

PROTOCOL
TO THE 1979 CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION
ON HEAVY METALS

The Parties.

Determined to implement the Convention on Long-range **Transboundary Air Pollution**,

Concerned that emissions of certain heavy metals are transported across national boundaries and may cause damage to ecosystems of environmental and economic importance and may have harmful effects on human health,

Considering that combustion and industrial processes are the predominant anthropogenic sources of emissions of heavy metals into the atmosphere,

Acknowledging that heavy metals are natural constituents of the **Earth's** crust and that many heavy metals in certain forms and appropriate concentrations are essential to life,

Taking into consideration existing scientific and technical data on the **emissions, geochemical** processes, atmospheric transport and effects on human health and the environment of heavy metals, as well as on abatement techniques and costs,

Aware that techniques and management practices are available to reduce air pollution caused by the emissions of heavy metals,

Recognizing that countries in the region of the United Nations Economic Commission for Europe (**UN/ECE**) have different economic **conditions**, and that in certain countries the economies are in transition,

Resolved to take measures to anticipate, prevent or minimize emissions of certain heavy metals and their related compounds, taking into account the application of the precautionary approach, as set forth in principle 15 of the Rio Declaration on Environment and Development,

Reaffirming that States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and development policies, and the responsibility to ensure that activities within their **jurisdiction** or control do not cause damage to the environment of Other States or of areas beyond the limits of national jurisdiction,

Mindful that measures to control emissions of heavy metals would also contribute to the protection of the environment and human health in areas outside the UN/ECE region, including the Arctic and international **waters**,

Noting that abating the emissions of **specific** heavy metals may provide additional benefits for the abatement of emissions of other pollutants,

Aware that further and more effective action to control and reduce emissions of certain heavy metals may be needed and that, for example, **effects-based** studies may provide a basis for further action,

Noting the important contribution of the private and **non-governmental** sectors to knowledge of the effects associated with heavy metals, available alternatives and abatement techniques, and their role in assisting in the reduction of emissions of heavy metals,

Bearing in mind the activities related to the control of heavy metals at the national level and in international **forums**,

Have agreed as follows :

Article 1

DEFINITIONS

For the purposes of the present **Protocol**,

1. "Convention" means the Convention on Long-range **Transboundary Air Pollution**, adopted in Geneva on 13 November 1979;
2. "EMEP" means the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in **Europe**;
3. "**Executive Body**" means the Executive Body for the Convention constituted under article 10, paragraph 1, of the Convention;
4. "Commission" means the United Nations Economic Commission for Europe;
5. "Parties" means, unless the context otherwise requires, the Parties to the present **Protocol**;
6. "Geographical scope of EMEP" means the area defined in article 1, paragraph 4, of the Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (**EMEP**), adopted in Geneva on 28 September 1984;
7. "Heavy metals" means those metals or, in some cases, metalloids which are stable and have a density greater than 4.5 g/cm³ and their **compounds**;
8. "Emission" means a release from a point or diffuse source into the **atmosphere**;
9. "Stationary source" means any fixed building, structure, facility, **installation**, or equipment that emits or may emit a heavy metal listed in annex I directly or indirectly into the **atmosphere**;
10. "New stationary source" means any stationary source of which the construction or substantial modification is commenced after the expiry of two years from the date of entry into force of: (i) this Protocol; or (ii) an amendment to annex I or II, where the stationary source becomes subject to the provisions of this Protocol only by virtue of that amendment. It shall be a matter for the competent national authorities to decide whether a modification is substantial or not, taking into account such factors as the environmental benefits of the **modification**;
11. "Major stationary source category" means any stationary source category that is listed in annex II and that contributes at least one per cent to a **Party's** total emissions from stationary sources of a heavy metal listed in annex I for the reference year specified in accordance with annex I.

Article 2

OBJECTIVE

The objective of the present Protocol is to control emissions of heavy metals caused by anthropogenic activities that are subject to long-range **transboundary** atmospheric transport and are likely to have significant adverse

effects on human health or the environment, in accordance with the provisions of the following articles.

Article 3

BASIC OBLIGATIONS

1. Each Party shall reduce its total annual emissions into the atmosphere of each of the heavy metals listed in annex I from the level of the emission in the reference year set in accordance with that annex by taking effective **measures**, appropriate to its particular **circumstances**.
2. Each Party shall, no later than the timescales specified in annex IV, apply:
 - (a) The best available techniques, taking into consideration annex III, to each new stationary source within a major stationary source category for which annex III identifies best available **techniques**;
 - (b) The limit values specified in annex V to each new stationary source within a major stationary source category. A Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission **levels**;
 - (c) The best available techniques, taking into consideration annex III, to each existing stationary source within a major stationary source category for which annex III identifies best available **techniques**. A Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission **reductions**;
 - (d) The limit values specified in annex V to each existing stationary source within a major stationary source category, insofar as this is technically and economically feasible. A Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission reductions.
3. Each Party shall apply product control measures in accordance with the conditions and timescales specified in annex VI.
4. Each Party should consider applying additional product management **measures, taking into consideration annex VIZ.**
5. Each Party shall develop and maintain emission inventories **for** the heavy metals listed in annex I, for those Parties within the geographical scope of EMEP, using as a minimum the methodologies specified by the Steering Body of EMEP, and, for those Parties outside the geographical **scope** of EMEP, using as guidance the methodologies developed through the work plan of the Executive **Body**.
6. A Party that, after applying paragraphs 2 and 3 above, cannot achieve the requirements of paragraph 1 above for a heavy metal listed in annex I, shall be exempted from its obligations in paragraph 1 above for that heavy **metal**.
7. Any Party whose total land area is greater than 6,000,000 **km²** shall be exempted from its obligations in paragraphs 2 **(b), (c), and (d)** above, if it can demonstrate that, no later than eight years after the date of entry into force of the present Protocol, it will have reduced its total annual emissions of each of the heavy metals listed in annex I from the source categories specified in annex II by at least 50 per cent from the level of emissions from these categories in the reference year specified in accordance with annex I.

A Party that intends to act in accordance with this paragraph shall so specify upon signature **of**, or accession **to**, the present **Protocol**.

Article 4

EXCHANGE OF INFORMATION AND TECHNOLOGY

1. The Parties **shall**, in a manner consistent with their **laws**, regulations and practices, facilitate the exchange of technologies and techniques designed to reduce emissions of heavy metals, including but not limited to exchanges that encourage the development of product management measures and the application of best available techniques, in particular by promoting:

- (a) The commercial exchange of available technology;
- (b) Direct industrial contacts and cooperation, including joint ventures;
- (c) The exchange of information and experience; and
- (d) The provision of technical assistance.

2. In promoting the activities specified in paragraph 1 above, the Parties shall create favourable conditions by facilitating contacts and cooperation among appropriate organizations and individuals in the private and public sectors that are capable of providing technology, design and engineering **services**, equipment or finance.

Article 5

STRATEGIES, **POLICIES**, PROGRAMMES AND MEASURES

1. Each Party shall **develop**, without undue **delay**, **strategies**, policies and programmes to discharge its obligations under the present **Protocol**.

2. A Party may, in addition:

- (a) Apply economic instruments to encourage the adoption of cost-effective approaches to the reduction of heavy metal emissions;
- (b) Develop government/industry covenants and voluntary agreements;
- (c) Encourage the more efficient use of resources and raw materials;
- (d) Encourage the use of less polluting energy sources;
- (e) Take measures to develop and introduce less polluting transport systems;
- (f) Take measures to phase out certain heavy metal emitting processes where substitute processes are available on an industrial **scale**;
- (g) Take measures to develop and employ cleaner processes for the prevention and control of pollution.

3. The Parties may take more stringent measures than those required by the present **Protocol**.

Article 6

RESEARCH, DEVELOPMENT AND MONITORING

The Parties shall encourage research, **development**, monitoring and cooperation, primarily focusing on the heavy metals listed in annex I, related, but not limited, to:

- (a) Emissions, long-range transport and deposition levels and their modelling, existing levels in the biotic and abiotic environment, the formulation of procedures for harmonizing relevant **methodologies**;
- (b) Pollutant pathways and inventories in representative ecosystems;
- (c) Relevant effects on human health and the **environment**, including quantification of those effects;
- (d) Best available techniques and practices and emission control techniques currently employed by the Parties or under **development**;
- (e) Collection, recycling and, if necessary, disposal of products or wastes containing one or more heavy metals;
- (f) Methodologies permitting consideration of socio-economic factors in the evaluation of alternative control **strategies**;
- (g) An **effects-based** approach which integrates appropriate information, including information obtained under subparagraphs (a) to (f) above, on measured or modelled environmental levels, pathways, and effects on human health and the environment, for the purpose of formulating future optimized control strategies which also take into account economic and technological **factors**;
- (h) Alternatives to the use of heavy metals in products listed in annexes VI and VII;
- (i) Gathering information on levels of heavy metals in certain products, on the potential for emissions of those metals to occur during the manufacture, processing, distribution in commerce, use, and disposal of the product, and on techniques to reduce such emissions.

Article 7

REPORTING

1. Subject to its laws governing the **confidentiality** of commercial **information**:

- (a) Each Party shall report, through the Executive Secretary of the Commission, to the Executive Body, on a periodic basis as determined by the Parties meeting within the Executive Body, information on the measures that it has taken to implement the present **Protocol**;
- (b) Each Party within the geographical scope of EMEP shall report, through the Executive Secretary of the Commission, to EMEP, on a periodic basis to be determined by the Steering Body of EMEP and approved by the Parties at a session of the Executive Body, information on the levels of emissions of the heavy metals listed in annex I, using as a minimum the methodologies and the temporal and spatial resolution specified by the Steering Body of EMEP. Parties in areas outside the geographical scope of EMEP shall make available similar information to the Executive Body if

requested to do so. In **addition**, each Party **shall**, as **appropriate**, collect and report relevant information relating to its emissions of other **heavy metals**, taking into account the guidance on the methodologies and the temporal and spatial resolution of the Steering Body of EMEP and the Executive Body.

2. The information to be reported in accordance with paragraph 1 (a) above shall be in conformity with a decision regarding format and content to be adopted by the Parties at a session of the Executive Body. The terms of this decision shall be reviewed as necessary to identify any additional elements regarding the format or the content of the information that is to be included in the **reports**.

3. In good time before each annual session of the Executive Body, EMEP shall provide information on the long-range transport and deposition of **heavy metals**.

Article 8

CALCULATIONS

EMEP shall, using appropriate models and measurements and in good time before each annual session of the Executive Body, provide to the Executive Body calculations of **transboundary** fluxes and depositions of heavy metals within the geographical scope of EMEP. In areas outside the geographical scope of EMEP, models appropriate to the particular circumstances of Parties to the Convention shall be **used**.

Article 9

COMPLIANCE

Compliance by each Party with its obligations under the present Protocol shall be reviewed regularly. The Implementation Committee established by decision 1997/2 of the Executive Body at its fifteenth session shall carry out such reviews and report to the Parties meeting within the Executive Body in accordance with the terms of the annex to that decision, including any amendments thereto.

Article 10

REVIEWS BY THE PARTIES AT SESSIONS OF THE EXECUTIVE BODY

1. The Parties shall, at sessions of the Executive Body, pursuant to article 10, paragraph 2 **(a)**, of the Convention, review the information supplied by the Parties, EMEP and other subsidiary bodies and the reports of the Implementation Committee **referred** to in article 9 of the present **Protocol**.

2. The Parties shall, at sessions of the Executive Body, keep under review the progress made towards meeting the obligations set out in the present **Protocol**.

3. The Parties shall, at sessions of the Executive Body, review the sufficiency and effectiveness of the obligations set out in the present **Protocol**.

(a) Such reviews will take into account the best available scientific information on the effects of the deposition of heavy metals, assessments of technological **developments**, and changing economic **conditions**;

(b) Such reviews **will**, in the light of the **research, development, monitoring and cooperation** undertaken under the present Protocol :

- (i) Evaluate progress towards meeting the objective of the present **Protocol**;
- (ii) Evaluate whether additional emission reductions beyond the levels required by this Protocol are warranted to reduce further the adverse effects on human health or the **environment**; and
- (iii) Take into account the extent to which a satisfactory basis exists for the application of an effects-based approach;

(c) The **procedures**, methods and timing for such reviews shall be specified by the Parties at a session of the Executive Body.

4. The Parties shall, based on the conclusion of the reviews referred to in paragraph 3 above and as soon as practicable after completion of the **review**, develop a work plan on further steps to reduce emissions into the atmosphere of the heavy metals listed in annex I.

Article 11

SETTLEMENT OF DISPUTES

1. In the event of a dispute between any two or more Parties concerning the interpretation or application of the present Protocol, the Parties concerned shall seek a settlement of the dispute through negotiation or any other peaceful means of their own **choice**. The Parties to the dispute shall inform the Executive Body of their dispute.

2. When **ratifying, accepting**, approving or acceding to the present Protocol, or at any time thereafter, a Party which is not a regional economic integration organization may declare in a written instrument submitted to the Depositary that, in respect of any dispute concerning the interpretation or application of the Protocol, it recognizes one or both of the following means of dispute settlement as compulsory ipso facto and without special agreement, in relation to any Party accepting the same **obligation**:

(a) Submission of the dispute to the International Court of Justice;

(b) Arbitration in accordance with procedures to be adopted by the Parties at a session of the Executive Body, as soon as practicable, in an annex on arbitration.

A Party which is a regional economic integration organization may make a declaration with like effect in relation to arbitration in accordance with the procedures referred to in **subparagraph (b)** above.

3. A declaration made under paragraph 2 above shall remain in **force** until it expires in accordance with its terms or until three months after written notice of its revocation has been deposited with the Depositary.

4. A new declaration, a notice of revocation or the expiry of a declaration shall not in any way affect proceedings pending before the International Court of Justice or the arbitral **tribunal**, unless the Parties to the dispute agree **otherwise**.

5. Except in a case where the Parties to a dispute have accepted the same means of dispute settlement under paragraph 2, if after twelve months

following notification by one Party to another that a dispute exists between **them**, the Parties concerned have not been able to settle their dispute through the means mentioned in paragraph 1 above, the dispute shall be submitted, at the request of any of the Parties to the dispute, to conciliation.

6. For the purpose of paragraph 5, a conciliation commission shall be created. The commission shall be composed of equal numbers of members appointed by each Party concerned or, where the Parties in conciliation share the same interest, by the group sharing that interest, and a chairman chosen jointly by the members so appointed. The commission shall render a recommendatory award, which the Parties shall consider in good faith.

Article 12

ANNEXES

The annexes to the present Protocol shall form an integral part of the **Protocol**. Annexes III and VII are recommendatory in **character**.

Article 13

AMENDMENTS TO THE PROTOCOL

1. Any Party may propose amendments to the present **Protocol**.

2. Proposed amendments shall be submitted in writing to the Executive Secretary of the Commission, who shall communicate them to all Parties. The Parties meeting within the Executive Body shall discuss the proposed amendments at its next **session**, provided that the proposals have been circulated by the Executive Secretary to the Parties at least ninety days **in advance**.

3. Amendments to the present Protocol and to annexes **I, II, IV, V** and **VI** shall be adopted by consensus of the Parties present at a session of the Executive Body, and shall enter into force for the Parties which have accepted them on the ninetieth day after the date on which two thirds of the Parties have deposited with the Depositary their instruments of acceptance **thereof**. Amendments shall enter into force for any other Party on the ninetieth day after the date on which that Party has deposited its instrument of acceptance **thereof**.

4. Amendments to annexes **III** and **VII** shall be adopted by consensus of the Parties present at a session of the Executive Body. On the expiry of ninety days from the date of its communication to all Parties by the Executive Secretary of the Commission, an amendment to any such annex shall become effective for those Parties which have not submitted to the Depositary a notification in accordance with the provisions of paragraph 5 below, provided that at least sixteen Parties have not submitted such a **notification**.

5. Any Party that is unable to approve an amendment to annex **III** or **VII** shall so notify the Depositary in writing within ninety days from the date of the communication of its adoption. The Depositary shall without delay notify all Parties of any such notification received. A Party may at any time substitute an acceptance for its previous notification and, upon deposit of an instrument of acceptance with the Depositary, the amendment to such an annex shall become effective for that Party.

6. In the case of a proposal to amend annex **I, VI** or **VII** by adding a heavy **metal**, a product control measure or a product or product group to the present Protocol:

(a) The **proposer shall** provide the Executive Body with the **information** specified in Executive Body decision 1998/1, **including** any amendments thereto; and

(b) The Parties shall evaluate the proposal in accordance with the procedures set forth in Executive Body decision 1998/1, including any amendments thereto.

7. Any decision to amend Executive Body decision 1998/1 shall be taken by consensus of the Parties meeting within the Executive Body and shall take effect sixty days after the date of adoption.

Article 14

SIGNATURE

1. The present Protocol shall be open for signature at Aarhus (Denmark) from 24 to 25 June 1998, then at United Nations Headquarters in New York until 21 December 1998 by States members of the Commission as well as States having **consultative** status with the **Commission** pursuant to paragraph 8 of Economic and Social Council resolution 36 (IV) of 28 March 1947, and by regional economic integration **organizations**, constituted by sovereign States members of the Commission, which have competence in respect of the negotiation, conclusion and application of international agreements in matters covered by the Protocol, provided that the States and organizations concerned are Parties to the **Convention**.

2. In matters within **their competence**, such regional economic integration organizations **shall**, on their own behalf, exercise the rights and fulfil the responsibilities which the present Protocol attributes to their member States. In **such cases**, the member States of these **organizations shall** not be entitled to exercise such rights individually.

Article 15

RATIFICATION, ACCEPTANCE, APPROVAL AND ACCESSION

1. The present Protocol shall be subject to ratification, acceptance or approval by Signatories.

2. The **present Protocol shall** be open for accession as from 21 December 1998 by the States and organizations that meet the requirements of article 14, paragraph 1.

Article 16

DEPOSITARY

The instruments of ratification, acceptance, approval or accession **shall** be deposited with the Secretary-General of the United Nations, who will perform the functions of Depositary.

Article 17

ENTRY INTO FORCE

1. The present Protocol shall enter into force on the ninetieth day following the date on which the sixteenth instrument of **ratification**, acceptance, approval or accession has been deposited with the Depositary.
2. For each State and organization referred to in article 14, paragraph 1, which ratifies, accepts or approves the present Protocol or accedes thereto after the deposit of the sixteenth instrument of **ratification**, acceptance, approval or accession, the Protocol shall enter into force on the ninetieth day following the date of deposit by such Party of its instrument of **ratification**, acceptance, approval or accession.

Article 18

WITHDRAWAL

At any time after five years from the **date** on which the present Protocol has come into force with respect to a Party, that Party may withdraw from it by giving written notification to the Depositary. Any such withdrawal shall take effect on the ninetieth day following the date of its receipt by the Depositary, or on such later date as may be specified in the notification of the withdrawal.

Article 19

AUTHENTIC TEXTS

The original of the present Protocol, of which the **English**, French and Russian texts are equally authentic, shall be deposited with the Secretary-General of the United **Nations**.

IN WITNESS WHEREOF the undersigned, being duly **authorized** thereto, have signed the present **Protocol**.

Done at Aarhus (**Denmark**), this **twenty-fourth** day of June, one thousand nine hundred and **ninety-eight**.

Annex I

**HEAVY METALS REFERRED TO IN ARTICLE 3, PARAGRAPH 1,
AND THE REFERENCE YEAR FOR THE OBLIGATION**

Heavy metal	Reference year
Cadmium (Cd)	1990; or an alternative year from 1985 to 1995 inclusive, specified by a Party upon ratification, acceptance, approval or accession.
Lead (Pb)	1990; or an alternative year from 1985 to 1995 inclusive , specified by a Party upon ratification, acceptance, approval or accession.
Mercury (Hg)	1990; or an alternative year from 1985 to 1995 inclusive, specified by a Party upon ratification, acceptance, approval or accession.

Annex II

STATIONARY SOURCE CATEGORIES

I. INTRODUCTION

1. Installations or parts of installations for research, development and the testing of new products and processes are not covered by this annex.

2. The threshold values given below generally **refer** to production capacities or output. Where one operator carries out several activities falling under the same subheading at the same installation or the same site, the capacities of such activities are added together.

II. LIST OF CATEGORIES

Category	Description of the category
1	Combustion installations with a net rated thermal input exceeding 50 MW.
2	Metal ore (including sulphide ore) or concentrate roasting or sintering installations with a capacity exceeding 150 tonnes of sinter per day for ferrous ore or concentrate, and 30 tonnes of sinter per day for the roasting of copper, lead or zinc, or any gold and mercury ore treatment .
3	Installations for the production of pig-iron or steel (primary or secondary fusion, including electric arc furnaces) including continuous casting , with a capacity exceeding 2.5 tonnes per hour.
4	Ferrous metal foundries with a production capacity exceeding 20 tonnes per day.
5	Installations for the production of copper, lead and zinc from ore , concentrates or secondary raw materials by metallurgical processes with a capacity exceeding 30 tonnes of metal per day for primary installations and 15 tonnes of metal per day for secondary installations , or for any primary production of mercury.
6	Installations for the smelting (refining, foundry casting, etc.), including the alloying, of copper, lead and zinc, including recovered products, with a melting capacity exceeding 4 tonnes per day for lead or 20 tonnes per day for copper and zinc.
7	Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day.
8	Installations for the manufacture of glass using lead in the process with a melting capacity exceeding 20 tonnes per day.
9	Installations for chlor-alkali production by electrolysis using the mercury cell process .
10	Installations for the incineration of hazardous or medical waste with a capacity exceeding 1 tonne per hour, or for the co-incineration of hazardous or medical waste specified in accordance with national legislation.
11	Installations for the incineration of municipal waste with a capacity exceeding 3 tonnes per hour , or for the co-incineration of municipal waste specified in accordance with national legislation.

Annex III

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

I. INTRODUCTION

1. This annex 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. "**Best** available techniques" (BAT) 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 emission limit values designed to prevent **and**, where that is not practicable, generally to reduce emissions and their impact on the environment as a whole:

- "Techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
- "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 territory of the Party in question, as long as they are reasonably accessible to the **operator**;
- "**Best**" means most effective in achieving a high general level of protection of the environment as a whole.

In determining the best available techniques, special consideration should be given, generally or in specific cases, to the factors below, bearing in mind the likely costs and benefits of a measure and the principles of precaution and **prevention**:

- The use of **low-waste technology**;
- The use of less hazardous substances;
- The furthering of recovery and recycling of substances generated and used in the process and of **waste**;
- Comparable **processes**, facilities or methods of operation which have been tried with success on an industrial scale;
- Technological advances and changes in scientific knowledge and **understanding**;
- The nature, effects and volume of the emissions **concerned**;
- The commissioning dates for new or existing **installations**;
- The time needed to introduce the best available technique;
- The consumption and nature of raw materials (including water) used in the process and its energy efficiency;
- The need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to **it**;
- The need to prevent accidents and to minimize their consequences **for the environment**.

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 Emissions and the Ad Hoc Preparatory Working Group on Heavy Metals. **Furthermore**, other international information on best available techniques for emission control has been taken into consideration (e.g. the European Community's technical notes on **BAT**, the **PARCOM** recommendations for **BAT**, and information provided directly by **experts**).

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 annex may, therefore, need amending and updating.

5. The annex 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 annex 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/m^3 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 per cent have been **demonstrated**. In particular cases experience has shown that control measures are able to reduce overall emissions by 90 per cent 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 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	< 10
Fabric filters, membrane type	< 1
Dry electrostatic precipitators	< 50
Wet electrostatic precipitators	< 50
High-efficiency scrubbers	< 50

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

14. Care should be taken to ensure that these control techniques do not create other environmental **problems**. The choice of a specific process because of its low emission into the air should be avoided if it worsens the total environmental impact of the heavy metals' **discharge**, e.g. due to more water pollution from liquid effluents. The fate of captured dust 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 are expressed in 1990 US\$ (US\$ 1 (1990) = ECU 0.8 (1990)). 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.

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.

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 a low heavy metal content instead of coal would also result in a significant reduction in heavy metal emissions such as mercury. Integrated gasification combined-cycle (IGCC) power plant technology is a new plant technology with a low-emission potential.

22. With the exception of mercury, heavy metals are emitted in solid form in association with fly-ash particles. Different coal combustion technologies show different magnitudes of fly-ash generation: grate-firing boilers 20-40%; fluidized-bed combustion 15%; dry bottom boilers (pulverized coal combustion) 70-100% of total ash. The heavy metal content in the small particle size fraction of the fly-ash has been found to be higher.

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

24. A total dust removal of more than 99.5% can be obtained with electrostatic precipitators (ESP) or fabric filters (FF), achieving dust concentrations of about 20 mg/m³ in many cases. 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. Low filter temperature helps to reduce the gaseous mercury off-gas content.

25. The application of techniques to reduce emissions of nitrogen oxides, sulphur dioxide and particulates from the flue gas can also remove heavy metals. Possible cross media impact should be avoided by appropriate waste water treatment.

26. Using the techniques mentioned above, mercury removal efficiencies vary extensively from plant to plant, as seen in table 3. Research is ongoing to develop mercury removal techniques, but until such techniques are available on an industrial scale, no best available technique is identified for the specific purpose of removing mercury.

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

Emission source	Control measure (s)	Reduction efficiency (%)	Abatement costs
Combustion of fuel oil	Switch from fuel oil to gas	Cd, Pb: 100; Hg: 70 - 80	Highly case-specific
Combustion of coal	Switch from coal to fuels with lower heavy metals emissions	Dust: 70 - 100	Highly case-specific
	ESP (cold-side)	Cd, Pb: > 90; Hg: 10 - 40	Specific investment US\$ 5-10/m ³ waste gas per hour (> 200,000 m ³ /h)
	Wet flue-gas desulphurization (FGD) a/	Cd, Pb: > 90; Hg: 10 - 90 b/	
	Fabric filters (FF)	Cd: > 95; Pb: > 99; Hg: 10 - 60	Specific investment US\$ 8-15/m ³ waste gas per hour (> 200,000 m ³ /h)

a/ Hg removal efficiencies increase with the proportion of ionic mercury. High-dust selective catalytic reduction (SCR) installations facilitate Hg(II) formation.

b/ This is primarily for SO₂ reduction. Reduction in heavy metal emissions is a side benefit. (Specific investment US\$ 60-250/kW_{el}.)

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

27. This section deals with emissions from sinter plants, pellet plants, blast furnaces, and steelworks with a basic oxygen furnace (BOF). Emissions of Cd, Pb and Hg occur in association with **particulates**. 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 metals added in **steel-making**. 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.

28. When using BAT in the primary iron and steel industry, the total specific emission of dust directly related to the process can be reduced to the **following** levels:

Sinter plants	40 - 120 g/Mg
Pellet plants	40 g/Mg
Blast furnace	35 - 50 g/Mg
BOF	35 - 70 g/Mg.

29. Purification of gases using fabric filters will reduce the dust content to less than 20 mg/m³, whereas electrostatic precipitators and scrubbers will reduce the dust content to 50 mg/m³ (as an hourly **average**). **However**, there are many applications of fabric filters in the primary iron and steel industry that can achieve much lower **values**.

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 (%)	Abatement costs (total costs US\$)
Sinter plants	Emission optimized sintering	ca. 50	..
	Scrubbers and ESP	> 90	..
	Fabric filters	> 99	..
Pellet plants	ESP + lime reactor + fabric filters	> 99	..
	Scrubbers	> 95	..
Blast furnaces	FF / ESP	> 99	ESP: 0.24-1/Mg pig-iron
Blast furnace gas cleaning	Wet scrubbers	> 99	..
	wet ESP	> 99	..
BOF	Primary dedusting: wet separator/ESP/FF	> 99	Dry ESP: 2.25/Mg steel
	Secondary dedusting: dry ESP/FF	> 97	FF: 0.26/Mg steel
Fugitive emissions	Closed conveyor belts, enclosure, wetting stored feedstock, cleaning of roads	80 - 99	..

30. Direct reduction and direct smelting are under development and 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.

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

31. 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. For all dust-emitting processes in the secondary iron and steel industry, dedusting in fabric filters, which reduces the dust content to less than 20 mg/m³, shall be considered as BAT. When BAT is used also for minimizing fugitive emissions, the specific dust emission (including fugitive emission directly related to the process) will not exceed the range of 0.1 to 0.35 kg/Mg steel. There are many examples of clean gas dust content below 10 mg/m³ when fabric filters are used. The specific dust emission in such cases is normally below 0.1 kg/Mg.

32. For the melting of scrap, two different types of furnace are in use: open-hearth furnaces and electric arc furnaces (EAF) where open-hearth furnaces are about to be phased out.

33. 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 steel-making. Measurements at EAF have shown that 95% of emitted mercury and 25% of cadmium emissions occur as vapour. The most relevant dust emission reduction measures are outlined in table 5.

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 (%)	Abatement costs (total costs US\$)
EAF	ESP	> 99	..
	FF	> 99.5	FF: 24/Mg steel

Iron foundries (annex II, category 4)

34. 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 and induction 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. These measures can reduce dust concentrations to 20 mg/m³, or **less**.

35. The iron foundry industry comprises a very wide range of process sites. For existing smaller **installations**, the measures listed may not be BAT if they are not economically viable.

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

Emission source	Control measure (s)	Dust reduction efficiency (%)	Abatement costs (total costs US\$)
EAF	ESP	> 99	..
	FF	> 99.5	FF: 24/Mg iron
Induction furnace	FF/dry absorption + FF	> 99	..
Cold blast cupola	Below-the-door take-off: FF	> 98	..
	Above-the-door take-off:		
	FF + pre-dedusting	> 97	8-12/Mg iron
	FF + chemisorption	> 99	45/Mg iron
Hot blast cupola	FF + pre-dedusting	> 99	23/Mg iron
	Disintegrator/ venturi scrubber	> 97	..

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

36. 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**. 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 are particularly relevant.

37. Mercury ores and concentrates are initially processed by crushing, and sometimes screening. Ore **beneficiation** techniques are not used extensively, although flotation has been used at some facilities processing low-grade ore. The crushed ore is then heated in either **retorts**, at small operations, or furnaces, at large operations, to the temperatures at which mercuric sulphide

sublimates. The resulting mercury vapour is condensed in a cooling system and collected as mercury **metal**. Soot from the condensers and settling tanks should be **removed**, treated with lime and returned to the retort or furnace.

38. For efficient recovery of mercury the following techniques can be used:

- Measures to reduce dust generation during mining and **stockpiling**, including minimizing the size of stockpiles;
- Indirect heating of the furnace;
- Keeping the ore as dry as possible;
- Bringing the gas temperature entering the condenser to only 10 to **20°C** above the dew **point**;
- Keeping the outlet temperature as low as possible; and
- Passing reaction gases through a post-condensation scrubber and/or a selenium filter.

Dust formation can be kept down by indirect heating, separate processing of fine grain classes of ore, and control of ore water content. Dust should be removed from the hot reaction gas before it enters the mercury condensation unit with cyclones and/or electrostatic **precipitators**.

39. For gold production by amalgamation, similar strategies as for mercury can be applied. Gold is also produced using techniques other than **amalgamation**, and these are considered to be the preferred option for new **plants**.

40. Non-ferrous metals are mainly produced from sulphitic **ores**. For technical and product quality reasons, the **off-gas** must go through a thorough dedusting ($< 3 \text{ mg/m}^3$) and could also require additional mercury removal before being fed to an **SO₂** contact plant, thereby also minimizing heavy metal **emissions**.

41. Fabric filters should be used when appropriate. A dust content of less than 10 mg/m^3 can be obtained. The dust of all pyrometallurgical production should be recycled **in-plant** or **off-site**, while protecting occupational health.

42. For primary lead production, first experiences indicate that there are interesting new direct smelting reduction technologies without sintering of the **concentrates**. These processes are examples of a new generation of direct autogenous lead smelting technologies which pollute less and consume less **energy**.

43. Secondary lead is mainly produced from used car and truck **batteries**, which are dismantled before being charged to the smelting furnace. This BAT should include one melting operation in a short rotary furnace or shaft **furnace**. **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 of 5 mg/m^3 .

44. 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 ($< 10 \text{ mg/m}^3$) of the CO-rich furnace **off-gases**.

45. 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**.

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	Suction hoods, enclosure, etc. off-gas cleaning by FF	> 99	..
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 Venturi scrubbers Double bell furnace top	> 95 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, Outokumpu and Mitsubishi processes
	Bath smelting, e.g. top blown rotary converter, Ausmelt, Isasmelt, 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

46. 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). Dust concentrations below 5 mg/m³ have been achieved in some cases using fabric filters.

Cement industry (annex II, category 7)

47. Cement kilns may use secondary fuels such as waste oil or waste tyres. Where waste is used, emission requirements for waste incineration processes may apply, and where hazardous waste is used, depending on the amount used in the plant, emission requirements for hazardous waste incineration processes may apply. However, this section refers to fossil fuel fired kilns.

48. Particulates are emitted at all stages of the cement production process, consisting of material handling, raw material preparation (crushers, **dryers**), clinker production and cement preparation. **Heavy** metals are brought into the cement kiln with the raw materials, fossil and waste **fuels**.

49. For clinker production the following kiln types are available: long wet rotary **kiln**, long dry rotary kiln, rotary kiln with cyclone preheater, rotary kiln with grate preheater, shaft **furnace**. In terms of energy demand and emission control **opportunities**, rotary kilns with cyclone **preheaters** are **preferable**.

50. 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**.

51. 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.

52. 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**.

53. 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**. With ESP, dust can be reduced to concentrations below 50 mg/m^3 . When FF are **used**, the clean gas dust content can be reduced to 10 mg/m^3 .

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

Emission source	Control measure (s)	Reduction efficiency (%)	Abatement costs
Direct emissions from crushers , mills, dryers	FF	Cd, Pb: > 95	..
Direct emissions from rotary kilns , clinker coolers	ESP	Cd, Pb: > 95	..
Direct emissions from rotary kilns	Carbon adsorption	Hg: > 95	..

Glass industry (annex II, category 8)

54. In the glass industry, lead emissions are particularly relevant given the various types of glass in which lead is introduced as raw material (**e.g.** crystal glass, cathode ray **tubes**). In the case of **soda-lime** container glass, lead emissions depend on the quality of the recycled glass used in the

process. The lead content in dusts from crystal glass melting is usually about 20-60%.

55. 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**.

56. The batch is melted in continuous **tanks**, day tanks or **crucibles**. 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**).

57. 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 in the batch, and applying a better selection of raw materials (size distribution) and recycled glass (avoiding **lead-containing fractions**). Exhaust gases can be cleaned in fabric filters, reducing the emissions below 10 **mg/m³**. With electrostatic precipitators 30 **mg/m³** is achieved. The corresponding emission reduction efficiencies are given in table 9.

58. The development of crystal glass without lead compounds is in **progress**.

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	> 98	..
	ESP	> 90	..

Chlor-alkali industry (annex II, category 9)

59. 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 and the diaphragm process, both of which need the introduction of good practices to avoid environmental problems. The membrane process results in no direct mercury emissions. **Moreover**, it shows a lower electrolytic energy and higher heat demand for alkali hydroxide concentration (the global energy balance resulting in a slight advantage for membrane cell technology in the range of 10 to 15%) and a more compact cell operation. It is, **therefore**, considered as the preferred option for new plants. 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.

60. 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**.

61. The sources of mercury emissions into the environment in the mercury process are: cell room ventilation; process **exhausts**; products, particularly

hydrogen; and waste water. With regard to emissions into air, Hg diffusely emitted from the cells to the cell room are 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.

62. The following measures can be taken to reduce emissions from existing mercury process plants :

- Process control and technical measures to optimize cell operation, maintenance and more efficient working methods;
- **Coverings**, sealings and controlled **bleeding-off** by suction;
- Cleaning of cell rooms and measures that make it easier to keep them clean; and
- Cleaning of limited gas streams (certain contaminated air streams and hydrogen gas).

63. These measures can cut mercury emissions to values well below 2.0 g/Mg of Cl₂ production capacity, expressed as an annual average. There are examples of plants that achieve emissions well below 1.0 g/Mg of Cl₂ production capacity. As a result of PARCOM decision 90/3, existing mercury-based chlor-alkali plants were required to meet the level of 2 g of Hg/Mg of Cl₂ by 31 December 1996 for emissions covered by the Convention for the Prevention of Marine Pollution from Land-based Sources. 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.

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

64. 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.

65. The best available technology for dedusting 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.

66. When BAT is used for cleaning the flue gases, the concentration of dust will be reduced to a range of 10 to 20 mg/m³; in practice lower concentrations are reached, and in some cases concentrations of less than 1 mg/m³ have been reported. The concentration of mercury can be reduced to a range of 0.05 to 0.10 mg/m³ (normalized to 11% O₂).

67. 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.

68. Heavy metals are found in all fractions of the municipal waste stream (e.g. products, paper, organic materials). Therefore, by reducing the quantity of municipal waste that is incinerated, heavy metal emissions can be reduced. This can be accomplished through various waste management strategies, including recycling programmes and the composting of organic materials. In addition, some UN/ECE countries allow municipal waste to be landfilled. In a properly managed landfill, emissions of cadmium and lead are

eliminated and mercury emissions may be lower than with **incineration**. Research on emissions of mercury from landfills is taking place in several **UN/ECE** countries.

Table 10: Emission **sources**, control **measures**, 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	Pb, Cd: > 98; Hg: ca. 50	..
	ESP (3 fields)	Pb , Cd: 80 - 90	10-20/Mg waste
	Wet ESP (1 field)	Pb, Cd: 95 - 99	..
	Fabric filters	Pb, Cd: 95 - 99	15-30/Mg waste
	Carbon injection + FF	Hg: > .85	operating costs: ca. 2-3/Mg waste
	Carbon bed filtration	Hg: > 99	operating costs: ca. 50/Mg waste

Annex IV

**TIMESCALES FOR THE APPLICATION OF LIMIT VALUES AND
BEST AVAILABLE TECHNIQUES TO NEW AND EXISTING
STATIONARY SOURCES**

The timescales for the application of limit values and best available techniques are :

- (a) For new stationary sources: two years after the date of entry into force of the present Protocol;
- (b) For existing stationary **sources**: eight years after the date of entry into force of the present Protocol. If **necessary**, this period may be extended for specific existing stationary sources in accordance with the amortization period provided for by national legislation.

Annex V

LIMIT VALUES FOR CONTROLLING EMISSIONS FROM MAJOR STATIONARY SOURCES

I. INTRODUCTION

1. Two types of limit value are important for heavy metal emission control:

- Values for **specific** heavy metals or groups of heavy metals; and
- Values for emissions of particulate matter in **general**.

2. In principle, limit values for particulate matter cannot replace specific limit values for cadmium, lead and mercury, because the quantity of metals associated with particulate emissions differs from one process to another. However, compliance with these limits contributes **significantly** to reducing heavy metal emissions in **general**. Moreover, monitoring particulate emissions is generally less expensive than monitoring individual species and continuous monitoring of individual heavy metals is in general not feasible. Therefore, particulate limit values are of great practical importance and are also laid down in this annex in most cases to complement or replace specific limit values for cadmium or lead or mercury.

3. Limit values, expressed as mg/m^3 , refer to standard conditions (volume at 273.15 K, 101.3 kPa, dry gas) and are calculated as an average value of **one-hour measurements**, covering several hours of operation, as a rule 24 hours. Periods of start-up and shutdown should be excluded. The averaging time may be extended when required to achieve sufficiently precise monitoring results. With regard to the oxygen content of the waste gas, the values given for selected major stationary sources shall apply. Any dilution for the purpose of lowering concentrations of pollutants in waste gases is forbidden. Limit values for heavy metals include the solid, gaseous and vapour form of the metal and its **compounds**, expressed as the **metal**. Whenever limit values for total emissions are given, expressed as **g/unit** of production or capacity respectively, they refer to the sum of stack and fugitive emissions, calculated as an annual value.

4. In cases in which an exceeding of given limit values cannot be excluded, either emissions or a performance parameter that indicates whether a control device is being properly operated and maintained shall be monitored. Monitoring of either emissions or performance indicators should take place continuously if the emitted mass flow of particulates is above 10 kg/h. If emissions are monitored, the concentrations of air pollutants in gas-carrying ducts have to be measured in a representative fashion. If particulate matter is monitored **discontinuously**, the concentrations should be measured at regular intervals, taking at least three independent readings per check. Sampling and analysis of all pollutants as well as reference measurement methods to calibrate automated measurement systems shall be carried out according to the standards laid down by the Comité européen de normalisation (CEN) or the International Organization for Standardization (ISO). While awaiting the development of the CEN or ISO standards, national standards shall apply. National standards can also be used if they provide equivalent results to CEN or ISO standards.

5. In the case of continuous monitoring, compliance with the limit values is achieved if none of the calculated average **24-hour** emission concentrations exceeds the limit value or if the **24-hour** average of the monitored parameter does not exceed the correlated value of that parameter that was established during a performance test when the control device was being properly operated and maintained. In the case of discontinuous emission monitoring, compliance is achieved if the average reading per check does not exceed the value of the limit. Compliance with each of the limit values expressed as total emissions

per unit of production or total annual emissions is achieved if the monitored value is not exceeded, as described **above**.

II. **SPECIFIC LIMIT VALUES FOR SELECTED MAJOR STATIONARY SOURCES**

Combustion of fossil fuels (annex II, category 1):

6. Limit values refer to 6% O₂ in flue gas for solid fuels and to 3% O₂ for liquid fuels.

7. Limit value for particulate emissions for solid and liquid **fuels**: 50 mg/m³.

Sinter plants (annex II, category 2):

8. Limit value for particulate **emissions**: 50 mg/m³.

Pellet plants (annex II, category 2):

9. Limit value for particulate **emissions**:

(a) Grinding, drying: 25 mg/m³; and

(b) Pelletizing: 25 mg/m³; or

10. Limit value for total particulate emissions: 40 g/Mg of pellets **produced**.

Blast furnaces (annex II, category 3):

11. Limit value for particulate emissions: 50 mg/m³.

Electric arc furnaces (annex II, category 3):

12. Limit value for particulate emissions: 20 mg/m³.

Production of copper and zinc, including Imperial Smelting furnaces (annex II, categories 5 and 6):

13. Limit value for particulate emissions: 20 mg/m³.

Production of lead (annex II, categories 5 and 6):

14. Limit value for particulate emissions: 10 mg/m³.

Cement industry (annex II, category 7):

15. Limit value for particulate emissions: 50 mg/m³.

Glass industry (annex II, category 8):

16. Limit values refer to different O₂ concentrations in flue gas depending on furnace type: tank furnaces: 8%; pot furnaces and day **tanks**: 13%.

17. Limit value for lead emissions: 5 mg/m³.

Chlor-alkali industry (annex II, category 9):

18. Limit values refer to the total quantity of mercury released by a plant into the air, regardless of the emission source and expressed as an annual **mean value**.

19. Limit values for existing **chlor-alkali** plants shall be evaluated by the Parties meeting within the Executive Body no later than two years after the date of entry into **force** of the present **Protocol**.

20. Limit value for new chlor-alkali plants: **0.01 g Hg/Mg Cl₂** production capacity.

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

21. Limit values refer to 11% **O₂** concentration in flue gas.

22. Limit value for particulate emissions:

(a) **10 mg/m³** for hazardous and medical waste **incineration**;

(b) **25 mg/m³** for municipal waste **incineration**.

23. Limit value for mercury emissions:

(a) **0.05 mg/m³** for hazardous waste incineration;

(b) **0.08 mg/m³** for municipal waste incineration;

(c) Limit values for **mercury-containing** emissions from medical waste incineration shall be evaluated by the Parties meeting within the Executive Body **no** later than two years after the date of entry into force of the present **Protocol**.

Annex VI

PRODUCT CONTROL MEASURES

1. Except as otherwise provided in this annex, no later than six months after the date of entry into force of the present Protocol, the lead content of marketed petrol intended for on-road vehicles shall not exceed 0.013 g/l. Parties marketing unleaded petrol with a lead content lower than 0.013 g/l shall endeavour to maintain or lower that level.
2. Each Party shall endeavour to ensure that the change to fuels with a lead content as specified in paragraph 1 above results in an overall reduction in the harmful effects on human health and the environment.
3. Where a State determines that limiting the lead content of marketed petrol in accordance with paragraph 1 above would result in severe socio-economic or technical problems for it or would not lead to overall environmental or health benefits because of, inter alia, its climate **situation**, it may extend the time period given in that paragraph to a period of up to 10 **years**, during which it may market leaded petrol with a lead content not exceeding 0.15 g/l. In such a case, the State shall specify, in a declaration to be deposited together with its instrument of **ratification, acceptance, approval or accession**, that it intends to extend the time period and present to the Executive Body in writing information on the reasons for **this**.
4. A Party is permitted to market small quantities, up to 0.5 per cent of its total petrol **sales**, of leaded petrol with a lead content not exceeding 0.15 g/l to be used by old on-road vehicles.
5. Each Party shall, no later than five years, or ten years for countries with economies in transition that state their intention to adopt a ten-year period in a declaration to be deposited with their instrument of **ratification, acceptance, approval or accession**, after the date of entry into force of this Protocol, achieve concentration levels which do not exceed:
 - (a) 0.05 per cent of mercury by weight in alkaline manganese batteries for prolonged use in extreme conditions (e.g. temperature below 0°C or above 50°C, exposed to **shocks**); and
 - (b) 0.025 per cent of mercury by weight in all other alkaline manganese **batteries**.

The above limits may be exceeded for a new application of a battery technology, or use of a battery in a new product, if reasonable safeguards are taken to ensure that the resulting battery or product without an easily removable battery will be disposed of in an environmentally sound manner. Alkaline manganese button cells and batteries composed of button cells shall also be exempted from this obligation.

Annex VII

PRODUCT MANAGEMENT MEASURES

1. This annex aims to provide guidance to Parties on product management **measures**.
2. The Parties may consider appropriate product management measures such as those listed below, where warranted **as** a result of the potential risk of adverse effects on human health or the environment from emissions of one or more of the heavy metals listed in annex I, taking into account all relevant risks and benefits of such **measures**, with a view to ensuring that any changes to products result in an overall reduction of harmful effects on human health and the environment :
 - (a) The substitution of products containing one or more intentionally added heavy **metals** listed in annex I, if a suitable **alternative** exists;
 - (b) The minimization or substitution in products of one or more intentionally added heavy metals listed in annex I;
 - (c) The provision of product information including labelling to ensure that users are informed of the content of one or more intentionally added heavy metals listed in annex I and of the need for safe use and waste **handling**;
 - (d) The use of economic incentives or voluntary agreements to reduce or eliminate the content in products of the heavy metals listed in annex I; and
 - (e) The development and implementation of programmes for the **collection**, recycling or disposal of products containing one of the heavy metals in annex I in an environmentally sound manner.
3. Each product or product group listed below contains one or more of the heavy metals listed in annex I and is the subject of regulatory or voluntary action by at least one Party to the Convention based for a significant part on the contribution of that product to emissions of one or more of the heavy metals in annex I. **However**, sufficient information is not yet available to confirm that they are a significant source for all Parties, thereby warranting inclusion in annex VI. Each Party is encouraged to consider available information **and**, where satisfied of the need to take precautionary measures, to apply product management measures such as those listed in paragraph 2 above to one or more of the products listed below:
 - (a) **Mercury-containing** electrical components, i.e. devices that contain one or several **contacts/sensors** for the transfer of electrical current such as relays, thermostats, level switches, pressure switches and other switches (actions taken include a ban on most **mercury-containing** electrical components; voluntary programmes to replace some mercury switches with electronic or special switches; voluntary recycling programmes for **switches**; and voluntary recycling programmes for **thermostats**);
 - (b) **Mercury-containing** measuring devices such as **thermometers**, manometers, barometers, pressure gauges, pressure switches and pressure transmitters (actions taken include a ban on **mercury-containing** thermometers and ban on measuring **instruments**);
 - (c) **Mercury-containing** fluorescent lamps (actions taken include reductions in mercury content per lamp through both voluntary and regulatory programmes and voluntary recycling **programmes**);

(d) **Mercury-containing** dental amalgam (actions taken include voluntary measures and a ban with exemptions on the use of dental amalgams and voluntary programmes to promote capture of dental **amalgam before** release to water treatment plants from dental **surgeries**);

(e) **Mercury-containing** pesticides including seed dressing (actions taken include bans on all mercury pesticides including seed treatments and a ban on mercury use as a **disinfectant**);

(f) **Mercury-containing** paint (actions taken include bans on all such **paints**, bans on such paints for interior use and use on **children's** toys; and bans on use in **antifouling paints**); and

(g) **Mercury-containing** batteries other than those covered in annex VI (actions taken include reductions in mercury content through both voluntary and regulatory programmes and environmental **charges** and voluntary recycling **programmes**).
