

Draft proposal for a guidance document (former Annex III of the HM protocol)

**BEST AVAILABLE TECHNIQUES FOR CONTROLLING EMISSIONS OF
HEAVY METALS AND THEIR COMPOUNDS FROM THE SOURCE
CATEGORIES LISTED IN ANNEX II**

The basis for this document was a proposal by Switzerland It was tabled by Switzerland at the 46th session of the WGSR in April 2010.

Comments were sent in by: Austria, Canada, Germany, The Netherlands, Norway, Romania, Sweden, Switzerland, U.S, by the industry association Eurofer and the company Albemarle.

The changes are made visible in track-changes mode. Sometimes comments have been added for better understanding. To improve readability, a separate version with adopted changes has been included.

For better comparison with the original proposal by Switzerland, the numbering of the paragraphs was not touched. In the version with adopted changes the numbering of paragraphs was "brought in line". Missing paragraphs are included now for the sake of completeness because they were not changed compared to the original Annex III.

Two Parties proposed a restructuring of sub-chapter IV, ie on the primary and secondary non-ferrous metal industry. Recent publications on technical information, new regulations from North America and a BREF being prepared in the EU could be taken into account.

One Party proposed to include references for technical information in the document. This is possible but has not been done so far due to a shortage of time and incompleteness of information. Here the proposal would be;

- first to decide on changes; e.g. restructuring sub-chapter IV,
- include information on secondary aluminium and manganese production,
- include waste containing metallic mercury,
- then forward this document to the members of the TF HM and interested Parties for further comments
- lastly, prepare a final version of a draft guidance document.

DRAFT proposal for a guidance document

BEST AVAILABLE TECHNIQUES FOR CONTROLLING EMISSIONS OF HEAVY METALS AND THEIR COMPOUNDS FROM THE SOURCE CATEGORIES LISTED IN ANNEX II

1. This annex [**guidance document**] aims to provide Parties with guidance on identifying best available techniques for stationary sources to enable them to meet the obligations of the Protocol.

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

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

(b) “available” techniques means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,

(c) “best” means most effective in achieving a high general level of protection of the environment as a whole.

Criteria for determining BAT are as follows:

1. The use of low-waste technology;
2. The use of less hazardous substances;
3. The furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;
4. Comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;
5. Technological advances and changes in scientific knowledge and understanding;
6. The nature, effects and volume of the emissions concerned;
7. The commissioning dates for new or existing installations;
8. The length of time needed to introduce the best available technique;
9. The consumption and nature of raw materials (including water) used in the process and energy efficiency;

10. The need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;

11. The need to prevent accidents and to minimize the consequences for the environment;

12. Information published by national and international organisations.

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.

3. The information regarding emission control performance and costs is based on official documentation of the Executive Body and its subsidiary bodies, in particular documents received and reviewed by the Task Force on Heavy Metal BAT reference documents from the European Integrated Pollution Prevention and Control Bureau (EIPPCB), the United Nations Environment Program (UNEP) 2002 Global Mercury Assessment, and various technical reports from United States Environmental Protection Agency (U.S. EPA), Environment Canada, and the European Commission and information provided directly by experts has been taken into consideration.

4. Experience with new products and new plants incorporating low-emission techniques, as well as with the retrofitting of existing plants, is growing continuously; this guidance document may, therefore, need amending and updating.

5. The guidance document lists a number of measures spanning a range of costs and efficiencies. The choice of measures for any particular case will depend on, and may be limited by, a number of factors, such as economic circumstances, technological infrastructure, any existing emission control device, safety, energy consumption and whether the source is a new or existing one.

6. This guidance document takes into account the emissions of cadmium, lead and mercury and their compounds, in solid (particle-bound) and/or gaseous form. Speciation of these compounds is, in general, not considered here. Nevertheless, the efficiency of emission control devices with regard to the physical properties of the heavy metal, especially in the case of mercury, has been taken into account.

7. Emission values expressed as mg/m³ refer to standard conditions (volume at 273.15 K, 101.3 kPa, dry gas) not corrected for oxygen content unless otherwise specified, and are calculated in accordance with draft CEN (Comité Européen de Normalisation) and, in some cases, national sampling and monitoring techniques.

II. GENERAL OPTIONS FOR REDUCING EMISSIONS OF HEAVY METALS AND THEIR COMPOUNDS

8. There are several possibilities for controlling or preventing heavy metal emissions. Emission reduction measures focus on add-on technologies and process modifications (including maintenance and operating control). The following measures, which may be implemented depending on the wider technical and/ or economic conditions, are available:

- (a) Application of low-emission process technologies, in particular in new installations;
- (b) Off-gas cleaning (secondary reduction measures) with filters, scrubbers, absorbers, etc.;
- (c) Change or preparation of raw materials, fuels and/or other feed materials (e.g. use of raw materials with low heavy metal content);
- (d) Best management practices such as good housekeeping, preventive maintenance programmes, or primary measures such as the enclosure of dust-creating units;
- (e) Appropriate environmental management techniques for the use and disposal of certain products containing Cd, Pb, and/or Hg.

9. It is necessary to monitor abatement procedures to ensure that appropriate control measures and practices are properly implemented and achieve an effective emission reduction. Monitoring abatement procedures will include:

- (a) Developing an inventory of those reduction measures identified above that have already been implemented;
- (b) Comparing actual reductions in Cd, Pb and Hg emissions with the objectives of the Protocol;
- (c) Characterizing quantified emissions of Cd, Pb and Hg from relevant sources with appropriate techniques;
- (d) Regulatory authorities periodically auditing abatement measures to ensure their continued efficient operation.

10. Emission reduction measures should be cost-efficient. Cost-efficient strategy considerations should be based on total costs per year per unit abated (including capital and operating costs). Emission reduction costs should also be considered with respect to the overall process.

III. CONTROL TECHNIQUES

11. The major categories of available control techniques for Cd, Pb and Hg emission abatement are primary measures such as raw material and/or fuel substitution and low-emission process technologies, and secondary measures such as fugitive emission control and off-gas cleaning. Sector-specific techniques are specified in chapter IV.

12. The data on efficiency are derived from operating experience and are considered to reflect the capabilities of current installations. The overall efficiency of flue gas and fugitive emission reductions depends to a great extent on the evacuation performance of the gas and dust collectors (e.g. suction hoods). Capture/collection efficiencies of over 99% have been demonstrated. In particular cases experience has shown that control measures are able to reduce overall emissions by 90% or more.

13. In the case of particle-bound emissions of Cd, Pb and Hg, the metals can be captured by dust-cleaning devices. Typical dust concentrations after gas cleaning with selected techniques are given in table 1. Most of these measures have generally been applied across sectors. The minimum expected performance of selected techniques for capturing gaseous mercury is outlined in table 2. The degree of mercury control shown in this table is largely dependent on the chemical state and form of the mercury (e.g., oxidized, elemental or particle bound). The application of these measures depends on the specific processes and is most relevant if concentrations of mercury in the flue gas are high.

Table 1: Performance of dust-cleaning devices expressed as hourly average dust concentrations

	Dust concentrations after cleaning (mg/m ³)
Fabric filters	< 1 - 5
Fabric filters, membrane type	< 1
Dry electrostatic precipitators	< 5 – 15
Wet electrostatic precipitators	< 1- 5
High-efficiency scrubbers	< 20
Ceramic filters	0.1 - 1

Note: Medium- and low-pressure scrubbers and cyclones generally show lower dust removal efficiencies.

Table 2: Minimum expected performance of mercury separators expressed as hourly average mercury concentrations

	Mercury content after cleaning (mg/m ³)
Selenium filter	< 0.01
Selenium scrubber	< 0.2
Carbon filter	< 0.01
Carbon injection + dust separator	< 0.05
Odda Norzink chloride process	< 0.1
Lead sulphide process	< 0.05
Bolkem (Thiosulphate) process	< 0.1
Injection of brominated activated carbon+ dust separator	0.001

14. Care should be taken to ensure that these control techniques do not create other environmental problems, e.g. due to more water pollution from liquid effluents. The fate of captured dust as well as of mercury-charged activated carbon resulting from improved gas cleaning must also be taken into consideration. A negative environmental impact from the handling of such wastes will reduce the gain from lower process dust and fume emissions into the air.

15. Emission reduction measures can focus on process techniques as well as on off-gas cleaning. The two are not independent of each other; the choice of a specific process might exclude some gas-cleaning methods.

16. The choice of a control technique will depend on such parameters as the pollutant concentration and/or speciation in the raw gas, the gas volume flow, the gas temperature, and others. Therefore, the fields of application may overlap; in that case, the most appropriate technique must be selected according to case specific conditions.

17. Adequate measures to reduce stack gas emissions in various sectors are described below. Fugitive emissions have to be taken into account. Dust emission control associated with the discharging, handling, and stockpiling of raw materials or by-products, although not relevant to long-range transport, may be important for the local environment. The emissions can be reduced by moving these activities to completely enclosed buildings, which may be equipped with ventilation and dedusting facilities, spray systems or other suitable controls. When stockpiling in unroofed areas, the material surface should be otherwise protected against wind entrainment. Stockpiling areas and roads should be kept clean.

18. The investment/cost figures listed in the tables have been collected from various sources and are highly case-specific.. They depend on such factors as plant capacity, removal efficiency and raw gas concentration, type of technology, and the choice of new installations as opposed to retrofitting.

IV. SECTORS

19. This chapter contains a table per relevant sector with the main emission sources, control measures based on the best available techniques, their specific reduction efficiency and the related costs, where available. Unless stated otherwise, the reduction efficiencies in the tables refer to direct stack gas emissions.

I. Combustion of fossil fuels in utility and industrial boilers (annex II, category 1)

20. The combustion of coal in utility and industrial boilers is a major source of anthropogenic mercury emissions. The heavy metal content is normally several orders of magnitude higher in coal than in oil or natural gas. Fuel switch is an option if mercury free fuels are available e.g. natural gas or specific types of coal with low mercury content.

21. Improved energy conversion efficiency and energy conservation measures will result in a decline in the emissions of heavy metals because of reduced fuel requirements. Combusting natural gas or alternative fuels with low heavy metal content instead of coal would also result in a significant reduction in heavy metal emissions such as mercury and can be regarded as one form of BAT. Integrated gasification combined-cycle (IGCC) power plant technology is a high efficiency technology that can have reduced emissions compared to large scale power production based on solid fuels that do not use IGCC.

22. With the exception of mercury, heavy metals are mostly emitted in solid form in association with fly-ash particles. Therefore, BAT to reduce the emissions of heavy metals is generally the application of high performance dedusting devices such as electrostatic precipitators or fabric filters.

23. Beneficiation, e.g. "washing" or "bio-treatment", of coal reduces the heavy metal content associated with the inorganic matter in the coal but is connected with emissions of heavy metals to water. However, the degree of heavy metal removal with this technology varies widely.

24. For the combustion of coal and lignite, of liquid fuels and of biomass and peat a total dust removal of more than 99.5% can be obtained with electrostatic precipitators (ESP, dust reduction rate >99.5 %) or fabric filters (FF, dust reduction rate >99.95 %). ESP and FF are both considered as BAT with daily average values for the concentration of dust in the range of below 5 up to 20 mg/m³ (referred to a flue gas oxygen content of 6%); when operated with well and continuously maintained equipment large coal fired power plants fitted with ESP or FF can achieve yearly average values of < 5 mg/m³. With the

exception of mercury, heavy metal emissions can be reduced by at least 90-99%, the lower figure for the more easily volatilized elements.

25. Mercury is at least partly and up to 90 % present in the vapour phase and its collection by dust control devices is highly variable. Low filter temperature helps to reduce the gaseous mercury off-gas content. By injecting brominated activated carbon into the flue gas stream prior to the ESP or FF, mercury (Hg⁰ and Hg²⁺) can be abated by more than 90% and be taken out with the fly ash.

26. The application of techniques to reduce emissions of nitrogen oxides by catalytic reduction (SCR) and sulphur dioxide from the flue gas can also remove heavy metals. For electrostatic precipitators (ESPs) or fabric filters (FFs) operated in combination with wet flue gas desulphurisation (FGD) techniques, an average removal rate of 75 % for Hg can be obtained. If a high dust Selective Catalytic Reduction (SCR) devices is added upstream of the FGD an average removal rate of 90% can be obtained for Hg as long as adequate amounts of halogens are present in the flue gas (e.g., naturally present chlorine or injected bromine).

The best levels of mercury control are generally achieved by emission control systems (e.g. FGD plus particulate control device) that use FFs. The capture of mercury can be enhanced by introducing carbon/injecting activated carbon into the flue gas upstream of the ESP or FF or by distributing the flue gas throughout a carbon filter bed.

27. The least costly retrofit options for the control of Hg emissions from units with ESP or FF are believed to include:

- The modification of dry FGD systems by the use of appropriate sorbents for the capture of Hg is considered to be the easiest retrofit problem to solve
- Injection of a sorbent upstream of the ESP or FF
- Injection of a sorbent between the ESP and a pulse-jet FF retrofitted downstream of the ESP
- Installation of a semi-dry circulating fluidized-bed absorber (CFA) upstream of an existing ESP used in conjunction with sorbent injection

The wet scrubber efficiency for mercury removal can be increased by:

- Improving the Liquid-to-Gas Ratio
- Wet FGD Tower Design. Research has shown that tray tower or open spray tower designs can be effective in removing oxidized mercury from boiler flue gas.
- Injection of activated carbon impregnated with additives (e.g. sulphur, bromine) increasing adsorption capacity
- Addition of Selective Catalytic Reduction device upstream of the wet scrubber
- Pre-treating of coal (e.g. CaBr₂).

28. The most cost-effective approach to control mercury emission from large combustion plants is probably an integrated multi-pollutant (SO₂, NO_x, PM, and mercury) control technology. By applying a combination of SCF, FGD and ESP or FF the concentration of mercury (gaseous and solid) in the flue gases can be reduced to levels below 0.003 mg/m³ as daily average at 6% O₂. A gas-phase oxidation process to simultaneously capture SO_x, NO_x and mercury (100 % reduction) is under demonstration.

Table 3: Control measures, reduction efficiencies and costs for fossil-fuel combustion emissions

Emission source	Control measure(s)	Reduction efficiency (%)	Abatement costs (total costs US\$)
All fuels	ESP or FF, and FGD	Hg: 75 (average)	
	ESP or FF, and FGD and SCR (multi-pollutant approach)	Hg: 90 (average) ($< 3 \mu\text{g}/\text{Nm}^3$)	No additional costs for Hg reduction based on the multi-pollutant approach for SO ₂ and NO _x
	Switch to fuels with lower heavy metals emissions	Dust 70 – 100	Highly case-specific
	ESP (cold-side)	Cd, Pb: > 90 ; Hg: 10 – 40 PM: $> 99.5 - 99.8$	Specific investment US\$ 5-10/m ³ waste gas per hour ($> 200,000 \text{ m}^3/\text{h}$)
	(Wet) flue-gas desulphurization (FGD) ^{a/}	Cd, Pb: > 90 ; Hg: 20 – 80 ^{b/}	15-30/Mg waste gas
	Fabric filters (FF)	Cd: > 95 ; Pb: > 99 ; Hg: 10 – 60 PM > 99.95 ($< 5 \text{ mg}/\text{m}^3$)	Specific investment US\$8-15/m ³ waste gas per hour ($> 200,000 \text{ m}^3/\text{h}$)
	ESP or FF, and FGD	Hg: 75 (average)	
	ESP or FF, and sorbent injection	Hg: 50 – > 95	90 % control: US\$ 35,000 – 70,000 per pound Hg removed / 0.0003 – 0.002 US \$/kWh
	Injection of (brominated) activated carbon (ACI)	Hg: $> 90\%$ ($< 1\mu\text{g}/\text{Nm}^3$)	US\$ 15,000 per pound Hg removed/ 0.0012 US\$/ kWh (ACI only)/ 6 – 30 Mio. € per installation or 0.0001€ per kWh)
	ESP or FF, and carbon filter bed	Hg: 80 – 90	US\$ 33,000 – 38,000 per pound Hg removed
	Coal cleaning	Cd, Pb: up to 80; Hg: 10 – 50	

Emission source	Control measure(s)	Reduction efficiency (%)	Abatement costs (total costs US\$)
^{a/} Hg removal efficiencies increase with the proportion of ionic mercury. High-dust selective catalytic reduction (SCR) installations facilitate Hg(II) formation. Removal can be facilitated by having adequate halogens present in the flue gas.			
^{b/} This is primarily for SO ₂ reduction. Reduction in heavy metal emissions is a side benefit. (Specific investment US\$ 60-250/kW _{el}). Wet scrubbers installed primarily for mercury cost between \$76,000 and \$174,000 per pound of mercury removed.			

Reference: Informal document 3, WGSR 48th session, 2011

II. Primary iron and steel industry (annex II, category 2)

29. This section deals with emissions from sinter plants, pellet plants, blast furnaces, and steelworks with a basic oxygen furnace (BOF) with subsequent casting. In integrated steelworks, sinter plants and steelworks dominate the overall emissions for most atmospheric pollutants including heavy metals. Emissions of Cd, Pb and Hg occur in association with dust. The content of the heavy metals of concern in the emitted dust depends on the composition of the raw materials and the types of alloying important. The most relevant emission reduction measures are outlined in table 4. Fabric filters should be used whenever possible; if conditions make this impossible, electrostatic precipitators and/or high-efficiency scrubbers may be used.

30. The following techniques are considered as BAT:

(a) **For sinter plants**, BAT for dedusting of primary waste gas is to reduce dust emissions from sinter strand waste gas by means of a bag filter. For existing plants when bag filters are not applicable, advanced electrostatic precipitators should be used. BAT for primary emissions from sinter strands is to prevent or reduce mercury emissions by selecting raw material with a low mercury content or to treat waste gases in combination with activated carbon or activated lignite coke injection. Waste gas should be recirculated if applicable.

BAT for secondary emissions from sinter strand discharge, sinter crushing, cooling, screening and conveyer transfer points is to prevent dust emissions and/or to achieve an efficient extraction of dust emissions by using a combination of the following techniques:

- hooding and/ or enclosure
- an electrostatic precipitator or a bag filter.

The emissions level for mercury from sinter plants is < 0.03 -0.05 mg/Nm³.

(b) **For pelletisation plants**, BAT is to reduce the dust emissions in the waste gases from the raw materials pre-treatment, drying, grinding, wetting, mixing and the balling;

- from the induration strand and
- from the pellet handling and screening

by using on or a combination of the following techniques:

- a) an electrostatic precipitator
- b) a bag filter
- c) a wet scrubber

(c) **For blast furnaces**, BAT for casting house (tap holes, runners, torpedo ladles charging points, skimmers) is to prevent or reduce diffuse emissions by using the following techniques:

- a) covering the runners
- b) optimising the capture efficiency for diffuse dust emissions and fumes with subsequent off-gas cleaning by means of an electrostatic precipitator or bag filter
- c) fume suppression using nitrogen while tapping, where applicable and where no collecting and de-dusting system for tapping emissions is installed Bat is to minimise the release of blast furnace gas during charging by using one or a combination of the following techniques:
 - bell-less top with primary and secondary equalising
 - gas or ventilation recovery system.

For blast furnace gas cleaning BAT is to reduce dust emissions by using one or a combination of the following techniques:

- using dry pre-dedusting devices (such as deflectors, dust catchers, cyclones, electrostatic precipitators)
- using subsequent dust abatement (such as hurdle-type scrubbers, venture scrubbers, annular gap scrubbers, wet electrostatic precipitators, disintegrators)

(d) **For basic oxygen furnace (BOF) plant:**

BAT for BOF gas recovery by suppressed combustion is to extract the BOF gas during blowing as much as possible and to clean it by using the following techniques in combination:

- using a suppressed combustion process
- pre-dedusting to remove coarse dust by means of dry separation techniques (e.g. deflector, cyclone) or wet separators
- dust abatement by means of
 - o dry dedusting (e.g. electrostatic precipitators) for new and existing plants
 - o wet dedusting (e.g. wet electrostatic precipitators or scrubber) for existing plants.

BAT for BOF gas recovery during oxygen blowing in the case of full combustion is to reduce dust emissions by using one of the following techniques

- dry dedusting (e.g. ESP or bag filter) for new and existing plants
- wet dedusting (e.g. wet ESP or scrubber) for existing plants.

BAT for secondary dedusting is to minimise dust emissions by means of process integrated techniques, such as general techniques to prevent or control diffuse or fugitive emissions, and by using appropriate enclosure and hoods with efficient extraction and a subsequent off-gas cleaning by means of a bag filter or an ESP or any other technique with the same removal efficiency. This applies also for the emissions from the following processes:

- reladling of hot metal from the torpedo ladle (or hot metal mixer) to the charging ladle
- hot metal pre-treatment (i.e. preheating of vessels, desulphurisation, dephosphorisation, deslagging, hot metal transfer processes and weighing)

- BOF-related processes like the preheating of vessels, slopping during oxygen blowing, hot metal and scrap charging, tapping of liquid steel and slag from BOF and
- secondary metallurgy and continuous casting.

Table 4: Emission sources, control measures, dust reduction efficiencies and costs for the primary iron and steel industry

Emission source	Control measure(s)	Dust reduction efficiency (%)	Dust emission levels (mg/Nm ³)	Abatement costs
Sinter plants primary emissions	Emission optimized sintering	ca. 50		..
	Fabric filters	> 99	1 - 10	3,000 – 16,000 €/a
	Advanced ESP (Moving Electrode ESP, ESP pulse system, high voltage ESP...)		20 - 40	
Sinter plants secondary emissions	Fabric filters Advanced ESP		< 5 < 10	
Pellet plants	ESP + lime reactor + fabric filters	> 99		..
	Scrubbers or semi-dry desulphurisation and subsequent de-dusting	> 95	< 10	..
	Crushing, grinding, drying Other process steps		<20 <10- 15	
Blast furnaces gas cleaning	ESP	> 99	< 10	ESP: 0.24-1 US\$/Mg pig iron
	Wet scrubbers	> 99	< 10	∞
	Wet ESP	> 99	< 10	∞
Blast furnace	Capture of fugitive emissions from the casting bay/cast house and subsequent dedusting by FF or ESP Diffuse emissions from casting bay/cast house		1 – 15 5 – 15 g/t hot metal	

Emission source	Control measure(s)	Dust reduction efficiency (%)	Dust emission levels (mg/Nm ³)	Abatement costs
BOF	Primary dedusting: - dry ESP or FF - wet ESP (existing plants)	> 99	10 -30 <50	Dry ESP: 2.25 US\$/Mg steel
	Secondary dedusting (including hot metal treatment and secondary metallurgy): dry ESP/FF	>97	FF: 1 – 10 ESP: <20	FF: 0.26 US\$/Mg steel
Fugitive emissions	Closed conveyor belts, enclosure, wetting stored feedstock, cleaning of reads	80 – 99		

31. Direct reduction and smelting reduction are two proven alternative iron making processes to the coke oven/blast furnace route that may reduce the need for sinter plants and blast furnaces in the future. The application of these technologies depends on the ore characteristics and requires the resulting product to be processed in an electric arc furnace, which should be equipped with appropriate controls.

II. Secondary iron and steel industry (annex II, category 3)

32. The secondary production of iron and steel is mainly based on the use of Electric Arc Furnaces (EAF).

BAT for EAF primary and secondary dedusting (including scrap preheating, charging, melting, tapping, ladle furnace and secondary metallurgy) is to achieve an efficient extraction of dust emissions from all emission sources by using one of the techniques listed below and to use subsequent dedusting by means of a fabric filter:

- a combination of direct off-gas extraction and hood systems
- direct gas extraction and doghouse systems
- direct gas extraction and total building evacuation

98% and more collection efficiency of primary and secondary emissions from EAF are achievable and considered as BAT. The captured off-gases should be treated with activated carbon injection and subsequent dedusting by means of a fabric filter, which reduces the dust content to less than 5 mg/Nm³. The emission level for mercury is <0.05 mg/Nm³. The specific dust emissions (including fugitive emission directly related to the process) range between 0.06 and 0.35 kg/Mg steel.

33. For the melting of scrap, also open-hearth furnaces are still in use, but are about to be phased out because of their inefficiency.

34. The content of the heavy metals of concern in the emitted dust depends on the

composition of the iron and steel scrap and the types of alloying metals added in steelmaking. Measurements at EAF have shown that 95% of emitted mercury and 25% of cadmium emissions occur as vapour. It is recommended as a best environmental practice to implement operating practices to prevent and minimize the presence of mercury and other heavy metals in the scrap, e.g. to remove mercury-bearing components prior to recycling in secondary iron and steel facilities.

The most relevant dust emission reduction measures are outlined in table 5. Dust abatement techniques also give significant reductions of emissions of heavy metals. Gaseous lead and cadmium and gaseous lead and cadmium compounds as well as mercury that pass the dust filter can be abated by carbon adsorption, e.g. leading to 95 % reduced emissions of mercury.

35. In recent years a number of new furnace types have been introduced, that might show advantages with regard to heavy metals and dust emissions, like the Comelt EAF, the Contiarc furnace and the Consteel process.

Table 5*: Emission sources, control measures, dust reduction efficiencies and costs for the secondary iron and steel industry

Emission source	Control measure(s)	Dust Reduction efficiency (%)	Emission levels (mg/Nm ³)	Abatement costs (total costs US\$)
EAF	ESP	> 99		
	FF	> 99.5	< 5	24/Mg steel
	Activated carbon + FF	Hg: > 98%		

III. Iron and steel foundries (annex II, category 4)

36. In the foundry process, emissions to air will typically not be limited to one (or several) fixed point(s). The process involves various emission sources (e.g. from melting and pouring processes). It is very important to capture all the emissions efficiently. That is possible by installing doghouses or movable hoods or by total building evacuation. The captured emissions must be cleaned. In iron foundries, cupola furnaces, electric arc furnaces, induction furnaces, hearth type furnaces and rotary furnaces are operated. Direct particulate and gaseous heavy metal emissions are especially associated with melting and sometimes, to a small extent, with pouring. Fugitive emissions arise from raw material handling, melting, pouring and fettling. The most relevant emission reduction measures are outlined in table 6 with their achievable reduction efficiencies and

costs, where available. The BAT associated emission level for dust, after collecting and dedusting exhaust gases, for all types of furnaces (cupola, induction, and rotary furnace) and mouldings (lost mould and permanent mould) as well as finishing operations is 5-20 mg/m³.

37. The following techniques are considered as BAT:

- For cupola furnace melting, use divided blast operation for cold blast cupolas, use oxygen enrichment of the blast air with oxygen levels between 22 and 25 %, minimise the blast-off periods for hot blast cupolas, use coke with known properties and of a controlled quality, and clean furnace off-gas using a bag filter or wet scrubber.
- For induction furnace melting, increase furnace efficiency, maximize off-gas collection during the full working cycle, and use dry flue-gas cleaning keeping dust emissions below 0.2 kg/tonne molten iron.
- For rotary furnace melting, optimise furnace operation and increase the melting efficiency, and to collect the off-gas close to the furnace exit, apply post combustion, cool it using a heat ex-changer and to apply dry dedusting.
- For electric arc furnaces a shortening of melt down times can be achieved by a close control of the composition (e.g. P,S, C content), temperature control and efficient methods of deslagging. The foamy slag practice reduces the energy consumption and therefore the amount of exhaust gases.
- For hearth type furnaces the use of oxyburners can reduce the amount of energy necessary (e.g. gas or oil) for smelting of iron and therefore the total flow of exhaust gases.
- For moulding, enclose all the unit operations and to dedust the exhaust gas, if necessary post combustion.
- For finishing operations, BAT is to collect and treat the finishing off-gas using a dry system.

Table 6: Emission sources, control measures, dust reduction efficiencies and costs for iron foundries

Emission source	Control measure(s)	Dust reduction efficiency (%)	Emission levels (mg/Nm ³)	Abatement costs (total costs US\$)
Induction furnace	FF/dry absorption + FF	> 99	5	
Cold blast cupola	Below-the-door take-off: FF	> 98		
	Above-the-door take-off: FF + pre-dedusting	> 97		
	FF + chemisorption	> 99		

Emission source	Control measure(s)	Dust reduction efficiency (%)	Emission levels (mg/Nm ³)	Abatement costs (total costs US\$)
Hot blast cupola	FF + pre-dedusting	> 99		
	Disintegrator/venturi scrubber	> 97		
Electric Arc Furnace	ESP FF	>99 >99.5	< 5 <10 existing plants	

IV. Primary and secondary non-ferrous metal industry (annex II, categories 5 and 6)

38. This section deals with emissions and emission control of Cd, Pb and Hg in the primary and secondary production of non-ferrous metals like lead, copper, zinc, ~~tin, and nickel~~ and aluminium. Due to the large number of different raw materials used and the various processes applied, nearly all kinds of heavy metals and heavy metal compounds might be emitted from this sector. Given the heavy metals of concern in this annex, the production of copper, lead and zinc, [manganese and the secondary aluminium] production are particularly relevant.

39. The main environmental issues for the production of most non-ferrous metals from primary raw materials include the potential emission to air of dust and metals/metal compounds. The pyrometallurgical processes are potential sources of dust and metals from furnaces, reactors and the transfer of molten metal. The production from secondary raw materials is also related to the off-gases from the various furnaces and transfers that contain dust and metals. In the majority of cases process gases are cleaned in fabric filters. Gas cleaning using wet scrubbers and wet electrostatic precipitators is particularly effective for process gases that undergo sulphur recovery in a sulphuric acid plant. In some cases where dust is abrasive or difficult to filter, wet scrubbers are also effective. The use of furnace sealing and enclosed transfers and storage is important in preventing fugitive emissions. The significance of fugitive emissions in many processes is very high and fugitive emissions can be much greater than those that are captured and abated. In these cases it is possible to reduce environmental impact by following the hierarchy of gas collection:

- Process optimisation and minimisation of emissions;
- Sealed reactors and furnaces;
- Targeted fume collection;

40. Use of mercury is declining, yet some significant uses remain. The main global uses are artisanal and small scale gold mining, batteries, fluorescent lamp production, dental amalgam and the chlor-alkali industry, together accounting for over 80% of consumption. Large amounts of mercury are currently brought out of use as a result of ongoing and anticipated substitution of mercury-based chlor-alkali production in Europe and North America. A globally harmonised effort is proposed to phase out primary production of

mercury and to stop surpluses re-entering the market. Reduced global demand for mercury in products and production processes may lead to a greater proportion of supply from secondary raw materials. Thus, BAT could be to produce mercury from secondary raw materials. Production of mercury from Cinnabar ore has ceased in Europe, but production from mercury content of other non-ferrous processes such as copper, lead and zinc via the sulphuric acid plant scrubber system continues to be a source of mercury.

41. For gold various alternative processes to amalgamation have been developed. The use of the copper route for smelting precious metals has a lower potential for the emission of lead to all environmental media and should be used if the combination of raw materials, equipment and products allows it. In the case of high content of mercury in the ore it is necessary to use an activated carbon adsorber bed. By applying pollution prevention measures, including mercury condensers, carbon adsorption units (e.g., single fixed carbon beds, multiple beds or columns or other designs), mercurous chloride scrubbers, venturi scrubbers, and chemical additives to improve mercury capture, mercury emissions from gold production have been reduced by 97 %.ⁱ

42. Non-ferrous metals are mainly produced from sulphitic ores. For technical and product quality reasons, the off-gas must go through a thorough dedusting (< 3 mg/m³) and could also require additional mercury removal before being fed to an SO₃ contact plant, thereby also minimizing heavy metal emissions. To remove mercury vapour from the gas stream, the following techniques are considered to be BAT: the Boliden/Norzink process, the Boliden/ Contec process, the Bolchem process, the Outotec process, the Sodium thiocyanate process, the Tynfoss Miltech application, the Lurgi process, the DOWA adsorption process or the use of an activated carbon filter. For processes where mercury removal from the gases is not practicable the Superlig Ion Exchange process and the potassium iodide process to reduce the mercury content in sulphuric acid produced during the production of non-ferrous metals are considered to be BAT. The emission level for mercury to air is 0.01 – 0.02 mg/ Nm³ as daily average.

43. Fabric filters should be used when appropriate. FFs may not be BAT for the recovery of non-ferrous metals from sulphur-bearing concentrates due to the potential for condensation of sulphuric acid on the baghouse filter media. For sticky or abrasive dusts, wet electrostatic precipitators or scrubbers can be effective. A dust content of less than 5 mg/m³ can be obtained. The dust of all pyrometallurgical production should be recycled in-plant or off-site, while protecting occupational health. BAT for gas collection and abatement for the various process stages regarding to PM and heavy metals are summarized in the following table:

Materials handling and storage.	Correct storage, handling and transfer. Dust collection and fabric filter if necessary.
Grinding, drying.	Process operation. Gas collection and fabric filter.
Sintering/roasting, Smelting, Converting, Fire refining	Gas collection, gas cleaning in fabric filter, heat recovery.

Slag treatment.	Gas collection, cooling and fabric filter.
Thermal refining.	Gas collection and fabric filter.
Electrode baking, graphitisation	Gas collection, condenser and ESP, afterburner or alumina scrubber and fabric filter.
Metal powder production	Gas collection and fabric filter.
Melting and casting.	Gas collection and fabric filter.

44. Depending on the raw materials available, BAT for primary lead production, are the Kaldor process, TBRC (totally enclosed), ISF and New Jersey Distillation, QSL, Kivcet furnace, Kaldor Furnace, Ausmelt/ISA Smelt Furnace, ISF and NEW Jersey Distillation, Flubor process (electrochemical leaching) and Blast Furnace.

45. Secondary lead is mainly produced from used car and truck batteries, which are dismantled before being charged to the smelting furnace. Depending on the raw materials available, processes that are BAT are: The blast furnace (with good process control), Ausmelt/ISA Smelt, the electric furnace and the rotary furnace. When only clean lead and clean scrap is used, also melting crucibles and kettles is BAT. Oxy-fuel burners can reduce waste gas volume and flue dust production by 60%. Cleaning the flue-gas with fabric filters makes it possible to achieve dust concentration levels below 1ⁱⁱ mg/Nm³. Efficient work zone enclosure and cleaning the exhaust air with filters are crucial in order to minimize diffuse emissions.

46. Primary zinc production is carried out by means of roast-leach electrowin technology. Pressure leaching may be an alternative to roasting and may be considered as a BAT for new plants depending on the concentrate characteristics. Emissions from pyrometallurgical zinc production in Imperial Smelting (IS) furnaces can be minimized by using a double bell furnace top and cleaning with high-efficiency scrubbers, efficient evacuation and cleaning of gases from slag and lead casting, and thorough cleaning of the CO-rich furnace off-gases (< 10 mg/m³). For any of these processes, good process control, gas collection and abatement systems are necessary.

47. To recover zinc from oxidized residues these are processed in an IS furnace. Very low-grade residues and flue dust (e.g. from the steel industry) are first treated in rotary furnaces (Waelz-furnaces) in which a high-content zinc oxide is manufactured. Metallic materials are recycled through melting in either induction furnaces or furnaces with direct or indirect heating by natural gas or liquid fuels or in vertical New Jersey retorts, in which a large variety of oxidic and metallic secondary material can be recycled. Zinc can also be recovered from lead furnace slags by a slag fuming process. For any of these processes, good process control, gas collection and abatement systems are necessary.

Table 7(a): Emission sources, control measures, dust reduction efficiencies and costs for the primary non-ferrous metal industry

Emission source	Control measure(s)	Dust reduction efficiency (%)	Abatement costs (total costs US\$)
Fugitive emissions	Furnace sealing, suction hoods, enclosure etc. off-gas cleaning by FF or ESP	Cleaning efficiency >99.75 (precipitator)	..
Roasting/sintering	Updraught sintering: ESP + scrubbers (prior to double contact sulphuric acid plant) + FF for tail gases	..	7 - 10/Mg H ₂ SO ₄
Conventional smelting (blast furnace reduction)	Shaft furnace: closed top/efficient evacuation of tap holes + FF, covered launders, double bell furnace top
Imperial smelting	High-efficiency scrubbing	>95	..
	Venturi scrubbers
	Double bell furnace top	..	4/Mg metal produced
Pressure leaching	Application depends on leaching characteristics of concentrates	> 99	site-specific
Direct smelting reduction processes	Flash smelting, e.g. Kivcet, Outotech and Mitsubishi process
	Bath smelting, e.g. top blown rotary converter (TBRC), Ausmelt/ISA Smelt, QSL and Noranda processes	Ausmelt: Pb 77, Cd 97; QSL: Pb 92, Cd 93	QSL: operating costs 60/Mg Pb

Table 7(b): Emission sources, control measures, dust reduction efficiencies and costs for the secondary non-ferrous metal industry

Emission source	Control measure(s)	Dust reduction efficiency (%)	Abatement costs (total costs US\$)
Lead production	Short rotary furnace: suction hoods for tap holes + FF; tube condenser, oxy-fuel burner	99.9	45/Mg Pb
Zinc production	Imperial smelting	> 95	14/Mg Zn

48. In general, processes should be combined with an effective dust collecting device for both primary gases and fugitive emissions. The most relevant emission reduction measures are outlined in tables 7(a) and (b). The BAT associated emission levels for dust are 1 – 5 mg/m³ using high performance fabric filters or alumina scrubber, and below 5 mg/m³ using wet ESP or ceramic filters.

49. For primary copper smelting, the continuous processes from Mitsubishi and Outotech/Kennecott are considered to be BAT for the smelting and converting stage. Similar environmental performance can be achieved using the Outotech Flash Smelting Furnace and the Ausmelt/ISA Smelt furnace, which are used in combination with the Peirce-Smith (or similar) converter. Depending on the raw materials available, other processes might be appropriate. Gases from the primary smelting and converting processes should be treated to remove dust and volatile metals.

50. For secondary copper smelting, Blast Furnaces, mini-smelter, TBRC, Sealed Submerged Arc Electric furnace, Ausmelt/ISA Smelt, KRS and the Peirce-Smith converter are considered BAT. The submerged arc electric furnace is a sealed unit and is therefore inherently cleaner than the others. For high grades of copper scrap without organic contamination, the reverberatory hearth furnace, the hearth shaft furnace and Contimelt process are considered to be BAT in conjunction with suitable gas collection and abatement systems. If batch operated converters such as the Peirce-Smith converters (or similar) are used they should be used with total enclosure or efficient primary and secondary fume collection systems. The Ausmelt/ISA Smelt furnace can be operated batch-wise, where smelting is carried out in a first stage followed by conversion in a second stage, and is also considered as BAT.

51. For secondary aluminium production, the Reverberatory furnace or Closed Well furnace, Tilting rotary furnace, Rotary furnace, Meltower Induction furnace, are considered to be BAT, when equipped with a sealed feeding system and targeted fume extraction systems and the use of fabric or ceramic filters for dust removal. The use of intelligent damper controls can improve fume capture and reduce fan sizes and hence costs. Sealed charging cars or skips are used with a reverberatory furnace at a secondary

aluminium smelter and reduces fugitive emissions to air significantly by containing emissions during charging.]

52. The application of selenium filter is proposed as a dry media process, which can be applied at both steel and non-ferrous metal smelters. Mercury removal of above 90 % has been achieved through this technique reducing the mercury concentrations to below 0.01 mg/m³. Selenium filters are recommended for the removal of mercury from the flue gas stream upstream of the acid plant in non-ferrous metal smelters. The mercury reduction of a selenium scrubber is about 90–95%, resulting in mercury concentrations of about 0.2 mg/m³. However, at low incoming Hg concentrations the removal efficiency can be less than 90 %. For the Odda chloride process, mercury concentrations of the treated gases are 0.05-0.1 mg/m³.

[53. For manganese production, depending on the content of mercury in manganese ore, it is a significant source to emissions of mercury. Using activated carbon adsorption of mercury in waste gas from furnace can give reductions of up to 99 %. Filters reducing dust particles < 1 mg/Nm³ give significant reduction of emissions of other heavy metals as well.]

54. Various processes are under development for the primary and secondary non-ferrous metal industry that may reduce dust and heavy metals emissions from this industry.

Table 7(c): Emission sources, control measures, mercury reduction efficiencies and costs for the non-ferrous metal industry

Emission source	Control measure(s)	Reduction efficiency (%)	Mercury content after cleaning (mg/m ³)	Abatement costs (annualised costs per t of product in US\$)
Gold production	carbon adsorption, mercurous chloride scrubbers, venturi scrubbers, chemical additives	75		
Sulphuric acid production	Superlig Ion Exchange process, Potassium Iodide process		~ 0.02	
Non ferrous metal production	wet scrubber	30 – 50		
	spray dry systems (+ FF)	35 – 85		
	Selenium filter	~ 90	< 0.01	10 – > 50 (for copper production, about 50% lower for lead)
	Lead sulfide process	99	0.01 – 0.05	
	Selenium scrubber	< 90 – 95	0.2	
	Odda chloride process		0.05 – 0.1	
[manganese production	combination of wet scrubber, wet ESP and Hg absorber	99		(full scale gas cleaning 5 Mio € /smelter in 2001/2002)]

V. Cement industry (annex II, category 7)

55. Cement kilns may use secondary fuels such as waste oil or waste tyres. The co-incineration of waste in cement kilns is treated within the waste incineration category. Mercury emissions can be reduced by controlling the amount of mercury in the input of the kiln. Fuels and raw materials with low mercury content should be used

56. Dust is emitted at all stages of the cement production process, consisting of material handling, raw material preparation (crushers, dryers), clinker production and cement preparation. Mercury is predominantly introduced into the kiln with raw-materials with generally a minor amount coming from the fuels. There is a constant increase in the use of waste fuels in the clinker production, which can be a source of heavy metals. It is generally the raw material input and not the process type which has the greater effect on heavy metal emissions.

57. For clinker production the following kiln types are available: long wet rotary kiln, long dry rotary kiln, rotary kiln with cyclone pre-heater, rotary kiln with grate pre-heater and precalciner, shaft furnace. The selected process has a major impact on the energy use and air emissions from the manufacture of cement clinker. For new plants and major upgrades the best available technique for the production of cement clinker is considered to be a dry process kiln with multi-stage preheating and precalcination.

58. For heat recovery purposes, rotary kiln off-gases are conducted through the preheating system and the mill dryers (where installed) before being dedusted. The collected dust is returned to the feed material. Excess heat from the kiln off-gases as well as from the clinker cooler can be used for electricity generation (cogeneration) or externally, e.g. for district heating.

59. Less than 0.5% of lead and cadmium entering the kiln is released in exhaust gases. The high alkali content and the scrubbing action in the kiln favour metal retention in the clinker or kiln dust.

60. The emissions of heavy metals into the air can be reduced by, for instance, taking off a bleed stream and stockpiling the collected dust instead of returning it to the raw feed. However, in each case these considerations should be weighed against the consequences of releasing the heavy metals into the waste stockpile. Another possibility is the hot-meal bypass, where calcined hot-meal is in part discharged right in front of the kiln entrance and fed to the cement preparation plant. Alternatively, the dust can be added to the clinker. Another important measure is a very well controlled steady operation of the kiln in order to avoid emergency shut-offs of the electrostatic precipitators. These may be caused by excessive CO concentrations. It is important to avoid high peaks of heavy metal emissions in the event of such an emergency shut-off.

BAT for the manufacturing of cement with regard to dust and heavy metals emissions the combination of the following general primary measures:

- A smooth and stable kiln process. Therefore to carry out monitoring and measurement of process parameters and emissions on a regular basis is important.
- Minimising fuel energy use.

- Careful selection and control of substances entering the kiln; when practicable selection of raw materials and fuels with low contents of sulphur, nitrogen, chlorine, metals and volatile organic compounds should be preferred.
- Use of a quality assurance system to control the characteristics of wastes to be used as raw material and/or fuel for constant quality and other physical and chemical criteria. Relevant parameters for any waste to be used as raw material and/or fuel should be controlled.

and

- The minimisation/prevention of dust emissions from fugitive sources
- The efficient removal of dust from point sources by application of electrostatic precipitators with fast measuring and control equipment to minimise the number of carbon monoxide trips or fabric filters with multiple compartments and ‘burst bag detectors’.

61. The most relevant emission reduction measures are outlined in table 8. To reduce direct dust emissions from crushers, mills, and dryers, fabric filters are mainly used, whereas kiln and clinker cooler waste gases are controlled by electrostatic precipitators or fabric filters. Dust can be reduced to concentrations < 10 – 20 mg/Nm³ (daily mean value, 10 vol% O₂).

Table 8: Emission sources, control measures, reduction efficiencies and costs for the cement industry

Emission source	Control measure(s)	Reduction efficiency (%)	Reported emissions (mg/m ³)	Abatement costs	
Direct emissions from crushers, mills, dryers, rotary kilns, clinker coolers	Primary measures plus FF or ESP	Cd, Pb: > 95	Dust: < 10 - 20		
Direct emissions from rotary kilns	Activated carbon adsorption	Hg: > 95	Hg: 0.01 – 0.03		

62. A way to minimize mercury emissions is to lower the exhaust temperature. When high concentrations of volatile metals (especially mercury) occur, adsorption on activated carbon is an option.

VI. Glass industry (annex II, category 8)

63. In the glass industry, lead emissions are particularly relevant given the various types of glass in which lead is introduced as raw material. Lead is used in fluxes and coloring

agents in the frit industry, in some special glasses (e.g. coloured glasses, CRT funnels) and domestic glass products (lead crystal glasses). In the case of soda-lime container glass, lead emissions depend on the quality of the recycled glass used in the process. External cullet is an important source of metal contamination particularly for lead. The lead content in dusts from crystal glass melting is usually about 20 - 80%.

64. Dust emissions stem mainly from batch mixing, furnaces, diffuse leakages from furnace openings, and finishing and blasting of glass products. They depend notably on the type of fuel used, the furnace type and the type of glass produced. Oxy-fuel burners can reduce waste gas volume and flue dust production by 60%. The lead emissions from electrical heating are considerably lower than from oil/gas-firing. In general and where it is economically viable, predominantly electrical melting is considered BAT for lead crystal, crystal glass and opal glass production, since this technique allows efficient control of potential emissions of volatile elements. Where crystal glass is produced with a less volatile formulation, other techniques may be considered when determining BAT for a particular installation.

65. The batch is melted in continuous tanks or day tanks. During the melting cycle using discontinuous furnaces, the dust emission varies greatly. The dust emissions from crystal glass tanks (< 5 kg/Mg melted glass) are higher than from other tanks (< 1 kg/Mg melted soda and potash glass).

66. Some measures to reduce direct metal-containing dust emissions are:

- pelleting the glass batch,
- changing the heating system from oil/gas-firing to electrical heating,
- charging a larger share of glass returns (cullet) in the batch, and
- applying a better selection of raw materials (size distribution) and recycled glass (avoiding lead-containing fractions).

In general, BAT for controlling dust emissions from furnaces in the glass industry is the use of either an electrostatic precipitator (ESP) or fabric filter system, operating where appropriate, in conjunction with a dry or semi-dry acid gas scrubbing system. The BAT emission level for dust associated with these techniques is generally < 10 – 20 mg/Nm³, for some glass types such as domestic glass or special glass generally < 10 – 20 mg/Nm³ and 1 -10 mg/Nm³, when significant amounts of dangerous substances are applied which generally equates to less than 0.1 kg/tonne of glass melted. In some cases, the application of BAT for metals emissions may result in lower emission levels for dust. The emission level associated with BAT for the sum of the concentrations of heavy metals including lead (As, Co, Ni, Cd, Se, Cr, Sb, Pb, Cu, Mn, V, Sn) is generally < 1 - 5 mg/ Nm³. Secondary dust abatement represents BAT for most glass furnaces, unless equivalent emissions can be achieved with primary measures.

The corresponding emission reduction efficiencies are given in table 9.

67. The development of crystal glass without lead compounds is in progress. The Plasma Melter makes use of the electrical conductivity of molten glass and operates with negligible dust emissions. It is however not expected to be a viable technique for melting within the foreseeable future.

68. For potentially dusty downstream activities BAT is considered to be dust minimisation, e.g. by cutting, grinding or polishing under liquid or by extraction of off gases to a bag filter system. The emission level for these activities is <1 – 10mg/Nm³ (up to 20 mg/ Nm³ for flat glass and up to 50 mg/Nm³ only for mineral wool downstream processes).

Table 9: Emission sources, control measures, dust reduction efficiencies and costs for the glass industry

Emission source	Control measure(s)	Dust reduction efficiency (%)	Abatement costs (total costs)
Direct emissions	FF	> 99	
	ESP	> ~ 95	

VII. Chlor-alkali industry (annex II, category 9)

69. In the chlor-alkali industry, Cl₂, alkali hydroxides and hydrogen are produced through electrolysis of a salt solution. Commonly used in existing plants are the mercury process, the diaphragm process and the membrane process. All these processes need the introduction of good practices to reduce environmental problems. The selected process technology has a major impact on the energy use and emissions from the manufacture of chlor-alkali. BAT for the production of chlor-alkali is considered to be membrane technology. Non-asbestos diaphragm technology can also be considered as BAT. The use of mercury-cell technology has been declining in Europe and North America over the past few decades, as many such plants have shut down or been converted to non-mercury processes. Moreover, European and North American producers are committed to not building any new mercury-cell facilities. Also there is no legal restriction, the last chlor-alkali plant in Canada closed in 2008. European regulations do not allow the construction of these facilities.

Mercury releases from chlor-alkali operations can be entirely eliminated only by converting to a non-mercury process such as the membrane cell process. Conversion to membrane cell technology is considered as BAT. Decision 90/3 of 14 June 1990 of the Commission for the Prevention of Marine Pollution from Land-based Sources (PARCOM) recommends that existing mercury cell chlor-alkali plants should be phased out as soon as practicable with the objective of phasing them out completely by 2010. The Decision 90/3 was reviewed in 1999-2001 without any changes. Among OSPARCOM countries and in the EU there has been considerable discussion about the possible impacts the re-marketing of the mercury from decommissioned chlor-alkali facilities will have on the global mercury market. In 1999 all West European chlor-alkali producers presented the authorities with a voluntary commitment to shut down their chlor-alkali plants until 2020 latest. Another clause of which commits them not to sell or transfer mercury cells after plant shutdown to any third party for re-use.

In February 2009, the [Governing Council of UNEP](#) agreed on the need to develop a global legally binding instrument on mercury and started negotiations of a global mercury convention.

70. The specific investment for replacing mercury cells by the membrane process is reported to be in the region of US\$ 700-1000 /Mg Cl₂ capacity. Although additional costs may result from, inter alia, higher utility costs and brine purification cost, the operating cost will in most cases decrease. This is due to savings mainly from lower energy consumption, and lower waste-water treatment and waste-disposal costs.

71. The sources of mercury emissions into the environment in the mercury process are: cell room ventilation; end box ventilation air; by-product hydrogen. With regard to emissions into air, Hg diffusely emitted from the cells to the cell room is particularly relevant. Preventive measures and control are of great importance and should be prioritized according to the relative importance of each source at a particular installation. In any case specific control measures are required when mercury is recovered from sludges resulting from the process.

72. During the remaining life of mercury cell plants, all possible measures should be taken to protect the environment as a whole including:

Minimising mercury losses to air by:

- Use of equipment and materials and, when possible, a lay-out of the plant that minimise losses of mercury due to evaporation and/or spillage;
- Good housekeeping practices and good maintenance routines;
- Collection and treatment of mercury-containing gas streams from all possible sources, including hydrogen gas. Typical devices for removal of mercury air emissions are shown in table A;
- Reduction of mercury levels in caustic soda;
- Minimising current and future mercury emissions from handling, storage, treatment and disposal of mercury-contaminated wastes;
- Decommissioning carried out in a way that prevents environmental impact during and after the shutdown process as well as safeguarding human health.

Table A: Control measures, reduction efficiencies and costs for Chlor Alkali plants emissions

Emission source	Control measure	Reduction efficiency [%]	Abatement costs
Chlor-alkali production	gas stream cooling to remove mercury from hydrogen stream; mist eliminators; scrubbers; adsorption on activated carbon and molecular sieves.	> 90	---

73. These measures can cut mercury emissions to values well below 2.0 g/Mg of Cl₂ production capacity, expressed as an annual average. All plants comply with the limit value of 2 g Hg/Mg Cl₂ for air emissions in PARCOM Decision 90/3, and it is clear that in many plants, air emissions continue to fall. However, for reported emissions a wide range in actual values from 0.14 to 1.57 g Hg/Mg Cl₂ is shown. The best performing mercury cell plants are achieving total mercury losses to air, water and with products in the range of 0.2 – 0.5 g Hg/Mg Cl₂ as a yearly average, and with regard to air emissions 0.21 – 0.32 g Hg/Mg Cl₂, as shown in table B. Since emissions depend to a large extent on good operating practices, the average should depend on and include maintenance periods of one year or less.

Table B: Mercury losses to air from best performing mercury cell plants

	g Hg/Mg Cl ₂
Air: cell room	0.2 – 0.3
process exhausts, including Hg distillation unit	0.0003 – 0.01
untreated cooling air from Hg distillation unit	0.006 – 0.1
hydrogen gas	< 0.003

VIII. Municipal, medical and hazardous waste incineration (annex II, categories 10 and 11)

74. There are wastes that are neither classified as hazardous, municipal or medical wastes, depending on national legislation (e.g., non-hazardous industrial wastes, sludge etc.), that may be incinerated as well as co-incinerated in other industries, therefore potentially constituting a relevant source of heavy metal emissions. Furthermore, there are other thermal waste treatment methods (e.g. pyrolysis) that may be a relevant source of heavy metal emissions. For BAT, no differentiation is made between municipal, hazardous and medical waste in terms of applied techniques or achievable emission limits, as all types of waste are often incinerated in the same installation. Emissions of cadmium, lead and mercury result from the incineration of municipal, medical and hazardous waste. Mercury, a substantial part of cadmium and minor parts of lead are volatilized in the process. Particular actions should be taken both before and after incineration to reduce these emissions. The only relevant primary techniques for preventing emissions of mercury into the air before incinerating are those that prevent or control, if possible, the inclusion of mercury in waste. In some countries mercury-containing components are separated out of the solid waste stream and managed or recycled properly. Removing mercury from the waste stream before it enters the incinerator is much more cost-effective than capturing mercury later from flue gases using emissions control devices. Lower emissions of mercury from municipal waste combustors and medical waste incinerators can be achieved through product substitution. Although this is potentially applicable to a wide range of components, batteries have received the greatest attention because of their significant contribution to total mercury content in municipal and medical wastes. The applicability of the product substitution to other areas should be based on technical and economic feasibility.

75. The best available technique for dedusting and reducing heavy metals emissions is considered to be fabric filters in combination with dry or wet methods for controlling volatiles. Electrostatic precipitators in combination with wet systems can also be designed to reach low dust emissions, but they offer fewer opportunities than fabric filters especially with pre-coating for adsorption of volatile pollutants. Between 30 % and 60 % of mercury is retained by high efficiency ESPs or fabric filters (FFs), and flue gas desulphurisation (FGD) systems capture further 10 to 20 %.

When using dry system, the additional injection of activated carbon (impregnated with sorbents like sulphur, bromine or others), sodium hydrogen carbonate or calcium hydroxide upstream of a fabric filter or use of lignite coke or zeolite can reduce the mercury emissions by more than 90%.

When using a wet scrubber system with ESP or FF, to improve the mercury removal different chemicals can be added to the wet scrubber solution, e.g. hydrogen peroxide, liquid chelating reagents with copper or manganese salts or NaClO.

76. When BAT is used for cleaning the flue gases, the concentration of dust can be reduced to 1 – 5 mg/m³. In general, the use of fabric filters gives the lower levels within these emission ranges. Effective maintenance of dust control systems is very important. Controlling dust levels generally reduces metal emissions too. The concentration of

mercury can be reduced to a range of 0.001 – 0.02 mg/m³ (daily average, normalized to 11% O₂). Adsorption using carbon based reagents is generally required to achieve these emission levels with many wastes. Some waste streams have very highly variable Hg concentrations and waste pre-treatment may be required in such cases to prevent peak overloading of FGT system capacity.

77. The most relevant secondary emission reduction measures are outlined in table 10. It is difficult to provide generally valid data because the relative costs in US\$/tonne depend on a particularly wide range of site-specific variables, such as waste composition.

78. If re-burn of flue gas treatment residues is applied, then suitable measures should be taken to avoid the re-circulation and accumulation of Hg in the installation.

79. Selective catalytic reduction (SCR) for control of nitrogen oxides also reduces mercury emissions as a co-benefit by changing it into a form that can be collected by fabric filters.

80. Most Parties require discontinuous monitoring of mercury emissions only, while some consider continuous monitoring as BAT; proven systems for continuous measurements of mercury emissions are available on the market.

81. For the co-incineration of waste and recovered fuel in cement kilns, in general, the BAT for cement kilns apply.

82. For the co-incineration of waste and recovered fuel in combustion installations, in general, the BAT for combustion installations apply.

83. The PECK process is a promising technique with negligible heavy metals emissions in the flue gas. It has been developed for municipal solid waste treatment but could in principle be applied to other wastes. Other options to reduce heavy metals emissions may be the heavy metal evaporation process and the hydro-metallurgical treatment plus vitrification.

Table 10: Emission sources, control measures, dust reduction efficiencies and costs for municipal, medical and hazardous waste incineration

Emission source	Control measure(s)	Reduction efficiency (%)	Abatement costs (total costs US\$)
Stack gases	High-efficiency scrubbers	Pd, Cd: >98; Hg: ca. 50	..
	ESP (3 fields) with activated carbon or equivalent adsorptive reagents	Pb, Cd: 80 – 90	10-20/Mg waste
	Wet ESP (1 field) with additives, in combination with activated carbon injection, or activated carbon or coke filters	Pb, Cd: 95 – 99 Hg: > 90 (1µg/Nm ³)	1,600 – 4,000 per pound Hg removed
	Fabric filters	Pb, Cd: 95 – 99	15-30/Mg waste
	Activated Carbon injection + FF or ESP	Hg: 50 – 95 (<1 µg/Nm ³)	operating costs: ca. 2 – 3/Mg waste; MWCs 211 – 870; Medical Waste Incinerators, 2,000 – 4000 per pound Hg removed.
	Carbon bed filtration	Hg: > 99	operating costs: ca. 50/Mg waste; 513 – 1,083 per pound Hg removed
	Selenium filters (inlet mercury concentrations of up to 9 mg/m ³)		

IX. Facilities dealing with waste containing metallic mercury and certain mercury compounds and mixtures (Annex II, category xx)

[84. In large scale gold production and artisanal small-scale gold mining yearly more than 1000 tonnes of mercury are used of which over 500 tonnes are emitted to air. This is two times more than the total emission to air in 2008 from the EMEP territory. Although these emissions take place in developing countries, emissions undergo long-range transboundary transport and thus affect health and environment in the ECE territory. In this context export of mercury from Europe is very relevant.]

[85. Europe alone exported in 2008 1300 tonnes of mercury a year, while worldwide trade amounted to 2200 tonnes. Mercury in use and in stock is much bigger than the mercury traded globally. In the EU27 plus Norway and Switzerland 34.000 tonnes of mercury were in stock. Most of this is linked to the chlor-alkali industry where industry will abandon the mercury electrolysis process.]

[86. UNEP advises countries to ban the export of mercury and to dispose of mercury containing waste in an environmental sound manner. As a result the supply will go down and the prices will be likely to go up. The price of mercury on the global market is currently slowly decreasing and lies in the range of 4- 20 US\$ per kilogram. Norway and the the European Union (2011) have a general prohibition on export, sale and use of mercury and mercury compounds. They also have regulations on the safe disposal of mercury waste. The US has banned the export of elemental mercury from 2013 onwards and has created an obligation for the administration to provide for a facility for safe storage by 2013. The disposal costs have been calculated at 0.5 US \$per kilogram.]

[87. The following should be considered as waste and should be disposed of in an environmentally sound manner, taking into account relevant sub-regional, regional and global regimes governing the management of hazardous wastes and their disposal, in particular the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal:

- (a) Metallic mercury that is no longer used in the chlor-alkali industry;
- (b) Metallic mercury resulting from the cleaning of natural gas;
- (c) Metallic mercury and mercury compounds resulting from the cleaning of exhaust gasses of stationary sources;
- (d) Metallic mercury resulting from non-ferrous mining and smelting operations;
- (e) Metallic mercury extracted from cinnabar ore; and
- (f) Obsolete mercury-containing products.]

[88. The disposal of mercury-containing waste and the transboundary movement of waste should be carried out in an environmentally sound manner, taking into consideration applicable sub-regional, regional and global regimes governing the transboundary movement and the management of hazardous wastes and their disposal, in particular the Basel Convention and the Basel Convention Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of Elemental Mercury and Wastes Containing or Contaminated with Mercury.]

ⁱ EPA; National Emission Standards for Hazardous Air Pollutants: Gold Mine Ore Processing (EPA-HQ-OAR_2010-0239; FRL-9242-3)

ⁱⁱ EPA's proposed National Standard for secondary lead smelters