even the reinforcement of existing structures may have economic and social advantages, and should therefore be taken into account when developing or adapting waste management systems. Interesting examples of neighborhood associations that successfully recycle and compost come from Mumbai in India and from Cairo in Egypt (Kumar 2000; Faccini 1999).

7. Final disposal

Even with good results in prevention of waste and with ambitious goals for recycling, some waste remains for disposal. The quantity of waste, its composition and hazardous characteristics, and the technical and economic possibilities for its disposal, are factors that have to be taken into account in choosing the final disposal method.

If the mixed waste contains a large percentage of vegetable waste, the possibilities for composting or anaerobic digestion should be examined. In some cases the waste consists predominantly of vegetable material, dust and sand, and composting of the waste after sorting out some other fractions (e.g. plastics) may be a viable option. The quality and use of the produced compost has to be evaluated.

Biological treatment or mechanical biological treatment of waste are options when the mixed waste contains, besides biodegradable material, a larger proportion of plastics, metals and other waste fractions. Mechanical biological treatment processes incorporate mechanical sorting and separation of the waste stream to separate the biodegradable materials, which are sent to a biological process, from the non-biodegradable materials. The mechanical process can be configured to further separate the non-biodegradable materials into fractions that can be recycled. The recovery of combustible parts of waste is also possible. This combustible fraction, also called waste-derived fuel, will in most cases be polluted by heavy metals and will contain more chlorine than normal fuels. For this reason, such products of waste management can only be used as fuel in installations with air pollution control equipment and careful disposal of ashes. The products of the biological treatment may be used as composts if the quality is sufficient, or can be landfilled.

7.1 Landfill

In many countries household waste has always been disposed of by landfilling. Significant changes in the composition of waste (e.g. more plastics), and the increasing quantities requiring disposal, led to designated areas of land being set aside as local waste disposal sites.

In a landfill, the waste is deposited in layers in prepared cells and compacted to decrease its volume. It is then covered, at least daily, with a suitable soil-like material to deter vermin, flies, birds and other scavengers and to prevent injuries from sharps. Many wastes, especially hazardous wastes, should only be disposed of in specially engineered landfills. (For further information see Basel Convention technical guidelines: on specially engineered landfill (D5)).

The putrescible fraction of waste undergoes aerobic and anaerobic processes. Landfill gas, a mixture of methane and carbon dioxide, is produced, and other organic compounds are formed. Many of these are soluble in water and become dissolved in any surplus moisture in the landfill site to produce a liquid mixture termed leachate. Leachate can be highly polluting, and it is necessary to prevent it from mixing with groundwater and surface water. The treatment of leachate and the safe disposal or even use of landfill gas are components of an environmentally sound waste management policy. In any case it is necessary to prevent leachate migration since it can continue to produce landfill gas away from a landfill site.

Landfill is by far the most commonly practiced waste disposal method in the majority of countries. As a result of serious environmental and health problems experienced with historic and abandoned dump sites and the very high costs associated with clean-up measures at contaminated sites, many countries have introduced the specially engineered landfill concept, whereby the wastes are only consigned to sites selected for their containment properties. They may be natural, or augmented by or provided directly by liners, the overall engineering being such as to ensure as far as possible the isolation of wastes from the environment. Such landfills are considered a final resort option only to be used after every effort has been made to reduce, mitigate or eliminate the hazards posed by such wastes.

8. Incineration

In some countries with high population density and a lack of suitable areas for landfills, incineration of waste has become the main way for the treatment and disposal of the not recyclable waste over the last 50 years. As there are many combustible components in municipal solid waste, surplus heat can be produced. Pathogenic germs and organochemical constituents in waste can be destroyed almost completely. Because household waste contains a large variety of materials, including those that are not combustible, incinerators need to be rugged and versatile to cope with a highly variable feedstock both in terms of waste composition and calorific value. Traditionally, furnaces are based on either the chain or rocking grate principle or to a lesser extent a rotary kiln. For sewage sludge and for industrial wastes fluidized bed combustion is used. To ensure high combustion efficiency the temperature range at which the furnace is operated and burns waste, the time during which the waste reaches and is maintained at furnace temperature and turbulence within the furnace chamber all need to be strictly controlled. The so-called “3 Ts principle” – temperature, time and turbulence in the presence of sufficient oxygen - are the basic requirements for good combustion (see also section V.A of the present guidelines, on waste incinerators).

In order to avoid gaseous or particulate emissions, incinerators have to be equipped with efficient flue gas cleaning systems, which may in many cases include catalytic converters or addition of activated carbon to the flue gas and scrubbers. If water from scrubbers is discharged, it has to be treated. Fly ash from electrostatic precipitators and residues from air pollution equipment almost certainly contain significant amounts of chemicals listed in Annex C of the Convention, so these wastes have to be disposed of in a controlled way.

The need for reliable control of the parameters of combustion, the requirements of high-tech flue gas cleaning systems and the investment necessary for energy recovery (boilers, turbines, electrical generators) may explain why incinerators are highly developed, efficient but also rather expensive technology. Smaller installations exist, but in order to achieve economies of scale, in most cases at least 100,000 tons of waste per year are needed.

Over the last years some new methods for combustion of the non-recyclable components of municipal solid waste have been developed. In some cases the waste is first crushed or milled and then burnt in a specially designed plant. This offers the possibilities to use degasification at lower temperatures or to treat with very low or non oxygen as a first step (known as pyrolysis).and to omit oxygen excess as a first step. The resulting gas is then burnt – eventually after cleaning - at high temperatures in a second step. This high-temperature step allows vitrification of the combustion residues and offers some possibilities for controlled destruction of waste contaminated with chemicals listed in Annex C. Particular care must be taken with this processes that products of incomplete combustion are not released into the environment.

Annex 1 Treatment of quarantine waste

Quarantine controls at a country’s border provide significant protection from the introduction of disease, pests and pathological organisms. Products and substances intercepted at a quarantine barrier can vary widely and include aeroplane or ship wastes (including food and paper waste) raw or processed materials, such as baskets or souvenirs, materials infested with organisms (e.g. borer in wood) or grain with weed seeds, building materials or machinery contaminated with soil.

In all cases, priority must be given to the appropriate treatment to destroy the organism and/or material of concern. Historically, incineration has been the preferred method of treatment, however use of non-combustion technologies, such as steam sterilization, should also be considered. An example of a commercial decision, with local community input, to convert from high temperature incineration to steam sterilization occurred at Auckland International Airport in New Zealand in 2005. The 22 tones per day unit was commissioned in early 2006 and reports trouble-free, continuous operation at time of publication, December 2006.

Annex 2 Case study on health-care waste management [15]

The New Delhi-based non-governmental organizations Srishti and ToxicsLink have been supporting health-care facilities to solve health-care waste management problems since 1996. In their experience, administrative willingness was the most essential quality needed in a health-care institution. Several private hospitals in New Delhi started to work on this issue in 1998, soon after national rules on health-care waste were passed. In these cases, the senior administrator led the systems and policy change. Today these hospitals have established systems because of their commitment in 1998 and subsequent years. Hospitals typically failed if their senior staff viewed waste management as an unnecessary burden for themselves and their health-care workers.

In a successful waste management programme, the leading authority made regular rounds to identify and address problems directly with appropriate personnel. The head of the medical staff and the nursing superintendent also played an active role in waste management programmes. In other cases, a successful hospital programme was built around a team effort. While the top administrator was fully supportive, a full waste management committee was appointed and headed by the Deputy Director. The programme's success required regular and tailored training for all personnel. Necessary staff time was allocated for training and the importance of training was emphasized.

Since about 80% of wastes generated in health-care facilities were general, non-infectious or non-hazardous wastes, segregation and waste recycling were important activities. Many hospitals installed autoclaves, an advanced steam treatment system known as a hydroclave, or a microwave unit to treat much of their infectious waste. Pathological waste was sent to crematoria. Non-infectious waste was disposed of as regular domestic waste. The treatment and disposal of sharps were a particular concern in view of the particular hazards posed by contaminated needles. Some sharps waste was buried in specially designed sharps pits. Others treated sharps in autoclaves, shredded the treated sharps, and re-processed the separated plastic and metal pieces. Thirteen specific case studies were published by the World Health Organization in S*afe Management of Bio-Medical Sharps Waste in India*. The non-governmental organizations also promoted small-scale, low-cost treatment systems for small rural facilities, such as small solar-powered autoclaves and other designs from the Health-Care Without Harm international competition on alternative treatment technologies for rural areas (www.medwastecontest.org).

(iii) Co-benefits of best available techniques for chemicals listed in Annex C

1. General considerations

The application of best available techniques for chemicals listed in Annex C of the Stockholm Convention will often have various co-benefits. Conversely, measures to protect human health and the environment from other pollutants will also help to reduce and eliminate chemicals listed in Annex C.

These other pollutants include particulate matter, certain metals (such as mercury), nitrogen oxides (NO_x), sulphur dioxide (SO_2), and volatile organic compounds. Measures include flue gas cleaning processes, wastewater and solid residue treatment and monitoring and reporting.

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[15] Information obtained from: Srishti (New Delhi, India): http://www.toxicslink.org/ovrvw-prog.php?prognum=1 and *Safe Management of Bio-Medical Sharps Waste in India*, SEA-EH-548, World Health Organization South-East Asia Regional Office, 2005.

Examples of some of these linkages and co-benefits are outlined below, with further details on best available techniques and best environmental practices provided in sections of the document dealing with specific source categories.

2. Information, awareness and training

Information, awareness and training activities associated with environmental and health concerns and protection may have co-benefits for the reduction of chemicals listed in Annex C and other pollutants.

3. Flue gas cleaning processes

Various flue gas treatment processes will have co-benefits for chemicals listed in Annex C and other pollutants. Examples include:

3.1 Containment, collection and ventilation

These measures will reduce residential and occupational human exposure to total particulate matter, particulate matter less than 10 microns (PM10) and particulate matter less than 2.5 microns (PM2.5). Pollutants associated with particulate matter, such as metals and metal compounds (e.g. lead), and gaseous pollutants such as volatile organic compounds, may also be reduced.

3.2 Dust separation processes

Measures such as cyclones, electrostatic precipitators and fabric filters will reduce emissions of particulate matter and pollutants associated with particulate matter to the environment.

3.3 Scrubbing processes

These measures will reduce emissions of particulate matter using effective mist eliminators and may reduce gaseous pollutants such as acid gases and mercury. Flue gas desulphurization will reduce emissions of SO_2.

3.4 Sorption processes

Measures such as activated carbon adsorption will reduce emissions of mercury, volatile organic compounds, sulfur dioxide (SO_2), hydrogen chloride (HCl), hydrogen fluoride (HF) and polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) as applicable.

3.5 Catalytic processes

Measures such as selective catalytic reaction for reduction of NO_x may also reduce gas phase emission of chemicals listed in Annex C if catalytic oxidation also occurs in the system. Selective catalytic reaction may also oxidize elemental mercury, which is water soluble and can be removed in flue gas desulphurization systems. Catalytic fabric filters may also reduce volatile organic compounds.

4. Wastewater treatment processes

Primary wastewater treatment will remove suspended solids. Tertiary treatment such as activated carbon may remove various organics.

Filter cake from wastewater treatment is regarded as hazardous waste and has to be disposed of in an environmentally sound manner (e.g. specially engineered landfill).

5. Solid residue treatment processes

Measures such as waste residue solidification and thermal treatment will reduce the total content of pollutants and leaching of various pollutants to the environment.

6. Monitoring and reporting

Facilities may be required to monitor, measure, estimate and report releases to the environment. These could provide public information on various pollutants and incentives for continual improvements in the environmental performance of the facilities.

Periodic comprehensive measurement scans of a wide range of pollutants, including PCDD/PCDF, hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB), in addition to routine monitoring of common pollutants, could provide useful information on many potential sources of chemicals listed in Annex C and other pollutants.

(iv) Management of flue gas and other residues

1. Flue gas treatment techniques (air pollution control devices)

In principle, reduction of emissions of polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) can be achieved with the following exhaust gas cleaning processes:

- Afterburners;
- Rapid quench systems;
- Dust separation;
- Scrubbing processes;
- Sorption process;
- Catalytic oxidation.

Air pollution control devices may be wet, dry, or semi-dry, depending on the role of water in the process. Wet and, sometimes, semi-dry air pollution control devices require additional processes to clean any wastewater generated before it leaves the facility.[16] Solid waste arising from semi-dry and dry processes (and also from wet processes after wastewater treatment) has to be disposed of in an environmentally sound manner or undergo additional treatment before disposal or potential reuse.

Further information with regard to applications for waste incineration can be found in section V.A, subsection 6.4.

1.1 Comparison of PCDD/PCDF control techniques

The techniques that have been found to be most effective at reducing persistent organic pollutants in flue gases are those that utilize adsorbents and particulate control and those that utilize catalysts. Table 1 summarizes the collection efficiencies of selected PCDD/PCDF control techniques.

Costs for PCDD/PCDF control at existing facilities can be reduced by using synergies with existing air pollution control devices:

- Through activated coke injection an existing fabric filter or electrostatic precipitator can be extended to a flow injection reactor to reduce PCDD/PCDF. The additional costs for PCDD/PCDF reduction arise from the storage, transport, injection and disposal of the activated coke, which is used as an additional adsorbent, and safe handling of the carbon and disposal of the residues, which may change in character.
- PCDD/PCDF can be destroyed with an oxidation catalyst. An existing catalyst for the selective removal of nitrogen oxides (NO_x) can be used for this purpose. Additional costs arise from

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[16] Combustion controls and other factors that affect formation and release of chemicals listed in Annex C of the Stockholm Convention upstream of the flue gases are described in the sector-specific guidance notes (sections V and VI).

enlarging the surface of the catalyst by adding one or two layers of catalyst to achieve PCDD/PCDF concentrations below 0.1 ng I-TEQ/Nm^3.[17]

In addition to the removal or destruction of PCDD/PCDF, other pollutants such as heavy metals, aerosols or other organic pollutants will be reduced.

Table 1. Comparison of PCDD/PCDF control systems

Control option	PCDD/PCDF removal efficiency	Co-benefits
Cyclone	Low efficiency	Coarse dust removal
Electrostatic precipitator	Low efficiency	Designed for dust removal
Bag filter	Medium efficiency	Designed for dust removal
Wet scrubber	Medium efficiency	Designed for dust or acid gas removal
Quenching and subsequent high-efficiency wet scrubber	Medium to high efficiency	Simultaneous reduction of dust, aerosols, HCl, HF, heavy metals and SO_2
Afterburner	High efficiency	No residues, but quenching of flue gases required
Catalytic oxidation (selective catalytic reaction)	High efficiency; destruction of PCDD/PCDF and other organics	No residues, simultaneous reduction of NO_x
Catalytic bag filter	High efficiency	Simultaneous dust removal
Dry absorption in resins (carbon particles dispersed in a polymer matrix)	Depends on the amount of installed material	Selective for PCDD/PCDF; material can be incinerated after use
Entrained flow reactor with added activated carbon or coke/lime or limestone solutions and subsequent fabric filter	Medium to high efficiency	Simultaneous reduction of various pollutants such as PCDD/PCDF and mercury; material can be incinerated after use[a]
Fixed bed or circulating fluidized bed reactor, adsorption with activated carbon or open hearth coke	High efficiency	Simultaneous reduction of various pollutants such as PCDD/PCDF and mercury; material can be incinerated after use[a]

a. As a carbon adsorber will also adsorb mercury, care has to be taken about mercury circulation if the spent carbon is reburnt. Additional mercury removal is therefore needed.

1.2 Rapid quenching systems

Water quench systems are also used to bring flue gas temperatures down quickly to below the formation threshold for chemicals listed in Annex C of the Stockholm Convention. These systems and

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[17] 1 ng (nanogram) = 1 × 10^{-12} kilogram (1 × 10^{-9} gram); Nm^3 = normal cubic metre, dry gas volume measured at 0°C and 101.3 kPa. For information on reporting PCDD/PCDF results see section I.C, subsection 3 of the present guidelines.

associated wastewater treatment systems must be designed to deal with the higher particulate matter loadings that will end up in the scrubber water as a consequence.

1.3 Afterburners

Afterburners are either separate from or integrated into the main combustion chamber for destroying unburnt or partially burnt carbon compounds in the exhaust gas. Depending on the actual conditions a catalyst, additional combustion air or a (natural gas-fired) burner may be required. Where appropriate, legislation would indicate minimum temperatures to achieve this destruction for a given process. Measures are required to ensure that the afterburners are actually used as required.

1.4 Dust separation

PCDD/PCDF are released with flue gases via the gas phase as well as particle bound. The fine dust fraction may be enriched in particular due to its high specific surface. Since the separation of the fine dust fraction is not always achieved with electrostatic precipitators, well-designed fabric filters are often more efficient for PCDD/PCDF emission reduction. Addition of sorbents may enhance the removal efficiency (Hübner et al. 2000).

1.4.1 Cyclones and multicyclones

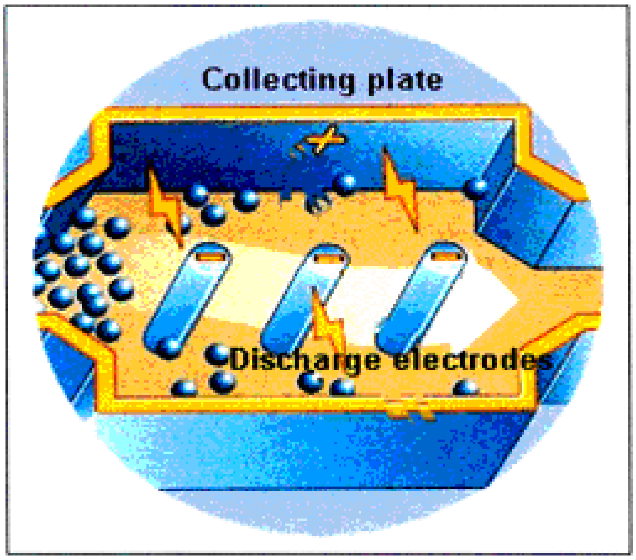
Cyclones and multicyclones (consisting of several small cyclones) extract particulate matter from the gas stream through the use of centrifugal force. Cyclones are much less effective than devices such as electrostatic precipitators or fabric filters in controlling particulate matter releases and are not used alone in advanced flue gas cleaning applications.

1.4.2 Electrostatic precipitators

Electrostatic precipitators (in Europe these systems are usually referred to as electrostatic filters) are generally used to collect and control particulate matter in combustion gas by introducing a strong electrical field into the flue gas stream (Figure 2). This acts to charge the particles entrained in the combustion gases.

Large collection plates receive an opposite charge to attract and collect the particles. The efficiency of collection is a function of the electrical resistivity of the entrained particles. Electrostatic precipitators efficiently remove most particulate matter, including chemicals listed in Annex C adsorbed to particles.

Figure 2. Electrostatic precipitator principle



Source: European Commission 2005.

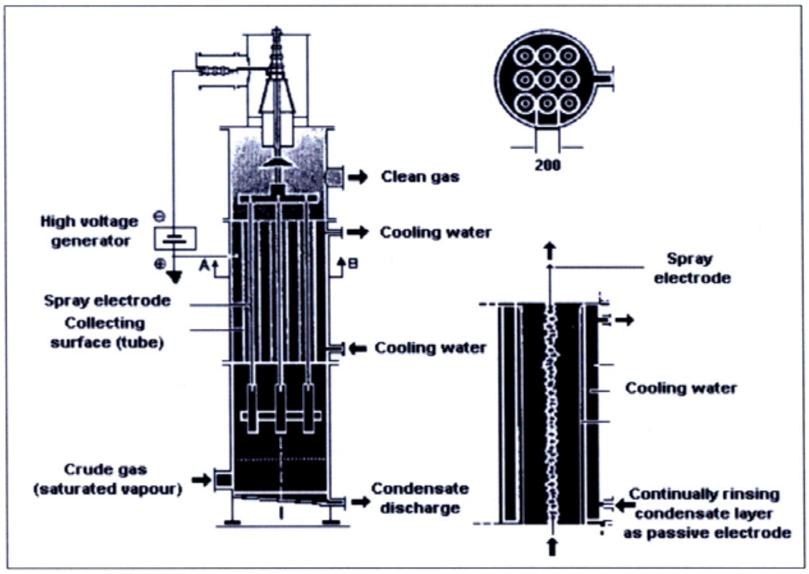
Formation of chemicals listed in Annex C can occur within the electrostatic precipitator at temperatures in the range of 200 °C to about 450 °C. As temperatures at the inlet to the electrostatic precipitator increase from 200 °C to 300 °C, PCDD/PCDF concentrations have been observed to increase with increase in temperature. As the temperature increases beyond 300 °C, formation rates decline.

Typical operational temperatures for electrostatic precipitators are 160 °C – 260 °C. Operation at higher temperatures (e.g. above 250 °C) is generally avoided as this may increase the risk of PCDD/PCDF formation.

Wet electrostatic precipitators use liquids, usually water, to wash pollutants off the collection plates. These systems operate best when the incoming gases are cooler or moist.

Condensation electrostatic precipitators use externally water-cooled bundles of plastic tubes that collect fine liquids or solids by facilitating condensation with a water quench (Figure 3).

Figure 3. Condensation electrostatic precipitator

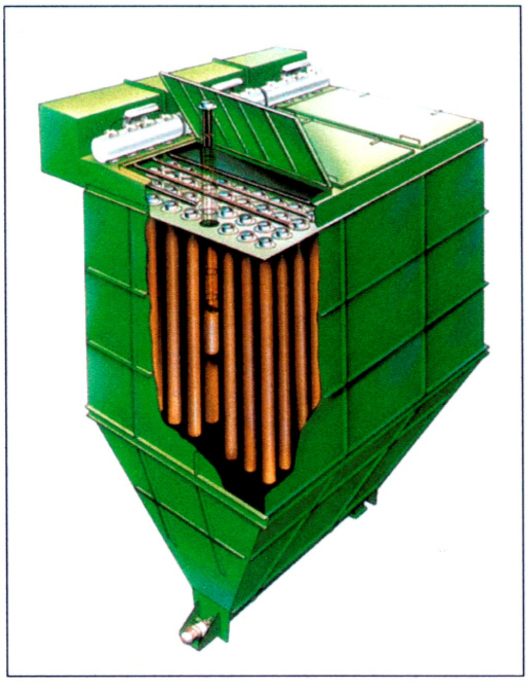


Source: European Commission 2005.

1.4.3 Fabric filters

Fabric filters are also referred to as baghouses or bag or sleeve filters (Figure 4). These particulate matter control devices are highly effective in removing chemicals listed in Annex C that may be associated with particles and any vapors that adsorb to the particles in the exhaust gas stream.

Figure 4. Schematic of a fabric filter



Source: European Commission 2005.

Filters are usually bags of 16 to 20 cm diameter, 10 m long, made from woven fibreglass material or polytetrafluoroethylene (PTFE), and arranged in series (see Table 2). An induction fan forces the combustion gases through the tightly woven fabric, which provides a bed for filter cake formation. The porosity of the fabric and the resulting filter cake allows the bags to act as filter media and retain a broad range of particle sizes down to less than 1 µm in diameter (although at 1 µm capture efficiency begins to decrease).[18] Fabric filters are subject to water damage and corrosion and gas streams must be maintained above the dew point (130-140 °C) to prevent these effects. Some filter materials are more resistant to damage. Fabric filters are sensitive to acids; therefore, they are commonly operated in combination with spray dryer adsorption systems for upstream removal of acid gases. Spray drying also serves to cool the inlet gases. Without such cooling, chemicals listed in Annex C may be formed in the fabric filters, similar to the situation with electrostatic precipitators. Dust removal systems are compared in Table 3.

Table 2. Characteristics of fabric filter materials

Fabric	Maximum temperature (°C)	Resistance		
		Acid	Alkali	Physical flexibility
Cotton	80	Poor	Good	Very good
Polypropylene	95	Excellent	Excellent	Very good
Wool	100	Fair	Poor	Very good
Polyester	135	Good	Good	Very good

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[18] 1 µm (micrometre) = 1×10^{-6} metre.

Fabric	Maximum temperature (°C)	Resistance		
		Acid	Alkali	Physical flexibility
Nylon	205	Poor to fair	Excellent	Excellent
PTFE	235	Excellent	Excellent	Fair
Polyamide	260	Good	Good	Very good
Fibreglass	260	Fair to good	Fair to good	Fair

Source: European Commission 2005.

Table 3. Comparison of dust removal systems

Dust removal system	Typical dust emission concentrations	Advantages	Disadvantages
Cyclone and multicyclone	Cyclones: 200–300 mg/m³ Multicyclones: 100–150 mg/m³	Robust, relatively simple and reliable Applied in waste incineration	Only for pre-dedusting Relatively high energy consumption (compared to electrostatic precipitator)
Electrostatic precipitator, dry	< 5–25 mg/m³	Relatively low power requirements Can use gas temperatures in the range 150 °C – 350 °C but effectively limited to 200 °C by PCDD/PCDF issue (see right)	Formation of PCDD/PCDF if used in range 200 °C – 450 °C
Electrostatic precipitator, wet	< 5–20 mg/m³	Able to reach low pollutant concentrations	Mainly applied for post-dedusting Generation of process wastewater Increase of plume visibility
Bag filter	< 5 mg/m³	Layer of residue acts as an additional filter and as an adsorption reactor	Relatively high energy consumption (compared to electrostatic precipitator) Sensitive to condensation of water and to corrosion

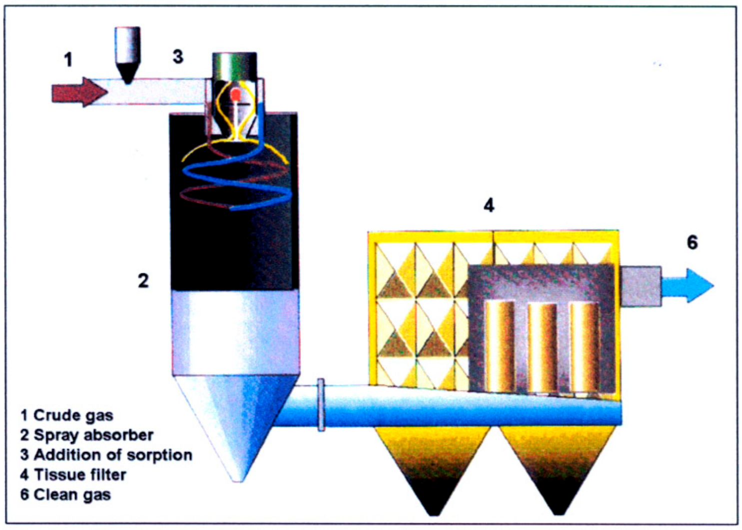
Source: European Commission 2005.

1.5 Scrubbing processes

1.5.1 Spray dry scrubbing

Spray dry scrubbing, also called spray dryer adsorption or semi-wet scrubbing, removes both acid gas and particulate matter from the post-combustion gases. In a typical spray dryer, hot combustion gases enter a scrubber reactor vessel (Figure 5).

Figure 5. Spray dry scrubbing/adsorption



Source: European Commission 2005.

An atomized hydrated lime slurry (water plus lime) is injected into the reactor at a controlled velocity. The slurry rapidly mixes with the combustion gases within the reactor. The water in the slurry quickly evaporates, and the heat of evaporation causes the combustion gas temperature to rapidly decrease. The neutralizing capacity of hydrated lime can reduce the acid gas constituents of the combustion gas (e.g. HCl and SO_2) by as much as 90%. However at waste incinerator plants spray dry scrubbing systems also typically achieve 93% SO_2 and 98% HCl control. A dry product consisting of particulate matter and hydrated lime either settles to the bottom of the reactor vessel or is captured by the downstream particulate capture device (electrostatic precipitator or fabric filter).

Spray drying technology is used in combination with fabric filters or electrostatic precipitators. In addition to reducing acid gas and particulate matter and control of volatile metals, spray drying reduces inlet temperatures to help reduce formation of chemicals listed in Annex C. PCDD/PCDF formation and release is substantially prevented by quenching combustion gases quickly to a temperature range that is unfavorable to their formation, and by the higher collection efficiency of the resulting particulate matter.

Solid residue from spray dry usually contains a mixture of sulphates, sulphites, fly ash, pollutants and unreacted adsorbents and has to be landfilled.

1.5.2 Wet scrubbers

Wet scrubbers encompass a number of processes designed for acid gas and dust removal. Alternative technologies include jet, rotation, venturi, spray, dry tower and packed tower scrubbers (European Commission 2005). Wet scrubbers help reduce formation and release of chemicals listed in Annex C in both vapour and particle forms. In a two-stage scrubber, the first stage removes hydrogen chloride (HCl) through the introduction of water, and the second stage removes sulphur dioxide (SO_2) by addition of caustic or hydrated lime. In the wet scrubbing process gypsum can be produced, which reduces the amount of waste going to landfills.

In the case of packed tower scrubbers, packing that contains polypropylene embedded with carbon can be used for specific removal of PCDD/PCDF.

Wet scrubbers have the highest removal efficiencies for soluble acid gases among the demonstrated techniques where removal efficiency is a function of pH of scrubber water. Solid particles in scrubber water may also cause interaction with PCDD/PCDF in the mobile gas stream, thus influencing the reliability of the relationship between results obtained from periodic stack gas monitoring and the destruction efficiency of the plant.

Memory effects are mainly due to the accumulation of various PCDD/PCDF congeners in plastic materials used in wet scrubbers. The effect may last several hours or may be long-term. As such, there is a preference for the removal of PCDD/PCDFF before wet scrubbing to reduce memory effects. An assessment should be carried out regarding PCDD/PCDF build-up in the scrubber and suitable measures adopted to deal with this build-up and prevent scrubber breakthrough releases. Particular consideration should be given to the possibility of memory effects during shut-down and start-up periods.

1.5.3 Fine dust absorber

Fine dust absorbers are equipped with a large number of pneumatic two-component jets (water and compressed air). Such high-efficiency absorbers can separate the PCDD/PCDF-covered fine dust through the very fine spray-like dispersal of the absorption solution and the high speed of the water droplets. In addition, the cooling of the exhaust gases and the undercooling in the dust absorber initiate condensation and improve the adsorption of volatile compounds on the dust particles. The absorption solution is treated by wastewater processing. The addition of adsorbents may further improve PCDD/PCDF reduction. With simple scrubbers for the separation of acid exhaust gases appreciable PCDD/PCDF removal is not possible. The achievable emission values of high-efficiency absorbers are in a range of 0.2–0.4 ng I-TEQ/Nm^3. This is equal to a separation efficiency of approximately 95% (Hübner et al. 2000). Waste arising from this process is normally disposed in a specially engineered landfill.

1.6 Sorption processes

1.6.1 Fixed bed filters

In the fixed bed process, precleaned exhaust gases are conducted at temperatures of 110 – 150 °C through an activated carbon based adsorbent material. Necessary devices include fresh adsorbent supply, fixed bed reactor and spent adsorbent system. The activated coke bed separates residual dust, aerosols and gaseous pollutants. It is moved cross-current and countercurrent in order to prevent blockage of the bed through, for example, residual dust.

Usually, the PCDD/PCDF-covered coke is disposed off through (internal) combustion, by which organic pollutants are to a large extent destroyed. Inorganic pollutants are released via slugs or separated in the exhaust gas fine cleaning again. The fixed bed process achieves PCDD/PCDF reductions of 99.9%. Compliance with a performance standard of 0.1 ng I-TEQ/Nm^3 is state-of-the-art (Hübner et al. 2000; Hartenstein 2003).

1.6.2 Flow injection process

In order to enhance the separation efficiency of fabric filters, adsorbents with high PCDD/PCDF take-up capacities are injected into the exhaust gas stream. In general, activated coal or hearth-type coke are used as adsorbents together with lime hydrate. The separation is carried out in a fabric filter located at the end of the process, where adsorbents and dust are separated and a filter layer is formed. The appropriate disposal of the PCDD/PCDF-containing filter dust has to be assured. Conventional operation temperatures range from 135 °C to 200 °C.

Usually, the PCDD/PCDF-covered coke is disposed off through (internal) combustion. By (internal) combustion organic pollutants are destroyed to a large extent. Inorganic pollutants are released via slugs or separated in the exhaust gas fine cleaning again.

With the flow injection process, filtration efficiencies of 99% are achieved. The PCDD/PCDF removal efficiency depends on the quality of the adsorbent injection, the effectiveness of the adsorbent-flue gas mixing system, the type of particulate filter and the operation of the system. Another critical parameter is the mass flow rate of the injected adsorbent. For applying this technology most effectively a baghouse should be used. Compliance with a performance standard of 0.1 ng I-TEQ/Nm^3 is state-of-the-art (Hübner et al. 2000; Hartenstein 2003).

1.6.3 Entrained flow reactor

For this technology the same adsorbents are applied as used for the adsorbent injection process. However, the adsorbent is usually applied in a mixture with hydrated lime or other inert materials such as limestone, quicklime or sodium bicarbonate. Upstream of the entrained flow reactor for flue gas polishing, a conventional flue gas cleaning system is required for removing the bulk of the fly ash and the acid gases. Necessary devices include fresh adsorbent supply, fabric filter, recirculation system and spent adsorbent system. Conventional operation temperatures range from 110 °C to 150 °C. Compliance with a performance standard of 0.1 ng I-TEQ/Nm^3 is state-of-the-art (Hartenstein 2003).

1.6.4 Dry absorption (in resins)

A new flue gas cleaning technology has been developed that combines adsorption and absorption of PCDD/PCDF into plastic structures containing dispersed carbon particles. In this new material, the PCDD/PCDF are first adsorbed in the polymer matrix and then diffuse to the surface of the carbon particles where they are irreversibly absorbed. The most common application of Adiox^{TM} is tower packings employed in gas cleaning systems. Until now, more than 30 full-scale incineration lines with flow gases ranging from 5,000 to 100,000 Nm^3/h are installed in wet flue gas cleaning systems. The removal efficiency depends on the amount of installed material. The technology can be applied as the main PCDD/PCDF cleaning system or to increase the safety margins or to reduce the memory effect in wet scrubbers. If Adiox is employed in dry adsorbers, the removal efficiency per installed amount is higher (Andersson 2005).

1.7 Catalytic oxidation of PCDD/PCDF

1.7.1 Selective catalytic reactions

Catalytic oxidation processes, which are normally used for reducing nitrogen oxide emissions, are applied for PCDD/PCDF destruction as well. Therefore, effective dedusting (e.g. emission values of particulate matter of below 5 mg/m^3) is a requirement for achieving low overall emissions of chemicals listed in Annex C. For the removal of PCDD/PCDF only (e.g. with the DeDiox process), ammonia injection is not necessary. In this case, operation temperatures range from 130 °C to 350 °C.

The main advantages of this process are an easy operation and no residues apart from very little spent catalyst. Therefore, catalytic oxidation does not cause disposal problems.

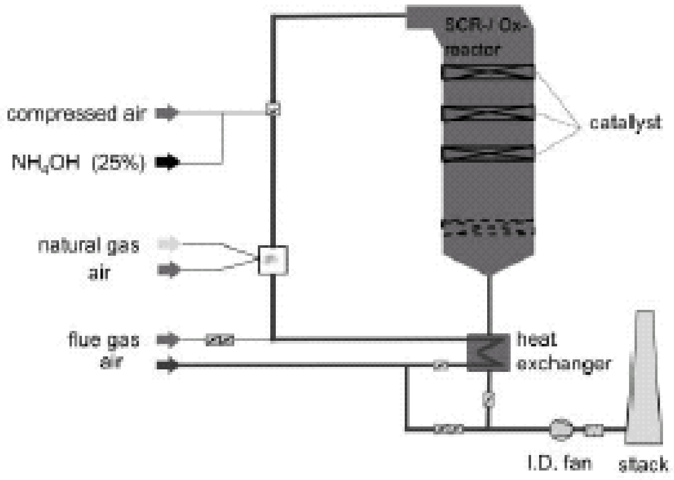
Decomposition reaction for Cl_4DD: $C_{12}H_4Cl_4O_2 + 11\ O_2 \rightarrow 12\ CO_2 + 4\ HCl$

In general, the installations are operated in clean gas circuits, i.e., dust and heavy metals are separated before the catalyst in order to prevent rapid wear and deactivation of the catalysts through catalyst poisons.

With catalytic oxidation, only the PCDD/PCDF fraction in the gas phase can be captured. Nevertheless, emission reductions of 95 to 99% can be achieved. PCDD/PCDF reduction rate depends on the installed catalyst volume, the reaction temperature and the space velocity of the flue gas through the catalyst. PCDD/PCDF testing showed emission values lower than 0.01 ng I-TEQ/Nm^3 (dry basis, 11% O_2).

In the selective catalytic reaction process for combined removal of PCDD/PCDF and NO_x an air-ammonia mix is injected into the flue gas stream and passed over a mesh catalyst (Figure 6). The ammonia and NO_x react to form water and N_2 (European Commission 2005; Hübner et al. 2000; Hartenstein 2003).

Figure 6. High-temperature selective catalytic reduction reactor for simultaneous NO_x and PCDD/PCDF removal



Source: Hartenstein 2003.

1.7.2 Catalytic bag filters

Catalytic bag filters with PTFE membrane enable dust concentrations in cleaned flue gases of about 1–2 mg/Nm^3. Currently applications are known in waste incineration, crematoria, metal industries and cement plants. Filter bags that are impregnated with a catalyst, or contain a powdered catalyst directly mixed in fibre production, have been used to reduce PCDD/PCDF emissions. This type of filter bag is generally used without the addition of activated carbon so that the PCDD/PCDF can be destroyed on the catalyst rather than absorbed in the carbon and discharged as solid residues. They operate at temperatures between 180 °C and 250 °C.

A catalytic filter system incorporates microporous PTFE fibre with the catalyst particles built into the fibre structure. In this process, PTFE particles are mixed with the catalyst and processed to produce fibres. A microporous ePTFE membrane is laminated to the ePTFE/catalyst microporous fibres to produce the filtration medium. This material is then sewn into filter bags, which can be installed in a baghouse. Applications at German and Japanese crematoria gave emissions below 0.1 ng I-TEQ/Nm^3 (Xu et al. 2003).

2. Treatment of flue gas treatment residues

The treatment of flue gases to remove contaminants (as described above) will generate a number of residues, which must either be disposed of or undergo additional treatment before disposal and potential reuse. Appropriate options for disposal or reuse of these residues will depend on the type and degree of contamination, as well as the waste matrix (inert fraction). Flue gas treatment residues may be solids (e.g. baghouse or electrostatic precipitator dust), wastewaters or slurries containing varying amounts of dissolved and suspended solids (e.g. from wet electrostatic precipitators and other wet scrubbers) or spent adsorbent materials (e.g. saturated resins). These residues may contain, in addition to the inert materials, toxic metals, such as arsenic, lead, cadmium, mercury or others, as well as PCDD/PCDF.[19] These residues could be handled in one of several different ways, as discussed below. Current practices for the treatment and disposal of flue gas treatment residues include reuse in the

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[19] For additional guidance on management of residues based on their concentration of persistent organic pollutants (including when the persistent organic pollutant content is low, as per Stockholm Convention Article 6.1 (d) (ii)), see Basel Convention Secretariat 2005.

process from which they were derived, disposal to landfill, stabilization and subsequent disposal, vitrification, incorporation into road-making materials, disposal or valorization in salt or coal mines, and catalytic or thermal treatment.

According to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, Annex I wastes, including fly ashes, containing PCDD or PCDF are classified as hazardous waste.

2.1 Management of solid flue gas treatment residues[20]

One major flue gas treatment residue (or air pollution control residue) is fly ash. Fly ash removal from flue gas by use of dry scrubbers, cyclones or fabric filters will result in dry fine solid particulate material having a range of properties and contaminants depending on the combustion source that produced it. Air pollution control of many types of combustion sources, including municipal and hazardous waste incinerators, steel-making electric arc furnaces and cement kilns, can generate such a fine dry particulate material when dry controls are used. These dry particulate residues will contain different levels of metals (depending on feedstocks) and may also have some PCDD/PCDF and other polycyclic aromatic hydrocarbons adsorbed onto them, depending on the combustion conditions.

Contaminant releases to the environment from these dry materials may be by a number of routes, including leaching to groundwater, wind-blown dust, crop plant uptake or direct ingestion by humans or wildlife (potentially including farm animals). All management of these materials must be done with consideration of these potential releases, as required by the particular residue. A number of management options, including both beneficial reuse and treatment or disposal, are available for these dry residues, depending on the properties of the inert fraction and the type and level of contamination with metals and organics.

2.1.1 Residue reuse

Limited reuse is appropriate for dry, solid residues.

A major reuse of coal fly ash is in the construction of roads or buildings because of its pozzolanic properties. It can be used in cement and concrete production.

Fly ashes should never be used as soil amendment in agricultural or similar applications. Addition to soil may result in subsequent dispersion of the ash and any contaminants. In agricultural uses plants may take up contaminants, resulting in exposure to human or animals that consume the plants. Pecking or grazing animals may directly ingest contaminants, with subsequent exposure to humans when they consume the animals or animal products (e.g. milk and eggs).

2.1.2 Stabilization and solidification

Treatment and disposal options for solid residues from flue gas control systems include solidification or stabilization with Portland cement (or other pozzolanic materials), alone or with additives or a number of thermally based treatments, followed by appropriate disposal (based on anticipated releases from the treated residuals). Some residues with low levels of contamination may require no treatment before disposal in a landfill, based on an assessment of their contaminant release potential.

The main purpose of solidification is to produce a material with physical and mechanical properties that promote a reduction in contaminant release from the residue matrix. An addition of cement, for example, generally decreases hydraulic conductivity and porosity of the residue, while increasing durability, strength and volume.

Solidification methods commonly make use of several, mostly inorganic, binder reagents: cement, lime and other pozzolanic materials such as coal fly ash, blast furnace bottom ash or cement kiln dust, although some organic binders such as bitumen/asphalt or paraffin and polyethylene can also be used.

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[20] The subparagraphs in paragraph 2 are cited from European Commission 2005, chapter 2.7.3.

Combinations of binders and various types of proprietary or non-proprietary additives are used as well. By far the most prevalent solidification technique is cement stabilization.

The main concept of chemical stabilization is to bind the heavy metals in more insoluble forms than those in which they occur in the original untreated residues. These stabilization methods make use of both the precipitation of metals in new minerals and the binding of metals to minerals by sorption. This process includes the solubilization of the heavy metals in the residues and a subsequent precipitation in, or sorption to, new minerals.

Several of the stabilization methods incorporate an initial washing step whereby a major part of soluble salts and to some extent metals are extracted before chemical binding of the remaining metals. These methods are completed by dewatering the stabilized product.

Treatment options using extraction and separation processes can, in principle, cover all types of processes for extracting specific components from the residues. However, most emphasis has been put on processes involving the extraction of heavy metals and salts with acid.

While stabilization and solidification approaches to waste treatment are typically directed at controlling the release of contaminant metals, PCDD/PCDF and other polycyclic aromatic hydrocarbons may be only partially controlled by these treatments (although these compounds are very hydrophobic and so generally do not leach very fast or at very high concentrations). Addition of adsorbents (such as clays or activated carbon), which are then incorporated into the treated waste matrix, can improve control of these organics. Laboratory leaching tests or other evaluations should be applied for assessing the effectiveness of any of these treatment approaches.

2.2 Thermal treatment of flue gas treatment residues

Thermal treatment can be grouped into three categories: vitrification, melting and sintering. The differences between these processes are chiefly related to the characteristics and properties of the final product.

- Vitrification is a process whereby residues are treated at high temperature (currently 1,300 °C to 1,500 °C) and then quickly quenched (with air or water) to obtain an amorphous glassy matrix. After cooling down, the melt forms a single-phase product called a vitrificate. The vitrificate can be a glass-like or stone-like product, depending on the melt composition. Additives are sometimes (but not usually) added to the residues to favour the formation of the glassy matrix.
- Melting is similar to vitrifying, but the quenching step is controlled to allow crystallization of the melt as much as possible. It results in a multiphase product. Temperatures and the possible separations of specific metal phases are similar to those used in vitrifying. It is also possible to add specific additives to favour the crystallization of the matrix.
- Sintering involves the heating of residues to a level where bonding of particles occurs and the chemical phases in the residues reconfigure. This leads to a denser product with less porosity and a higher strength than the original product. Typical temperatures are around 900 °C. When municipal solid waste is incinerated some level of sintering will typically take place in the incineration furnace. This is especially the case if a rotary kiln is used as part of the incineration process.

Regardless of the actual process, the thermal treatment of residues in most cases results in a more homogeneous, denser product with improved leaching properties. The energy requirements of stand-alone treatments of this type are generally very high.

These processes are generally employed to immobilize metals or radiological contaminants, and will significantly reduce the potential for leaching of many contaminants likely to be found in flue gas treatment solid residues. Again, leaching tests may be useful in evaluating the effectiveness of these treatments. Because these are high-temperature processes, any PCDD/PCDF or other polycyclic aromatic hydrocarbons adsorbed onto the original dry solids may well be destroyed as part of the treatment process. However, as high-temperature processes, air emissions must be monitored from the treatment itself, as it may result in air pollution control residues of its own, which will then need to be managed in an environmentally sound manner.

2.3 Treatment of spent dry adsorption resins

Use of specialized dry resins to remove flue gas contaminants such as PCDD/PCDF before release to the air will also generate a treatment residue in the form of the spent resin cartridge or bulk resin material. If such resins are designed to be regenerated, either through thermal desorption or by other means, then the regeneration process will itself generate residues or releases to the air that must be controlled and managed. If spent resins are to be disposed of after a single use (or for regenerated resins that are no longer useful), evaluation of the level and type of contaminants on the resin will help determine whether it can be landfilled without treatment, or requires some treatment before disposal. For some resins, incineration or some other treatment that destroys both the resin and adsorbed contaminants may also be a possibility.

2.4 Treatment of wastewaters

Many processes have wastewater streams that cannot reasonably be released to the open environment without treatment. Flue gas treatment systems are similar to chemical processes in that they each may have wastewater treatment needs.

Various wet processes may also be used to remove pollutants from flue gas streams and so prevent their release to the air. Resultant wastewaters will contain some amount of dissolved as well as suspended materials.

As with many chemical processes, the first step in handling these flue gas treatment residues, particularly where metals are the main concern, is often separation of the liquid and solid portions. This can often be accomplished using settling ponds or tanks, although land-based ponds may require liner systems to prevent leaching of contaminants into groundwater. The solid fraction may be further dewatered and dried and then handled as a solid material as discussed above. The water portion may require further removal of contaminants before meeting requirements for discharge to surface water or groundwater recharge areas. Treatments could include addition of chemicals to precipitate out metal salts, or use of adsorbent materials to remove organics. These wastewater treatment residuals would then also require appropriate treatment and disposal.

Flue gas treatment residues from wet processes may also contain organic constituents, including PCDD/PCDF or other polycyclic aromatic hydrocarbons. Biological treatment in ponds or impoundments can usually reduce the concentration of these and other organic constituents that may occur in flue gas treatment residues.

Most wastewaters do not present opportunities for reuse. However, treatment of flue gas to remove sulphur, using ground and slaked lime, presents one such opportunity. In the fully oxidized form of this treatment, the solid residue in the wastewater is a high-quality calcium sulphate, or gypsum. This gypsum can be dewatered and used to manufacture wallboard for residential or other buildings, sometimes at costs that are much lower than those for wallboard from mined gypsum.

(v) Training of decision makers and technical personnel

The importance of technical assistance, in particular training, as a need to strengthen the national capabilities of developing countries (in particular the least developed) and countries with economies in transition, is recognized in the preambular paragraphs of the Stockholm Convention, and Article 12 states: “Parties recognize that rendering of timely and appropriate technical assistance in response to requests from developing country Parties and Parties with economies in transition is essential to the successful implementation of this Convention.”

In this regard capacity-building technical assistance, in particular training in available environmental methodologies, practices and tools, with specific reference to the particular needs of a Party, may give a better understanding of procedures for conducting, on a sustained basis, daily operational practices and preventive maintenance of the best available techniques and best environmental practices being introduced as components of the Party's national implementation plan. It is of utmost importance that capacity-building technical assistance, in particular training, should be provided at both managerial and technical or operating levels in public and private sector organizations involved in the implementation of the guidelines for best available techniques and best environmental practices. Taking into consideration the complexity of many best available techniques and the required holistic and preventive approach for introducing best environmental practices, life cycle management, in addition to relevant health and safety issues, should be given priority consideration in capacity-building, with a risk prevention and reduction approach.

(vi) Testing, monitoring and reporting

1. Testing and monitoring

Monitoring of releases of chemicals listed in Annex C of the Stockholm Convention is critical to achieving the goals of the Convention. However, many developing countries and countries with economies in transition do not have the necessary capacity in terms of costs, technical expertise and laboratories and, in some cases, the economic returns for facilities may not be sufficient to cover all costs associated with monitoring. Consequently, it is necessary to establish and strengthen regional, subregional and national technical capacity and expertise, including laboratories. This enhanced capacity may also promote monitoring at specified intervals for existing sources.

Proposals for new facilities or proposals to significantly modify existing facilities should, as part of best available techniques and best environmental practices, include plans for the evaluation of compliance with the target values for releases of chemicals listed in Annex C in stack gases and other outputs that are given in this guidance document. Accordingly, as part of ongoing operation, these facilities should demonstrate, through monitoring at specified intervals, as appropriate, that the performance levels continue to be achieved.[21, 22]

1.1 Sampling and analysis of PCDD/PCDF and dioxin-like PCB

Validated, standardized methods of sampling and analysis are available for polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) but not yet for all chemicals listed in Annex C (Table 4). The methods for sampling and monitoring for polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB) must be developed and validated. Methods for sampling stack gases include those with sampling periods of 4 to 8 hours as well as those that are quasi-continuous. Most if not all regulatory regimes for PCDD/PCDF are currently based on toxic equivalents (TEQ).23

Sampling of PCDD/PCDF emissions to date is mainly undertaken by using one of the methods listed in Table 4.

Table 4: Methods for stack sampling and analysis of PCDD/PCDF and PCB

Method	Substances analyzed	Analytical principle	Reference
EN 1948	PCDD/PCDF	HRGC/HRMS	European Committee for Standardization
US EPA Method 23	PCDD/PCDF	HRGC/HRMS	U.S. Environmental

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[21] Determination of the mass concentration of chemicals listed in Annex C in releases from a given source should follow nationally or internationally recognized standard methods of sampling, analysis and evaluation of compliance.

[22] In most cases, target values currently exist only for PCDD/PCDF.

[23] To determine TEQ concentrations, each of the 17 PCDD/PCDF congeners that are of greatest toxicological concern are quantified using capillary gas chromatograph high-resolution/mass spectrometer.

Method	Substances analyzed	Analytical principle	Reference
			Protection Agency
VDI Method 3499	PCDD/PCDF	HRGC/HRMS	Association of German Engineers (VDI)
Canada Methods EPS 1/RM/2 and EPS 1/RM/3	PCDD/PCDF, PCB	HRGC/HRMS	Environment Canada
Japanese Industrial Standard K 0311	PCDD/PCDF, dioxin-like PCB	HRGC/HRMS	Japanese Industrial Standards Committee

PCDD/PCDF analysis is carried out using high-resolution mass spectrometry. Quality control procedures are required at each stage of the analysis and recovery spike concentrations associated with both sampling and extraction. United States EPA Method 23 specifies that all recoveries should be between 70% and 130%. Canada provides detailed quality assurance guidance on the analysis of samples containing dioxins and furans in a range of matrices in its Reference Method EPS 1/RM/2.

The European Standard EN 1948 has been developed for separation detection, and quantification of PCDD/PCDF and dioxin-like PCB in emission samples from stationary sources at concentrations at about 0.1 ng TEQ/Nm^3. Parts 1-3 detail sampling; extraction and clean-up; and identification and quantification of PCDD/PCDF (adopted in 1996, revision adopted in 2006). Part 4 details the standard for dioxin-like PCB (adopted in 2007).

The lower detection limits measured during the validation test of EN 1948 at a municipal solid waste incinerator varied between 0.0001 and 0.0088 ng/Nm^3 for the 17 individual PCDD/PCDF toxic congeners (CEN 1996c; see also CEN 1996a, 1996b)

In the new draft of EN 1948-3 of February 2004 (updating CEN 1996c), Annex B, the uncertainty for the complete procedure is given to be 30–35% and the external variability is estimated to be ± 0.05 ng I-TEQ/m^3 at a mean concentration 0.035 ng I-TEQ/Nm^3.

Taking into account the toxic equivalence factors for the individual congeners the resulting overall detection limits vary between 0.001 and 0.004 ng I-TEQ/Nm^3. It is reasonable to assume that concentrations lower than 0.001 ng I-TEQ/m^3 should be considered as being below the detection limit.

A study performed by Environment Canada assessed the variability of sampling and analysis of 53 sets of PCDD/PCDF emission data from 36 combustion facilities. The limit of quantification for PCDD/PCDF emissions was estimated to be 0.032 ng I-TEQ/m^3, although this limit may vary depending on sampling volume, interfering substances and other factors.

Interferences should be expected to occur from compounds that have similar chemical and physical properties to PCDD/PCDF (CEN 1996c).

1.2 Limit of detection and limit of quantification

The "limit of detection" (LOD) is the smallest amount or concentration of analyte in the test sample that can be reliably distinguished, with stated significance, from the background or blank level.

The "limit of quantification" (LOQ) of an analytical procedure is the lowest amount or concentration of analyte in a sample which can be quantitatively determined with an acceptable level of precision and accuracy. The limit of quantification should be stated if it is necessary to specify a lower limit of measurement below which acceptable accuracy and precision is not attained. Using the method, carry out a number of independent determinations, preferably >20, using a sample which is known to contain the analyte at between 2 and 5 times the estimated detection limit. The limit of quantification is the concentration at which an acceptable degree of performance, in terms of RSD% (relative standard deviation), is obtained. It is usually the case that the limit of quantification corresponds to the lowest standard concentration level in the calibration range.

In the context of regulatory limit values, or for reporting measured concentrations, there is no general rule how to treat results below LOQ. Very often, the regulations or laws define the way of reporting results. For reporting, the following definitions should be taken into account:

– Lower-bound:	Non-quantifiable peaks are set to zero
– Upper-bound:	Full LOQ included in presentation of result

Criteria should be set to define lower-bound and upper-bound concentrations and the reporting value and therefore the LOQ should be at least 1/5 of the regulatory limit or level of interest or baseline concentration.

1.3 Gas reference conditions

Table 5 presents reference condition conversions used in Canada, the European Union and the United States of America.

Table 5: Reference Condition Conversions

Unit	Country/Region	Temperature (°C)	Pressure (atm)	Gas conditions
Nm^3 (Normal cubic meter)	European Union (EU)	0	1	Dry; 11% oxygen for municipal waste incinerators and co-combustion of waste; 10% oxygen for cement plants; no oxygen level requirements for all other plants (i.e., concentrations are reported at the actual oxygen content and are not normalized to any fixed O_2 content)
Rm^3 (Reference cubic meter)	Canada	25	1	Dry; 11% oxygen for incinerators and coastal pulp and paper mill boilers, operating oxygen levels for sinter plants and steel manufacturing electric arc furnaces
Sm^3 (or dscm) (Dry standard cubic meter)	United States (U.S.)	20	1	Dry; 7% oxygen or 12% carbon dioxide for incinerators and most combustion sources.

0.1 ng TEQ/Nm^3 (EU) = **0.131** ng TEQ/Sm^3 (U.S.) = **0.092** ng TEQ/Rm^3 (Canada)

1.4 Bioassay methods

Four bioassay methods, three reporter gene bioassay methods and one enzyme imunoassay method, have been approved in Japan for measuring dioxins in emission gas, dust and cinders from waste incinerators. The methods provide a less costly alternative to high-resolution gas chromatography/mass spectrometry and are approved for measuring emissions from incinerators with a capacity less than 2 tons/hour (emission standards for new facilities: 5 ng WHO-TEQ/Nm^3) and dust and cinders from all waste incinerators (treatment standard 3 ng WHO-TEQ/g).

Table 6: Bioassay methods for stack and residue measurements at small waste incinerators

Method	Analytical Principle	Reference
CALUX Assay	Reporter gene assay	Xenobiotic Detection Systems International
P450 Human Reporter	Reporter gene assay	Columbia Analytical

Gene System		Services
AhR Luciferase Assay	Reporter gene assay	Sumitomo Chemical Co., Ltd

Guidelines for appropriate monitoring programmes are also necessary. In that regard, the United Nations Environment Programme (UNEP, 2004) has developed guidance for prioritizing measurements and minimizing the number of measurements for impact assessment. The European Commission has prepared a reference document on the general principles of monitoring; and some companies and industry associations have agreed monitoring requirements. Model legislation and regulations will also facilitate the establishment and implementation of programmes to monitor releases of chemicals listed in Annex C, including such approaches as bioassay monitoring.

2. Reporting

Reporting of releases and other relevant information is a key part of meeting Party obligations under Article 9 (Information exchange), Article 10 (Public information, awareness and education) and Article 11 (Research, development, and monitoring) of the Stockholm Convention. Parties seeking to employ best environmental practices for Annex C sources should include measures described in these articles, including:

- Mechanisms such as pollutant release and transfer registers to collect and disseminate comprehensive and chemically specific information on production and releases of chemicals listed in Annexes A, B or C together with their sources;
- Public participation in the regulation of sources of chemicals listed in Annex C;
- Public availability of monitoring data collected from sources in Annex C (taking into account paragraph 5 of Article 9);
- Making the results of their research, development and monitoring activities accessible to the public on a timely and regular basis (Article 11, paragraph 2 (e)).

Full provision of relevant information can encourage and facilitate public participation.

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Section IV

Compilation of summaries from the source categories included in sections V and VI

Contents

Preamble

This section includes a compilation of all the summaries from the source categories in sections V and VI of the draft guidelines on Best Available techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants.

Each summary may include the following information, as appropriate:

- A brief description of the source, its purpose and the processes involved;
- Potential of the source for generation of chemicals listed in Annex C of the Stockholm Convention, namely: polychlorinated dibenzo-*p*-dioxins (PCDD); polychlorinated dibenzofurans (PCDF); polychlorinated biphenyls (PCB); and hexachlorobenzene (HCB);
- Best available techniques and best environmental practices to minimize emissions of chemicals listed in Annex C;
- Primary and secondary measures that may assist in reducing emissions;
- Alternatives, where applicable, that may be preferable to current processes and practices;
- Performance levels associated with best available techniques.

Summaries of section V: source categories included in Part II of Annex C

A. Waste incinerators

(i) Municipal solid waste, hazardous waste and sewage sludge

Summary

Waste incinerators are identified in the Stockholm Convention as having the potential for comparatively high formation and release of chemicals listed in Annex C to the environment.

The potential purposes of waste incineration include volume reduction, energy recovery, destruction or at least minimization of hazardous constituents, disinfection and the recovery of some residues.

When considering proposals to construct new waste incinerators, priority consideration should be given to alternatives such as activities to minimize the generation of waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste. Priority consideration should also be given to approaches that prevent the formation and release of persistent organic pollutants.

The environmentally sound design and operation of waste incinerators requires the use of both best available techniques and best environmental practices (which are to some extent overlapping) to prevent or minimize the formation and release of chemicals listed in Annex C.

Best environmental practices for waste incineration include appropriate off site procedures (such as overall waste management and consideration of environmental impacts of siting) and on site procedures (such as waste inspection, proper waste handling, incinerator operation and management practices and handling of residues).

Best available techniques for waste incineration include appropriate selection of site; waste input and control; techniques for combustion, flue gas, solid residue and effluent treatment.

To achieve best results for environmental protection as a whole it is essential to coordinate the waste incineration process with upstream activities (e.g. waste management techniques) and downstream activities (e.g. disposal of solid residues from waste incineration).

Releases of chemicals listed in Annex C from municipal solid waste incinerators designed and operated according to best available techniques and best environmental practices occur mainly via fly ash, bottom ash and filter cake from wastewater treatment. Therefore it is of major importance to provide for a safe sink of these waste types, for example by pretreatment and final disposal in dedicated landfills, which are designed and operated according to best available techniques.

With a suitable combination of primary and secondary measures, PCDD/PCDF performance levels in air emissions no higher than 0.1 ng I-TEQ/Nm^3 (at 11% O_2) are associated with best available techniques. It is further noted that under normal operating conditions emissions lower than this level can be achieved with a well designed waste incineration plant.

Best available techniques for discharges of waste water from effluent treatment plants, receiving flue gas treatment scrubber effluents, are associated with PCDD/PCDF concentration levels well below 0.1 ng I-TEQ/l.

(ii) Medical waste

Summary

Incineration of medical waste (infectious health-care waste, biological health-care waste and sharps in dedicated waste incineration plants is performed in order to minimize chemical, biological and physical risks, and to reduce the volume of waste as a pretreatment step to environmentally sound landfilling.

If medical waste is incinerated in conditions that do not constitute best available techniques or best environmental practices, there is potential for the release of PCDD and PCDF in relatively high concentrations. For small medical waste incinerators, application of best available techniques is often difficult, given the high costs associated with building, operating, maintaining and monitoring such facilities.

Possible alternatives to incineration are sterilization (steam, advanced steam, dry heat), microwave treatment, alkaline hydrolysis, biological treatment or in certain cases landfilling. The most important step in managing medical waste is segregating different types of waste at the source. As between 75% and 90% of waste in hospitals is comparable to municipal solid waste, segregation greatly reduces the volume of medical waste. Effective waste management, including waste minimization and segregation at the source, is essential.

Appropriate treatment of bottom ashes and residues from flue gas cleaning is essential for the reduction of PCDD/PCDF releases into the environment. The use of best available techniques in incinerators will also reduce emissions of hydrochloric acid and metals (in particular mercury) and will also, in effect, reduce subsequent releases from residues disposed of into landfills.

With regard to incineration, primary measures alone will significantly reduce emission of the chemicals listed in Annex C of the Stockholm Convention. However, implementation of best available techniques requires both primary and secondary measures. .

With a suitable combination of primary and secondary measures, PCDD/PCDF emission levels in air emissions no higher than 0.1 ng I-TEQ/Nm^3 (at 11% O_2) are associated with best available techniques. It is further noted that under normal operating conditions emissions lower than this level can be achieved with a well designed waste incineration plant.

Best available techniques for discharges of waste water from effluent treatment plants, receiving flue gas treatment scrubber effluents, are associated with PCDD/PCDF concentration levels well below 0.1 ng I-TEQ/l.

B. Cement kilns firing hazardous waste

Summary

The main purpose of cement kilns is clinker production. Firing wastes in cement kilns aims at energy recovery and substitution of fossil fuels or substitution of minerals. In some cases hazardous wastes are disposed of in these installations.

The manufacturing process includes the decomposition of calcium carbonate ($CaCO_3$) at about 900 °C to calcium oxide (CaO, lime) (calcination) followed by the clinkering process at about 1450 °C in a rotary kiln. The clinker is then ground together with gypsum and other additives to produce cement. According to the physical and chemical conditions the main process routes for the manufacture of cement are termed dry, wet, semi-dry and semi-wet.

The combustion process in the kiln, has the potential to result in the formation and subsequent release of chemicals listed in Annex C of the Stockholm Convention. In addition, releases from storage sites may occur.

Well-designed process conditions, and the installation of appropriate primary measures, should enable cement kilns firing hazardous waste to be operated in such a manner that the formation and release of chemicals listed in Annex C can be minimized sufficiently to achieve concentrations of PCDD and PCDF in flue gases of < 0.1 ng I-TEQ/Nm^3 (oxygen content 10%), depending on such factors as the use of clean fuels, waste feeding, temperature and dust removal. Where necessary, additional secondary measures to reduce such emissions should be applied.

Many data on PCDD/PCDF emissions to air are available

PCDD/PCDF releases via cement kiln dust and possibly clinker have been reported and are currently under further investigation. Data on PCB and HCB releases are still scarce

The performance levels associated with best available techniques and best environmental practice for control of PCDD/PCDF in flue gases are < 0.1 ng I-TEQ/Nm^3 with reference conditions of 273 K, 101.3 kPa, 10% O_2 and a dry gas basis.

C. Production of pulp using elemental chlorine or chemicals generating elemental chlorine

Summary

The main processes involved in making pulp and paper products are raw material handling and preparation, storage (and preservation for non-woods), wood debarking, chipping and agricultural residue cleaning, deknotting, pulping, pulp processing and bleaching if required and, finally, paper or paperboard manufacturing.

Of the chemicals listed in Annex C of the Stockholm Convention, only PCDD and PCDF have been identified as being produced during the production of pulp using elemental chlorine. Of the 17 PCDD/PCDF congeners with chlorine in the 2,3,7 and 8 positions, only two congeners – namely 2,3,7,8-TCDD and 2,3,7,8-TCDF – have been identified as potentially being produced during chemical pulp bleaching using chlorine. Most of the formation of the 2,3,7,8-TCDD and 2,3,7,8-TCDF is generated in the C-stage of bleaching via the reaction of chlorine with precursors of TCDD and TCDF. HCB and PCB are not formed during pulp bleaching.

As a summary, the following primary measures can be taken for decreasing or eliminating the formation of 2,3,7,8-TCDD and 2,3,7,8-TCDF in wood and non-wood bleaching processes: eliminate elemental chlorine by replacing it with chlorine dioxide (elemental chlorine-free bleaching) or in some cases with totally chlorine-free processes; reduce application of elemental chlorine by decreasing chlorine multiple or increasing the substitution of chlorine dioxide for molecular chlorine; minimize precursors such as dibenzo-*p*-dioxin and dibenzofuran entering the bleach plant by using precursor-free additives and thorough washing; maximize knot removal; and eliminate pulping of furnish contaminated with polychlorinated phenols.

D. Thermal processes in the metallurgical industry

(i) Secondary copper production

Summary

Secondary copper smelting involves copper production from sources that may include copper scrap, sludge, computer and electronic scrap, and drosses from refineries. Processes involved in copper production are feed pretreatment, smelting, alloying and casting. Factors that may give rise to chemicals listed in Annex C of the Stockholm Convention include the presence of catalytic metals (of which copper is a highly effective example); organic materials in feed such as oils, plastics and coatings; incomplete combustion of fuel; and temperatures between 250 °C and 500 °C.

Best available techniques include presorting, cleaning feed materials, maintaining temperatures above 850 °C, utilizing afterburners with rapid quenching, activated carbon adsorption and fabric filter dedusting.

PCDD/PCDF performance levels in air emissions associated with best available techniques and best environmental practices for secondary copper smelters are < 0.5 ng I-TEQ/Nm3 (at operating oxygen concentrations).

(ii) Sinter plants in the iron and steel industry

Summary

Sinter plants in the iron and steel industry are a pretreatment step in the production of iron whereby fine particles of iron ores and, in some plants, secondary iron oxide wastes (collected dusts, mill scale) are agglomerated by combustion. Sintering involves the heating of fine iron ore with flux and coke fines or coal to produce a semi-molten mass that solidifies into porous pieces of sinter with the size and strength characteristics necessary for feeding into the blast furnace.

Chemicals listed in Annex C appear to be formed in the iron sintering process mainly via de novo synthesis. PCDF generally dominate in the waste gas from sinter plants. The PCDD/PCDF formation mechanism appears to start in the upper regions of the sinter bed shortly after ignition, and then the dioxins, furans and other compounds condense on cooler burden beneath as the sinter layer advances along the sinter strand towards the burn-through point.

Primary measures identified to prevent or minimize the formation of PCDD/PCDF during iron sintering include the stable and consistent operation of the sinter plant, continuous parameter monitoring, recirculation of waste gases, minimization of feed materials contaminated with persistent organic pollutants or contaminants leading to formation of such pollutants, and feed material preparation.

Secondary measures identified to control or reduce releases of PCDD/PCDF from iron sintering include adsorption/absorption (for example, activated carbon injection), suppression of formation using urea addition, and high-efficiency dedusting, as well as fine wet scrubbing of waste gases combined with effective treatment of the scrubber wastewaters and disposal of wastewater sludge in a secure landfill.

PCDD/PCDF performance levels in air emissions associated with best available techniques and best envioronmental practices for an iron sintering plant are < 0.2 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

(iii) Secondary aluminium production

Summary

Secondary aluminium smelting involves the production of aluminium from used aluminium products or process waste to recover metals by pretreatment, smelting and refining.

Fuels, fluxes and alloys are used, while magnesium removal is practised by the addition of chlorine, aluminium chloride or chlorinated organics. Chemicals listed in Annex C of the Stockholm Convention probably result from demagging additions, incomplete combustion, organics in the feed, chlorine compounds and formation in the system at temperatures between 250 °C and 500 °C.

Best available techniques include high-temperature advanced furnaces, oil- and chlorine-free feeds (if alternatives are available), afterburners with rapid quench, activated carbon adsorption and dedusting fabric filters, as well as avoiding the use of hexachloroethane for the removal of magnesium from the melt (demagging) and maintaining careful control over demagging in general.

PCDD/PCDF performance levels in air emissions associated with best available techniques and best environmental practices for secondary aluminium smelters are < 0.5 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

(iv) Secondary zinc production

Summary

Secondary zinc smelting involves the production of zinc from materials such as dusts from copper alloy production and electric arc steel making, and residues from steel scrap shredding and galvanizing processes.

Production processes include feed sorting, pretreatment cleaning, crushing, sweating furnaces to 364 °C, melting furnaces, refining, distillation and alloying. Contaminants in the feed (including oils and plastics), poor combustion and temperatures between 250 °C and 500 °C may give rise to chemicals listed in Annex C of the Stockholm Convention.

Best available techniques include feed cleaning, maintaining temperatures above 850 °C, fume and gas collection, afterburners with quenching, activated carbon adsorption and fabric filter dedusting.

PCDD/PCDF performance levels in air emissions associated with best available techniques and best environmental practices for secondary zinc smelters are < 0.5 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

Summaries of section VI: source categories included in Part III of Annex C

A. Open burning of waste, including burning of landfill sites

Summary

Open burning is an environmentally unacceptable process that generates chemicals listed in Annex C of the Stockholm Convention and numerous other pollutant products of incomplete combustion. Consistent with Annex C, Part V, section A, subparagraph (f) of the Stockholm Convention, the best guidance is to reduce the amount of material disposed of via this method with the goal of elimination altogether.

Other techniques which may effect improvement include, with respect to the materials burned: avoid including non-combustible materials, such as glass and bulk metals, wet waste and materials of low combustibility; avoid waste loads containing high chlorine content, whether inorganic chloride such as salt, or chlorinated organics such as PVC; and avoid materials containing catalytic metals such as copper, iron, chromium and aluminum, even in small amounts. Materials to be burned should be dry, homogeneous or well blended, and of low density, such as non-compacted waste.

With respect to the burning process, aims should include: supply sufficient air; maintain steady burning or rate of mass loss; minimize smouldering, possibly with direct extinguishment; and limit burning to small, actively turned, well-ventilated fires, rather than large poorly ventilated dumps or containers.

B. Thermal processes in the metallurgical industry not mentioned in Annex C, Part II

(i) Secondary lead production

Summary

Secondary lead smelting involves the production of lead and lead alloys, primarily from scrap automobile batteries, and also from other used lead sources (pipe, solder, drosses, lead sheathing). Production processes include scrap pretreatment, smelting and refining. Incomplete combustion; high levels of oils, plastics and other organic materials in feed; and temperatures between 250 °C and 500 °C may all give rise to chemicals listed in Annex C of the Stockholm Convention.

Best available techniques include the use of plastic-free and oil-free feed material, high furnace temperatures above 850 °C, effective gas collection, afterburners and rapid quench, activated carbon adsorption, and dedusting fabric filters.

PCDD/PCDF performance levels associated with best available techniques for secondary lead smelters are < 0.1 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

(ii) Primary aluminium production

Summary

Primary aluminium is produced directly from the mined ore, bauxite. The bauxite is refined into alumina through the Bayer process. The alumina is reduced into metallic aluminium by electrolysis through the Hall-Héroult process (either using self-baking anodes – Söderberg anodes – or using prebaked anodes).

Primary aluminium production is generally thought not to be a significant source of chemicals listed in Annex C of the Stockholm Convention. However, contamination with PCDD and PCDF is possible through the graphite-based electrodes used in the electrolytic smelting process.

Possible techniques to reduce the production and release of chemicals listed in Annex C from the primary aluminium sector include improved anode production and control, and using advanced smelting processes. The performance levels associated with best available techniques for air emissions of PCDD/PCDF in the primary aluminium sector are < < 0.1 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

(iii) Magnesium production

Summary

Magnesium is produced either from raw magnesium chloride with molten salt electrolysis, or magnesium oxide reduction with ferrosilicon or aluminium at high temperatures, as well as through secondary magnesium recovery (for example, from asbestos tailings).

The addition of chlorine or chlorides, the presence of carbon anodes and high process temperatures in magnesium production can lead to the formation of chemicals listed in Annex C of the Stockholm Convention and their emission to air and discharge to water.

Alternative techniques may include the elimination of the carbon source by using non-graphite anodes, and the application of activated carbon. However, performance levels associated with best available techniques depend on the type of process and controls utilized for air and water releases.

(iv) Secondary steel production

Summary

Secondary steel is produced through direct smelting of ferrous scrap using electric arc furnaces. The furnace melts and refines a metallic charge of scrap steel to produce carbon, alloy and stainless steels at non-integrated steel mills. Ferrous feed materials may include scrap, such as shredded vehicles and metal turnings, or direct reduced iron. In addition scrap may be added to other melting furnaces in the foundry and primary iron and steel sectors.

Chemicals listed in Annex C of the Stockholm Convention, such as PCDD and PCDF, appear to be most probably formed in the electric arc furnace steel-making process via de novo synthesis by the combustion of non-chlorinated organic matter such as plastics, coal and particulate carbon in the presence of chlorine donors. Many of these substances are contained in trace concentrations in the steel scrap or are process raw materials such as injected carbon.

Primary measures include adequate off-gas handling and appropriate off-gas conditioning to prevent conditions leading to de novo synthesis formation of PCDD/PCDF. This may include post-combustion afterburners, followed by rapid quench of off-gases. Secondary measures include adsorbent injection (for example, activated carbon) and high-level dedusting with fabric filters.

Performance levels for PCDD/PCDF air emissions associated with best available techniques for secondary steel production are < 0.1 ng/Nm^3 (at operating oxygen concentrations).

(v) Primary base metals smelting

Summary

Primary base metals smelting involves the extraction and refining of nickel, lead, copper, zinc and cobalt. Generally, primary base metals smelting facilities process ore concentrates. Most primary smelters have the technical capability to supplement primary concentrate feed with secondary materials (e.g. recyclables).

Production techniques may include pyrometallurgical or hydrometallurgical processes. Chemicals listed in Annex C of the Stockholm Convention are thought to originate through high-temperature thermal metallurgical processes; hydrometallurgical processes are therefore not considered in this section on best available techniques for primary base metals smelting.

Available information on emissions of PCDD and PCDF from a variety of source sectors (e.g. incinerators, steel electric arc furnaces, iron sintering plants) suggests that process technologies and techniques, and associated off-gas conditioning, can influence the formation and subsequent release of PCDD/PCDF. Consideration should be given to hydrometallurgical processes, where technically and economically feasible, as alternatives to pyrometallurgical processes when considering proposals for the construction and commissioning of new base metals smelting facilities or processes.

Primary measures include the use of hydrometallurgical processes, quality control of feed materials and scrap to minimize contaminants leading to PCDD/PCDF formation, effective process control to avoid conditions leading to PCDD/PCDF formation, and use of flash smelting technology. Identified secondary measures include high-efficiency gas cleaning and conversion of sulphur dioxide to sulphuric acid, effective fume and gas collection and high-efficiency dust removal.

PCDD/PCDF performance levels in air emissions associated with best available techniques for base metals smelters are < 0.1 ng I-TEQ/Nm^3 (at operating oxygen concentrations).

C. Residential combustion sources

Summary

This section considers the combustion of wood, coal, gas, as well as other organic matter mainly for residential heating and cooking. Combustion takes place in hand-fired stoves or fireplaces or, in the case of larger central heating systems, in automatically fired installations. Studies have shown that significant levels of chemicals listed in Annex C of the Stockholm Convention are released from residential combustion sources. The amount of chemicals released depends primarily on the fuel used (household waste, sea-salt laden driftwood and treated wood are significant sources of PCDD/PCDF) as well as combustion efficiency. The efficiency of combustion depends upon the combustion temperature, how well the gases are mixed, residence time, sufficient oxygen and the fuel properties. Given their large numbers, residential combustion appliances contribute noticeably to overall releases of chemicals listed in Annex C.

The use of efficient combustion of clean, untreated fuels for cooking and heating is of primary importance for reducing the formation and release of chemicals listed in Annex C. Strategies to minimize releases of chemicals listed in Annex C from residential combustion sources include public education, awareness and training programmes on the proper use of the appliances, use of appropriate fuels and the health impacts from uncontrolled residential combustion. The abatement technologies commonly used in industrial settings are not generally available for smaller residential heating and cooking appliances. However, the use of well-designed stoves with good operation can be effective in reducing chemicals listed in Annex C, with the important added benefit of improving indoor air quality.

Best available techniques include enclosed low emission burners with ducted flues and the use of dry, well-seasoned wood. For countries or regions where these fuels and appliances are not available, best available techniques and best environmental practices for residential combustion include ensuring separation of household waste from fuel to avoid burning of such waste in cooking and heating appliances. In all countries the use of treated wood or sea-salt laden driftwood and the use of plastics as a firelighter or fuel should be avoided.

Cooking and heating with wood is a common and significant practice in all countries of the world. Any action for reducing the emissions of chemicals listed in Annex C from residential combustion will also have to take into consideration local social, cultural and economic factors. Case studies from Australia and New Zealand are provided to highlight this.

D. Fossil fuel-fired utility and industrial boilers

Summary

Utility and industrial boilers are facilities designed to burn fuel to heat water or to produce steam for use in electricity generation or in industrial processes. The volumetric concentrations of chemicals listed in Annex C of the Stockholm Convention in the emissions from fossil fuel-fired boilers are generally very low. However, the total mass emissions from the boiler sector may be significant because of the scale of fossil fuel combustion, in terms of both tonnage and distribution, for electricity generation and heat or steam production.

Measures that can be taken to decrease the formation and release of chemicals listed in Annex C include: maintenance of efficient combustion conditions within the boiler and ensuring sufficient time is available to allow complete combustion to occur; undertaking measures to ensure fuel is not contaminated with PCB, HCB or chlorine, and is low in other components known to act as catalysts in the formation of PCDD and PCDF; use of appropriate gas-cleaning methods to lower emissions that may contain entrained pollutants; and appropriate strategies for disposal, storage or ongoing use of collected ash.

PCDD/PCDF air emission levels associated with best available techniques can be significantly lower than 0.1ng I-TEQ/Nm^3 (oxygen content: 6% for solid fuels; 3% for liquid fuels) .

E. Firing installations for wood and other biomass fuels

Summary

The main purpose of firing installations for wood and other biomass fuels is energy conversion. Large-scale installations for firing wood and other biomass fuels mainly use fluidized bed combustion and grate furnaces. Technologies for small-scale plants include underfeed furnaces and cyclone suspension furnaces. Recovery boilers in the pulp and paper industry apply specific combustion conditions. Technology selection is related to fuel properties and required thermal capacity.

Chemicals listed in Annex C of the Stockholm Convention can result from the firing of wood and other biomass fuels, particularly in the case of fuel contamination. For biomass-fired plants, particularly wood-fired installations, PCDD/PCDF emission levels associated with best available techniques are generally below 0.1 ng I-TEQ/Nm^3. Among the primary measures, control of fuel quality is a key issue (including exclusion of treated wood). Control measures for non-contaminated biomass include optimized combustion techniques and dust removal. Straw combustion increases fouling of surfaces and requires combustion techniques that are not sensitive to the slagging of ashes.

Combustion of contaminated biomass, such as wood waste, should be avoided in these installations. Fly ash (especially the finest fraction) from biomass combustion has to be landfilled due to its high heavy metal content. In many countries (including in the European Union), wood treated with chlorinated compounds or heavy metals is regarded as waste and falls within the scope of waste incineration directives or regulations.

Other environmental benefits that accrue from applying best available techniques and best environmental practices include resource conservation and avoidance of carbon dioxide emissions originating from fossil fuels (in the case of substitution).

F. Specific chemical production processes releasing chemicals listed in Annex C

Summary

This section focuses on processes for the manufacture of industrial chemicals that could theoretically give rise to persistent organic pollutants (particularly those chemicals listed in Annex C of the

Stockholm Convention). Most of the processes described share common steps, including chlorination of organic or inorganic raw materials, purification of the products, separation of product streams (usually by distillation), destruction of high-molecular-weight side products and recycle or sale of hydrogen chloride. Efficient separation and destruction of chlorinated organic side products, which may include persistent organic pollutants, is key to best available techniques applicable to these processes, as is the associated guidance for any incorporated incineration processes. For certain products, modernized manufacturing processes that reduce formation of persistent organic pollutants are also presented. A range of performance standards associated with best available techniques are provided relevant to the individual processes

G. Crematoria

Summary

From early history to the present day cremation has been a religiously and culturally important and accepted practice used by many cultures and countries as a way of dealing with the death of human beings. In many cases, cremation is integral to the religious and funeral practices of a particular country or culture; in others, it is a voluntary alternative to burial. These guidelines are not an attempt to redefine these practices or to demean their significance for the people involved. For those countries where cremation is practised and in keeping with the provisions of the Stockholm Convention, these guidelines seek to provide approaches that minimize or eliminate the formation and release of chemicals listed in Annex C of the Convention during the process of cremation.

The formation and release of PCDD and PCDF, HCB and PCB from crematoria is possible due to the presence of these chlorinated materials, precursors and chlorine in the cadavers and in some co-combusted plastics. Measures to minimize formation and release of chemicals listed in Annex C would include the avoidance of chlorinated material, the design of crematoria to deliver a minimum furnace temperature of 850 °C, a 2-second residence time for the combustion gases and sufficient air to ensure combustion. Larger new crematoria should also be fitted with air pollution control equipment to minimize emission of sulphur dioxide, hydrogen chloride, carbon monoxide, volatile organic compounds, particulate matter and persistent organic pollutants. Performance levels of < 0.1 ng I-TEQ/Nm^3 for PCDD/PCDF in air emissions are associated with best available techniques.

H. Motor vehicles, particularly those burning leaded gasoline

Summary

The major fuels used in motor vehicle transportation are gasoline and diesel. Liquefied petroleum gas, vegetable oil-based and other biofuels, and alcohol-oil mixtures are gaining importance.

PCDD and PCDF have been found in the emissions from motor vehicles fuelled with gasoline or diesel. The higher concentrations identified in emissions from vehicles run on leaded gasoline are due to the presence of chlorinated and brominated scavengers in the fuel.

As alternatives to leaded gasoline, the following fuels may be considered: unleaded gasoline (best when equipped with catalyst); diesel (best when equipped with diesel oxidation catalyst and particulate filter); liquefied petroleum gas; compressed natural gas; propane/butane gas; biofuels; and alcohol-oil mixtures.

Best available techniques include banning of halogenated scavengers, and fitting motor vehicles with an oxidation catalyst or particulate filter.

There are no measured data available for biofuels, alcohol-oil mixtures or liquefied petroleum gas, and no data for 2-stroke engines.

I. Destruction of animal carcasses

Summary

The formation and emission of PCDD, PCDF, PCB and HCB from animal carcass incinerators is due to the presence of these chlorinated materials, precursors and chlorine in the carcasses or in some plastics that can be co-incinerated with animal carcasses and by-products. Measures that can be taken to decrease the formation and release of persistent organic pollutants include the avoidance of co-incineration with other wastes, the requirement for a minimum furnace temperature of 850 °C, a 2-second residence time for the combustion gases and sufficient excess air to ensure combustion. Larger facilities (> 50 kg/h) should be fitted with air pollution control equipment to minimize emissions of sulphur dioxide, hydrogen chloride, carbon monoxide, volatile organic compounds, particulate matter and persistent organic pollutants. Performance levels associated with best available techniques of < 0.1 ng I-TEQ/Nm^3 can be achieved for PCDD/PCDF in air emissions.

Other methods of disposal, such as burial, landfill or composting, are not considered to contribute significantly to emissions of chemicals listed in Annex C, although environmental, public health, nuisance and animal health issues should be considered. Alkaline hydrolysis digestion is a further technique for the destruction of animal carcasses.

J. Textile and leather dyeing (with chloranil) and finishing (with alkaline extraction)

Summary

Contamination with PCDD and PCDF has been found in both textile and leather products. The occurrence of PCDD/PCDF in the textile and leather industries is due to use of chlorinated chemicals, especially pentachlorophenol and chloronitrofen, to protect the raw material (e.g. cotton, wool or other fibres, leather); and use of dioxin-contaminated dyestuffs (e.g. dioxazines or phthalocyanines). Smaller quantities of PCDD/PCDF may be formed during finishing, and during incineration of process-generated sludge.

Alternatives to the above-listed dye pigments exist and those listed should not be applied.

Possible alternatives to pentachlorophenol and chloronitrofen include 2-(thiocyanomethylthio) benzothiazole (TCMTB); *o*-phenylphenol (oPP); 4-chloro-3-methylphenol (CMK); and 2-*n*-octyl-4-isothiazolin-3-one (OIT).

As regards best available techniques, the most efficient primary measure to prevent contamination of textiles and leather goods with PCDD/PCDF would be not to use dioxin-contaminated biocides and dyestuffs in the production chains. Also, if any of the above-mentioned chemicals are being used, preference should be given to batches containing low concentration (e.g. distilled or otherwise purified chemicals). To the extent possible, burning of textile, upholstery, leather products and carpet should be avoided to prevent PCDD/PCDF formation.

In order to prevent or minimize formation and release of PCDD/PCDF when burning sludge from wastewater treatment and flotation, best available techniques should be applied as described in section VI.D of the present guidelines. However, other environmentally sound techniques should also be explored.

K. Shredder plants for the treatment of end-of-life vehicles

Summary

Shredder plants for treatment of end-of-life vehicles are listed in Annex C of the Stockholm Convention as a source that has the potential to form and release chemicals listed in Annex C. Shredders are large-scale machines equipped inside with one or more anvils or breaker bars and lined with alloy steel wear plates. An electric motor drives the rotor with the free-swinging alloy steel hammers. Beneath the shredder is a vibratory pan, which receives the shredded material discharged through the grates. Typically a ferrous metal stream is produced, which is relatively clean and consists of small (50 mm) pieces of steel and a “fluff” stream, which contains the fragments of non-ferrous metals and other materials that entered the shredder (also known as fragmentizer).

Very few data of stack emission measurements at shredder plants are available. However, the results of some studies have shown levels of PCDD/PCDF in air emissions greater than 0.1 ng I-TEQ/m^3. At present there is not sufficient evidence that in the (mechanical) shredding of vehicles, household electrical equipment or other electrical appliances new formation occurs of polychlorinated dibenzo-*p*-dioxins (PCDD), polychlorinated dibenzofurans (PCDF) or polychlorinated biphenyls (PCB). The data available indicate that the PCDD/PCDF and PCB released from shredder plants are from industrial, intentional production and have been introduced with oils, dielectric fluids, and other materials contained in these vehicles or consumer goods and which are simply set free through this mechanical process.

In any case, measures to prevent accidental fires (which could result in the formation of chemicals listed in Annex C) should be in place at shredder plants. Shredder light fluff consists of flammable plastic films and fibrous dust, which forces a careful plant operation for the prevention of accidental fire. Systems for dust suppression (e.g. wet shredding) or dust collection (e.g. cyclones, venture scrubbers or baghouse) are normally installed on shredder plants for the treatment of end-of-life vehicles. Dust suppression or collection systems would help to reduce potential emission of persistent organic pollutants. To improve emission control of the dust, fine dry residues should be stored in such a way that dispersion is minimized. Other sources of dioxin precursors that may result in the formation of PCDD/PCDF when burnt include PCB-containing condensers, PCB- or chlorobenzene-contaminated waste oils or textiles, and polymers containing brominated flame retardants (formation of polybrominated dibenzo-*p*-dioxins (PBDD) and polybrominated dibenzofurans (PBDF) as contaminants).

L. Smouldering of copper cables

Summary

Scrap copper is often recovered by open burning of plastic coatings from electrical cable and wiring. Chemicals listed in Annex C of the Stockholm Convention are probably formed from plastic and trace oils with copper as a catalyst at smouldering temperatures between 250 °C and 500 °C.

Best available techniques include mechanical cable chopping, stripping or high-temperature incineration > 850 °C. A consideration is to set premium pricing for unstripped cables and wiring and encourage sending the feed material to copper smelters using best available techniques for treatment.

Performance levels associated with best available techniques are not applicable, as the smouldering process is not a best available technique or best environmental practice and should not be practiced with copper cables.

M. Waste oil refineries

Summary

Waste oil refineries are listed in Annex C of the Stockholm Convention as a source that has the potential to form and release chemicals listed in Annex C.

For the purpose of this guidance section, waste oils (or used oils) are defined as any petroleum-based, synthetic, or plant- or animal-based oil that has been used. Waste oils may originate from two large sources: industrial waste oils, and vegetable and animal waste oils. Among the industrial waste oils, three main oil streams can be identified: industrial oil (e.g. hydraulic oil, engine lubricant, cutting oil); garage or workshop oil; and transformer oil.

Waste oils have been found to be contaminated with polychlorinated dibenzo-*p*-dioxins,, polychlorinated dibenzofurans and polychlorinated biphenyls.. At present there is no available evidence that polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans or polychlorinated biphenyls, are newly formed in waste oil refineries. The data available indicate that the polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans or polychlorinated biphenyls released from waste oil refineries or waste oil handling and management plants are from industrial, intentional production of polychlorinated biphenyls or chlorobenzenes that are present in the waste oils either by contamination in the synthesis process (of these chemicals) or have become contaminated during the use phase or earlier recycling processes. In this sense, waste oil refineries represent a distribution source of chemicals listed in Annex C rather than a formation source.

According to available information, waste oil management options include reuse or regeneration; thermal cracking; and incineration or use as fuel. It should be noted that dumping and open burning are also practiced in many countries.

For information on waste oil disposal in incinerators or on use as fuel, the relevant sections of this guidance document should be consulted (sections V.A Waste incinerators, V.B Cement kilns firing hazardous waste, VI.A Open burning of waste, VI.C Residential combustion sources, and VI.D Fossil fuel-fired utility and industrial boilers).