GUIDANCE ON MERCURY RELEASES

UN environment programme

MINAMATA CONVENTION ON MERCURY

This guidance document, which was adopted by the Conference of the Parties to the Minamata Convention on Mercury at its fifth meeting in November 2023 (UNEP/MC/COP.5/Dec.9), has been formatted for outreach purposes.

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GUIDANCE ON BEST AVAILABLE TECHNIQUES AND BEST ENVIRONMENTAL PRACTICES TO CONTROL RELEASES OF MERCURY FROM RELEVANT SOURCES

Note by the secretariat

This document sets out guidance on best available techniques and best environmental practices (BAT/BEP) to control releases of mercury from relevant sources, adopted by the Conference of the Parties (COP) to the Minamata Convention on Mercury at its fifth meeting in 2023, pursuant to paragraph 7 of Article 9 of the Convention.

Article 9 of the Convention addresses releases of mercury and mercury compounds to land and water. Emissions of mercury to air are provided for in Article 8. Paragraph 3 of Article 9 provides that Parties shall identify the relevant point source categories of releases of mercury and mercury compounds to land and water. Paragraph 4 provides that a Party with relevant sources shall take measures to control releases. Paragraph 5 provides that such measures shall include one or more of the elements listed in that paragraph, which include the use of BAT/BEP. Paragraph 7 provides that the COP shall adopt guidance on BET/BEP, taking into account any differences between new and existing sources and the need to minimize cross-media effects.

The COP, at its fourth meeting in 2022, requested the Group of Technical Experts established by the COP at its second meeting in 2019 to develop a draft guidance on BAT/BEP. The Group of Technical Experts submitted to the COP at its fifth meeting in 2023 document UNEP/MC/COP.5/8 which contained a draft guidance, as well as document UNEP/MC/COP.5/INF/11 which contained a technical reference document to support the use of the guidance.

The COP, in its decision MC-5/9, adopted the guidance as submitted, invited Parties with relevant sources of mercury releases to take account of the guidance when taking measures to control releases of mercury and preparing a national plan thereon, if any, pursuant to paragraph 4 of article 9, and requested the Secretariat to support Parties, especially developing-country Parties and Parties with economies in transition, in the application of the guidance.

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1. INTRODUCTION

INTRODUCTION

1.1. PURPOSE OF THE GUIDANCE

1. The present document contains guidance related to best available techniques and best environmental practices to assist parties in fulfilling their obligations under article 9 of the Minamata Convention on Mercury (hereinafter referred to as "the Convention"). Article 9 concerns controlling and, where feasible, reducing releases of mercury and mercury compounds to land and water from the relevant point sources not addressed in other provisions of the Convention.

2. The guidance has been prepared and adopted as required by article 9 of the Convention. It does not establish mandatory requirements, nor does it attempt to add to, or subtract from, a party's obligations under article 9. In determining best available techniques, each party will take account of its national circumstances in accordance with the definition of best available techniques set out in paragraph (b) of article 2, which explicitly mentions taking into account economic and technical considerations for a given party or a given facility within its territory. It is recognized that, for technical or economic reasons, some of the control measures described in this guidance may not be available to all parties. Financial support, capacity-building, technology transfer and technical assistance are made available as set out in articles 13 and 14 of the Convention.

1.2. HOW TO USE THE GUIDANCE

3. The guidance contains five sections. Section 1 introduces the guidance and provides general information on how the Minamata Convention addresses mercury releases to land and water; section 2 provides some cross-cutting information, including considerations in the selection and implementation of best available techniques and best environmental practices; section 3 provides general information on common release control techniques generally applicable to many source categories; section 4 addresses techniques for selected specific source categories; and section 5 addresses the monitoring of mercury releases.

4. Additional technical information, including on emerging techniques that are at the pilot stage, is available as a separate reference document (UNEP/MC/COP.5/INF/11), although that document is not part of the formal guidance.

1.3. CHEMICAL FORMS OF MERCURY

5. Mercury is an element, which may also be found in various chemical forms. The Convention deals with both elemental mercury and mercury compounds, but only where the mercury and its compounds are anthropogenically emitted or released. Inorganic mercury compounds include oxides, sulfides or chlorides, for example. In this guidance, the term "mercury" refers to both elemental mercury and mercury compounds unless the context makes it clear that a specific form is meant. This is consistent with the scope of article 9 on releases, which concerns controlling and, where feasible, reducing emissions of mercury and mercury compounds, often expressed as "total mercury", to land and water.

6. The chemical form of mercury releases varies, depending on the source type and other factors. Mercury, once released to land and water, may, under certain circumstances, undergo transformation into organic compounds such as methyl or ethyl mercury, which are the most toxic forms of mercury.

1.4. HOW THE MINAMATA CONVENTION ADDRESSES MERCURY RELEASES

7. The objective of the Minamata Convention (article 1) is to protect the human health and the environment from anthropogenic emissions (to air) and releases (to land and water) of mercury and mercury compounds. The Convention addresses the life cycle of mercury and mercury compounds from their supply sources to their trade, use, emission, release, storage and waste management and the management of contaminated sites. Mercury and mercury compounds can be released to land and water at all stages of the life cycle, and some of the provisions of the Convention that address those stages also cover such releases.

8. Article 9 "concerns controlling and, where feasible, reducing releases of mercury and mercury compounds, often expressed as 'total mercury', to land or water from the relevant point sources". A "relevant source" is "any significant anthropogenic point source of release as identified by a party that is not addressed in other provisions of the Convention". Article 9 requires parties to identify the relevant point source categories no later than three years after the entry into force of the Convention and on a regular basis thereafter. The Conference of the Parties, in its decision MC-4/5, on mercury releases, invited parties to consider the list of potentially relevant point source categories as included in the guidance on the methodology for preparing inventories of releases (UNEP/MC/COP.4/30).

9. Parties with relevant sources have an obligation to take measures to control releases pursuant to article 9.

Article 9, paragraphs 4 and 5

4. A party with relevant sources shall take measures to control releases and may prepare a national plan setting out the measures to be taken to control releases and its expected targets, goals and outcomes. Any plan shall be submitted to the Conference of the Parties within four years of the date of entry into force of the Convention for that party. If a party develops an implementation plan in accordance with article 20, the party may include in it the plan prepared pursuant to this paragraph.

5. The measures shall include one or more of the following, as appropriate:

   (a) Release limit values to control and, where feasible, reduce releases from relevant sources;

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

   (c) A multi-pollutant control strategy that would deliver co-benefits for control of mercury releases;

   (d) Alternative measures to reduce releases from relevant sources.

10. Each party is to determine the releases that are significant for that party and that are therefore to be controlled. The discharge of wastewater to a body of water may be considered as a significant release to water, whether discharged directly to the body of water or indirectly via an off-site wastewater treatment plant or a common discharge pipe. The discharge of wastewater to land or the deposit of objects containing mercury onto land other than controlled containment areas may be regarded as a significant release to land.

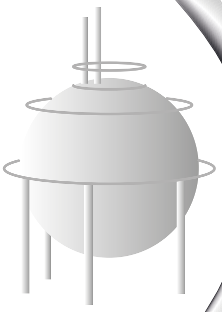
1.5. SOURCES OF MERCURY RELEASES COVERED BY THIS GUIDANCE

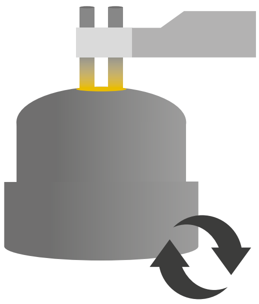
11. To support the parties in taking measures to control releases from relevant point sources that they have identified, this guidance addresses potentially relevant point source categories, as mentioned in subsection 1.4. Table 1 lists the potentially relevant point source categories and release sources not addressed in other provisions of the Convention that were included in the guidance on the methodology for preparing inventories of releases, together with a reference to the sections and subsections of the present guidance where information on best available techniques and best environmental practices is given.

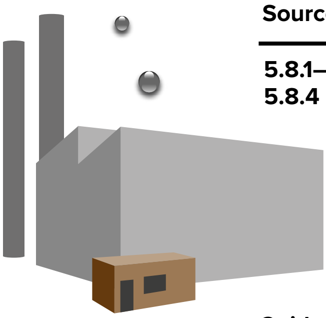
12. Point sources addressed specifically in other provisions of the Convention and therefore not covered by this guidance include vinyl chloride monomer production (covered by article 5, on manufacturing processes in which mercury or mercury compounds are used), polyurethane production (covered by article 5), artisanal and small-scale gold mining (article 7) and mercury wastes (article 11).

TABLE 1 LIST OF POTENTIALLY RELEVANT POINT SOURCE CATEGORIES

Source category in the UNEP Toolkit for identification and quantification of mercury releases		Release sources not addressed in other provisions of the Minamata Convention[a]	Relevant sections and subsections of this guidance
Source category: 5.1 Extraction and use of fuels/energy sources			
5.1.1	Coal combustion in large power plants	Releases to land and water from coal storage, coal washing and air pollution control systems	Subsection 4.1, on releases from air pollution control systems, and subsection 4.2, on coal combustion
5.1.2	Other coal combustion	Releases to land and water from coal storage, coal washing and air pollution control systems	Subsection 4.1, on releases from air pollution control systems, and subsection 4.2, on coal combustion
	Coal mining[b]	Releases to land and water from wet processing methods, such as coal flotation and coal washing	Subsection 4.2, on coal combustion
5.1.3	Mineral oils –extraction, refining and use (petroleum)	Releases to land and water from oil extraction, oil refining and air pollution control systems	Subsection 4.1, on releases from air pollution control systems, and subsection 4.3, on oil and gas
5.1.4	Natural gas –extraction, refining and use	Releases to land and water from natural gas extraction and refining	Subsection 4.1, on releases from air pollution control systems, and subsection 4.3, on oil and gas
5.1.6	Biomass-fired power and heat production	Releases to land and water from air pollution control systems	Subsection 4.1, on releases from air pollution control systems
Source category: 5.2 Primary (virgin) metal production			
5.2.1	Mercury extraction and initial processing	Releases to land and water from mining and mineral processing	Subsection 4.4, on primary mercury metal production
5.2.3–5.2.8	Mining, mineral processing, smelting and roasting of non ferrous metals other than mercury	Releases to land and water from collected mine drainage, mineral processing, air pollution control systems, associated smelting and roasting and process residues	Subsection 4.1, on releases from air pollution control systems, and subsection 4.5, on non ferrous metal production
5.2.9	Primary ferrous metal production	Releases to land and water from air pollution control systems associated with coke production, coal tar processing, pig-iron production and process residues	Subsection 4.1, on releases from air pollution control systems
Source category: 5.3 Production of other minerals and materials with mercury impurities			
5.3.1	Cement clinker production	Releases to land and water from air pollution control systems; possible releases to land from disposal of process residues such as cement kiln dust	Subsection 4.1, on releases from air pollution control systems
5.3.2	Pulp and paper production	Releases to land and water from air pollution control systems and from process residues	Subsection 4.1, on releases from air pollution control systems
5.3.4	Other minerals and materials	Releases to land and water from fertilizer production, dyes, pigments and other chemicals	Techniques in section 3 may be considered

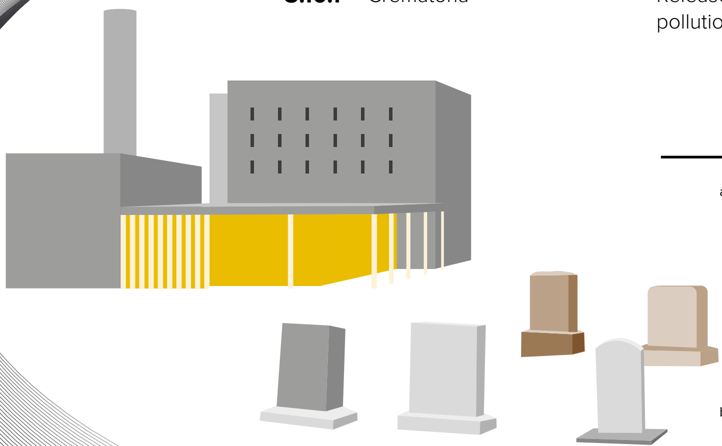






Source category in the UNEP Toolkit for identification and quantification of mercury releases		Release sources not addressed in other provisions of the Minamata Convention[a]	Relevant sections and subsections of this guidance
Source category: 5.4 Intentional use of mercury in industrial processes			
5.4.1	Chlor-alkali production with mercury technology	Releases to land and water from the production process and from contaminated plants	Subsection 4.6, on chlor-alkali production.
Source category: 5.5 Consumer products with intentional use of mercury			
5.5.1–5.5.9	Manufacturing of products containing mercury	Releases to land and water from the manufacture of product categories not listed in annex A to the Convention and product categories below the mercury content limits in annex A	Techniques in section 3 may be considered
Source category: 5.6 Other intentional products/process uses			
5.6.1	Dental mercury amalgam fillings	Releases to water, such as from new fillings or from the drilling of old fillings in dental clinics (Note: Parties may, but are not required to, address such releases under article 4.)	Techniques in section 3 may be considered
5.6.3	Laboratory chemicals and equipment	Reagents containing mercury and mercury compounds discharged in wastewaters	Techniques in section 3 may be considered
Source category: 5.7 Production of recycled metals (secondary metal production)			
5.7.1	Production of recycled mercury ("secondary production")	Releases to land and water from air pollution control systems	Subsection 4.1, on releases from air pollution control systems
5.7.2	Production of recycled ferrous metals (iron and steel) (includes the recycling of scrap vehicles)	Releases to land and water from air pollution control systems	Subsection 4.1, on releases from air pollution control systems
	Reuse or recycling of used industrial equipment[c]	Releases may take place during the dismantling of factories, oil rigs, etc. where mercury contaminated equipment (e.g., pipelines, tanks, heat exchangers) is recycled	Techniques described for chlor alkali production may be used
Source category: 5.8 Waste incineration			
5.8.1–5.8.4	Waste incineration	Releases to land and water from air pollution control systems associated with hazardous waste, medical waste, municipal waste/ industrial waste, and sewage sludge incinerators	Subsection 4.1, on releases from air pollution control systems and subsection 4.7, on waste incineration.

Source category in the UNEP Toolkit for identification and quantification of mercury releases		Release sources not addressed in other provisions of the Minamata Convention[a]	Relevant sections and subsections of this guidance
Source category: 5.9 Waste deposition/landfilling and wastewater treatment			
5.9.1	Controlled landfills/ deposits	Releases to water from landfill leachate	Techniques in section 3 may be considered
5.9.5	Wastewater systems/ treatment	Releases/treated wastewater from industrial and municipal wastewater treatment processes	Techniques in section 3 may be considered
		When residues/sludges are incinerated, releases/wastewater from air pollution control systems	Subsection 4.1, on releases from air pollution control systems
Source category: 5.10 Crematoria and cemeteries			
5.10.1	Crematoria	Releases to land and water from air pollution control systems	Subsection 4.1, on releases from air pollution control systems



[a] According to paragraph 2 of article 9, the term “releases” means releases of mercury or mercury compounds to land and water and the term “relevant source” means any significant anthropogenic point source of release as identified by a party that is not addressed in other provisions of the Convention. In its decision MC-3/4, on releases of mercury, the Conference of the Parties noted that “while wastewater is addressed under article 9, parties may additionally control wastewater under article 11 of the Convention”.

[b] Not included in the UNEP toolkit. Thus there is no number for these sources.

[c] Not included in the UNEP toolkit. Thus there is no number for these sources.

2. CONSIDERATIONS IN THE SELECTION AND IMPLEMENTATION OF BEST AVAILABLE TECHNIQUES AND BEST ENVIRONMENTAL PRACTICES

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2.1. GENERAL CONSIDERATIONS RELATING TO BEST AVAILABLE TECHNIQUES

13. The definition of the term "best available techniques" in article 2 of the Convention forms the basis for the parties' selection process.

Article 2, paragraph (b)

(b) "Best available techniques" means those techniques that are the most effective to prevent and, where that is not practicable, to reduce emissions and releases of mercury to air, water and land and the impact of such emissions and releases on the environment as a whole, taking into account economic and technical considerations for a given party or a given facility within the territory of that party. In this context:

(i) "Best" means most effective in achieving a high general level of protection of the environment as a whole;

(ii) "Available" techniques means, in respect of a given party and a given facility within the territory of that party, those techniques developed on a scale that allows implementation in a relevant industrial sector under economically and technically viable conditions, taking into consideration the costs and benefits, whether or not those techniques are used or developed within the territory of that party, provided that they are accessible to the operator of the facility as determined by that party; and

(iii) "Techniques" means technologies used, operational practices and the ways in which installations are designed, built, maintained, operated and decommissioned.

14. The consideration of a number of factors guides analysis of the best available techniques, including the age of the equipment and facilities involved, the processes employed, process changes, non-water-quality environmental impacts (including energy requirements) and the cost of applying the techniques. Best available techniques may also include changes in processes or the conduct of internal controls. Best available techniques are determined to be technologically and economically achievable, justifiable under the jurisdiction of the party concerned.

15. The process of selecting and implementing best available techniques could be expected to include the following general steps:

(a) ***Step 1:*** Establishment of information about the source or source category. This may include, but is not limited to, information on the related processes, input materials, feedstocks or fuels and on the actual or expected level of activity, including the throughput. Other relevant information could include the expected lifespan of the facility, which is likely to be of particular relevance when an existing facility is being considered, and any requirements or plans related to the control of other pollutants;

(b) ***Step 2:*** Identification of the full range of options for the prevention of releases of mercury to wastewater or for its removal therefrom and combinations of such techniques that are relevant to the source under consideration, including the techniques described in the present guidance in section 3, on common techniques for the control of releases, and section 4, on techniques for specific sources of release;

(c) ***Step 3:*** Identification of technically viable control options, with consideration being given to the techniques applicable to the particular type of facility within the sector and to any physical or operational limitations that might influence the choice of technique;

(d) ***Step 4:*** Selection, from among the techniques identified in step 3, the control techniques that are the most effective for the removal and, where feasible, reduction of mercury releases, taking into account the performance levels mentioned in this guidance, and for the achievement of a high general level of protection of human health and the environment;

(e) ***Step 5:*** Determination of which techniques can be implemented under economically and technically viable conditions, taking into consideration the costs and benefits and whether the techniques are accessible to the operator of the facility as determined by the party concerned. It is to be noted that the options selected for new and existing facilities may differ. The need for sound maintenance and operational control of the techniques should also be taken into account, so that the level of performance achieved can be maintained over time.

2.2. PERFORMANCE LEVELS

16. Sections 3 and 4 of the present guidance include information about the performance levels that have been achieved in facilities implementing the techniques to control releases of mercury that are described in those sections, where such information is available. This information is not intended to be interpreted as providing recommendations for release limit values as defined in subparagraph 2 (f) of article 9, namely limits "on the concentration or mass of mercury or mercury compounds, often expressed as 'total mercury', released from a relevant point source". Paragraph 5 of article 9 includes release limit values in the list of measures that parties may select to apply to their relevant sources. If a party chooses to apply limit values, it should consider factors similar to those described in subsection 2.1 in relation to best available techniques.

2.3. BEST ENVIRONMENTAL PRACTICES

17. The term "best environmental practices" is also defined in article 2 of the Convention.

Article 2, paragraph (c)

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

18. The proper maintenance of facilities and measurement equipment is important for the effective implementation of control and monitoring techniques. Skilled operators who are suitably trained and aware of the need to pay attention to processes are indispensable for ensuring good performance. Careful planning and the commitment of all levels of the organization operating the facility will also help to maintain performance, as will administrative controls and other facility management practices.

19. The establishment and operation of an environmental management system is a good practice that contributes to the control of releases. An environmental management system is a structured approach to managing the environmental aspects of an operation that typically includes reviewing the company's environmental goals; analysing environmental risks, the company's environmental impact and related legal requirements; setting environmental objectives and targets to reduce environmental impact and ensure compliance with legal requirements; establishing programmes to meet those objectives and targets; monitoring and measuring the progress made in achieving the objectives; ensuring employees' environmental awareness, knowledge of the national environmental laws and competence; and reviewing the operation of the system and continuously improving it.

2.4. CONSIDERATION OF THE COSTS AND BENEFITS OF TECHNIQUES AND PRACTICES

20. Analysis of the costs and benefits of techniques and practices is an important element in determining best available techniques and best environmental practices and is to be done taking into account the economic and technical considerations of the party or the facility. The implementation of measures to control mercury releases will usually involve some cost. There may be capital costs associated with the installation of the control technologies or an increase in the cost of operating and maintaining the facilities, or both. Some examples of these costs in relation to particular facilities are included in the associated technical reference document, where reliable information is available. The actual costs, however, are likely to depend on the specific circumstances of a facility; thus, the figures quoted should be taken only as a broad indication of the likely scale of the costs. For each particular case, information specific to the facility in question will need to be obtained. It is recognized that the costs will generally fall to the operator of the facility, while the benefits are reaped by society in general.

2.5. CROSS-MEDIA EFFECTS AND MULTI-POLLUTANT CONTROL TECHNIQUES

21. Many techniques for controlling mercury releases to land and water will result in the generation of a solid waste, such as sludge, precipitate or spent ion-exchange resin. Where such wastes meet the definition of mercury waste provided in the paragraph 2 of article 11 of the Convention, parties should take appropriate measures so that they are managed in an environmentally sound manner in order to avoid secondary mercury pollution.

22. Techniques for controlling mercury emissions to air may also have cross-media effects. The guidance on best available techniques and best environmental practices for the control of mercury emissions includes consideration of such cross-media effects, and the present guidance also addresses the control of releases from air pollution control systems.

23. There are techniques that may be used to control releases of a range of pollutants, such as suspended particulates, metals including mercury and organic pollutants. For example, sulfide precipitation of mercury will also reduce the concentration of other metals in the water. Consideration should be given to the advantages of using techniques that are capable of controlling several pollutants simultaneously, to deliver co-benefits. In the consideration of release-control techniques, factors such as how efficient they are at controlling both mercury and other pollutants and whether there are any potential adverse consequences should be taken into account. For example, an assessment of the potential releases from treatment aids and the pollutants released during the regeneration of treatment media or equipment might be necessary in specific situations.

3. COMMON TECHNIQUES FOR THE CONTROL OF RELEASES

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24. Most of the techniques for controlling mercury releases to land and water relate to the removal of mercury from wastewater, where mercury is dissolved in wastewater, adsorbed onto suspended particles or present within the mineral matrix of suspended particles. Subsections 3.1 to 3.7 describe techniques for removing mercury from wastewater, while subsection 3.8 covers other forms of mercury releases.

25. Release control may start with processes to remove suspended particles, such as gravity separation. Dissolved mercury can be removed by techniques including precipitation and adsorption, while the removal of mercury adsorbed onto soil or solid wastes first involves its separation (also known as desorption) from the materials onto which it is adsorbed by physical, chemical or thermal treatment.

26. Mercury contained in wastewater can be removed by several techniques using physicochemical and biological treatments. Removal techniques may reduce or oxidize mercury to make it more amenable to adsorptive techniques or biological treatments using microorganisms.

27. Section 3 provides general information on control techniques that are applicable across all the relevant source categories listed in the subsection 1.5. Additional information relevant to specific individual sectors can be found in section 4.

3.1. REMOVAL OF SOLID CONTENT

28. Where mercury content is present within the mineral matrix of suspended particles, separation techniques that avoid its mobilization or release are required. Suitable separation or clarification techniques include:

    (a) Gravity separation (grit separation, sedimentation)

    (b) Coagulation and flocculation

    (c) Flotation

    (d) Centrifugal separation

    (e) Filtration.

29. Some techniques to remove dissolved or adsorbed mercury from wastewater need to be as free of solid content as possible, which often makes an upstream filtration step necessary. For example, adsorbent active surfaces are often prone to clogging and blockage, and, in case of ion exchange, suspended particles in the feed should normally be less than 50 mg per litre to prevent plugging. Clogging and blockage is also an significant issue in filtration and needs to be taken into account in the maintenance of the filtration system.

3.2. PRECIPITATION OF METALS

30. Precipitation is a process that forms insoluble particulates (solid precipitate) in water, which is followed by an additional process of separating those particulates from the water. It is a technology frequently used to treat groundwater and wastewater contaminated with mercury. Water characteristics or contaminants that may affect other technologies, such as hardness or the existence of other heavy metals, are less likely to reduce the effectiveness of this technology. Systems that use precipitation generally require skilled operators, which means that this technology is more cost-effective when conducted on a large scale, so that the labour costs can be spread over a larger amount of treated water. It may be complemented with other treatment techniques to improve treatment efficiency. The best performances consist of a combination of precipitation with filtration, co-precipitation and adsorption.

31. Precipitation usually involves pH adjustment and the addition of a chemical precipitant or coagulant to transform soluble metals and inorganic contaminants into insoluble metals and inorganic salts. Mercury removal usually includes changing the pH of the water to be treated because removal is maximized at the pH level at which the precipitated species is least soluble. The optimal pH range for precipitation depends on the waste being treated and the specific treatment process. The precipitated solid is typically removed by clarification or filtration.

32. Sulfide precipitation is a common technique used to remove inorganic mercury from wastewater. Mercury ions dissolved in the wastewater can be removed by precipitation with the addition of sulfide reagents. In this process, the adjusted pH range is between 7 and 9, and the addition of sulfide reagents to an aqueous solution of mercury ions ($Hg^{2}+$) results in the formation of mercury sulfide, which is insoluble and precipitates out of the solution. There may be harmful effects on occupational health during metal sulfide precipitation. Typical chemicals used to precipitate mercury sulfide are sodium sulfide and polyorganosulfides. The simplified chemical reaction is as follows:

$$Hg^{2+}(\text{aqueous}) + S^{2-}(\text{aqueous}) \leftrightarrows HgS\ (\text{solid})$$

33. The precipitants usually have to be disposed of as sludge. Depending on the precipitating agent used, this waste may contain carbonates, fluorides, hydroxides (or oxides), phosphates, sulfates and sulfides of heavy metals. Excess use of chemical sulfide precipitants can also form soluble mercury sulfide species. Mercury can resolubilize from sulfide sludges under conditions that exist in landfills, which could lead to mercury contamination of leachate and potential groundwater pollution. The effluent from mercury precipitation may also require further treatment, such as pH adjustment, before discharge or reuse. Sulfide precipitation of mercury may generate residual sulfide in the effluent, and treatment to remove it may be needed before discharge.

3.3. RECOVERY OF MERCURY BY REDUCTION AND COALESCENCE

34. As a pretreatment, before techniques such as adsorption to activated carbon, reducing agents such as hydroxylamine can be used to convert ionic mercury fully into its elemental form. It can then be removed by coalescence, and the metallic mercury can be recovered.

3.4. ION EXCHANGE

35. Ion exchange is the removal of undesired or hazardous ionic constituents of wastewater and their replacement with more acceptable ions from an ion-exchange resin, in which they are temporarily retained and then released into a regeneration or backwashing liquid. In order to be removed by ion exchange, mercury must first be oxidized to the mercuric cation ($Hg^{2}+$) with oxidizing agents such as hypochlorite, chlorine or hydrogen peroxide.

36. Ion exchange is not commonly used for mercury treatment as it is more likely to be affected by the characteristics of the media and by contaminants other than mercury than co-precipitation and sulfide precipitation techniques. The use of adsorption and ion exchange is more appropriate when mercury is the only contaminant to be treated, in smaller-capacity systems and for the polishing of pre-treated effluent.

37. Ion exchange implies the consumption of ion-exchange resins, regeneration liquids, water for backwashing and rinsing and energy for the pumps. The addition of other chemicals – for example, to suppress microbiological fouling – may also be necessary. The regeneration of ion-exchange resins results in a small volume of concentrated acid or salt solution, which contains the ions that have been removed from the resin. This enriched liquid has to be treated separately to remove these ions – for example, by undergoing precipitation to remove heavy metals.

3.5. ADSORPTION

38. Adsorption has been used to remove inorganic mercury from groundwater and wastewater. Its effectiveness is likely to be affected by the characteristics of the untreated water and by contaminants other than mercury therein, more so than the process of precipitation. It can be a primary treatment method, but it is often used to remove mercury left in the waste stream after a primary treatment process.

39. Adsorption tends to be used more often when mercury is the only contaminant to be treated, for systems with relatively smaller capacity and as a polishing technology for the effluent from larger systems. Small-capacity systems using adsorption technologies tend to have lower operating and maintenance costs and require less operator expertise.

3.5.1. Activated carbon

40. Activated carbon, a highly porous carbonaceous substance, is usually used to remove organic materials from wastewater, but it also has applications in the removal of mercury and precious metals. For instance, granular activated carbon has a wide efficiency range and is not restricted to polar or non-polar compounds. As a pretreatment, reducing agents such as hydroxylamine can be used to convert ionic mercury fully into its elemental form for subsequent removal by coalescence and the recovery of the metallic mercury, followed by adsorption onto activated carbon.

41. Powdered activated carbon adsorption is applied to the same contaminants as granular activated carbon. It is dosed to the wastewater to be treated as a slurry and subsequently removed by separation processes such as sedimentation and filtration.

42. When the adsorptive capacity of the adsorbent has been exhausted, it will be replaced and subsequently regenerated (with the exception of powdered activated carbon, which is disposed of together with other wastewater sludge). Each adsorbent has its own regeneration method. Common to these methods, however, is the need for energy and/or chemicals for their operation. Granular activated carbon is thermally regenerated at temperatures of up to 750–1,000°C. If the granular activated carbon cannot be regenerated, it has to be disposed of as chemical waste and incinerated.

3.5.2. Chelating resins

43. Chelating resins are resins comprising functional groups that form chelates (complexes) with ions of specific metals. They are used to remove toxic heavy metals such as mercury, copper, zinc and cadmium and to recover precious and valuable metals such as gold, platinum and palladium.

44. Selective adsorption and removal of mercury is generally performed by resins with chelate-forming groups containing sulfur, such as the thiol group (-SH) and the thiourea group ($-NH \cdot CS \cdot NH_2$). Table 2 shows the specific nature of certain exchange groups. After filtration and separation of the suspended matter and the insoluble mercury-compound particles in the wastewater, a small amount of chlorine is added under acidic conditions (approximately pH 2–6) to ionize the mercury completely. The liquid is then passed through a reaction tower filled with chelating resin to adsorb and remove the mercury. Since the sulfur functional group of the mercury-chelating resin is sensitive to chlorine, the amount of chlorine added should be limited to 5 mg per litre.

45. Chelating resins can last longer than other adsorbents but are difficult and expensive to regenerate. When the mercury concentration is high, it is therefore desirable to remove most of the mercury in advance using the sulfide method.

TABLE 2 CHELATING-RESIN EXCHANGE GROUPS AND FEATURES

Exchange group	Adsorbed ion	Feature
Thiol system	Hg^{2+}	• Mercury can be selectively removed
Thiourea system	Hg^{2+}, Cd^{2+}, Pb^{2+}, Zn^{2+}, Cu^{2+}	• Sensitive to oxidants as the chelate forming group contains sulfur

46. Precious metals (such as gold, platinum and palladium) can be adsorbed in addition tomercury.

47. Chelating resins adsorb only mercury ions dissolved in water. Mercury that is not in ionic form, such as that in metallic mercury form, therefore needs to be ionized by means of an oxidizing agent and dissolved in water to be adsorbed by the chelating resins.

48. Chelating resins cannot be used to treat oxidizing solutions as the oxidizing substances will cause the resin to disintegrate.

49. Generally, chelating adsorption towers are employed during the last step of the process, as by that time other potentially competing constituents in the wastewater have been removed.

3.5.3. Other adsorbents

50. Other commonly used adsorbents include sulfur-impregnated activated carbon, functionalized activated alumina and self-assembled monolayers on mesoporous supports.

3.6. BIOLOGICAL TREATMENT

51. The biological reduction of organic pollutants involves metabolism by microorganisms, as opposed to chemical treatments, to perform redox reactions. While mercury is an inorganic contaminant, biological treatment can be used to turn hazardous soluble mercury compounds in wastewater into less soluble forms that can then be removed by additional techniques, such as adsorption or precipitation. This technique reduces oxidized species of mercury to elemental mercury using microbial metabolism in anoxic or anaerobic conditions.

52. Biological treatment is typically carried out in fixed-film bioreactors using activated carbon as a carrier for wastewater generated by wet abatement systems in large combustion plants. Anoxic/anaerobic biological treatment for the removal of mercury is used in combination with other techniques, such as adsorption onto activated carbon. Some coal-fired power plants use anoxic/anaerobic biological systems to reduce certain pollutants, including ionic mercury, and have reported it to be more effective than sedimentation, chemical precipitation or aerobic biological treatment processes. On the contrary, however, the biological treatment of mercury in wastewater from chlor-alkali plants has been shown to have higher residual mercury concentrations than those left by other common abatement techniques.

53. Activated sludge systems combined with sludge incineration and waste gas treatment is another technique for reducing mercury releases to wastewater. Mercury can easily be adsorbed onto the sludge, so if the sludge is incinerated, the mercury in emission gases needs to be controlled. If it is not incinerated, the sludge needs to be managed in an environmentally sound manner and should not be used, for example, for animal feed or composting.

3.7. MEMBRANE FILTRATION

54. Membrane filtration can remove a wide range of contaminants from water. This technology has been used in a limited number of full-scale applications to treat wastewater contaminated with mercury. Before membrane filtration, a pretreatment step may be used to cause the mercury to form precipitates or co-precipitates that can be more effectively removed by this technology.

55. Membrane filtration is effective for the treatment of mercury but is used less frequently because it tends to cost more and produce a larger volume of residuals than other mercury treatment technologies. In addition, it is sensitive to a variety of contaminants in and characteristics of the untreated water. Suspended solids, organic compounds, colloids and other contaminants can cause membrane fouling.

3.8. OTHER TECHNIQUES TO CONTROL RELEASES TO LAND AND WATER

56. Significant anthropogenic point sources of release to land and water may include releases of wastewater, releases directly to water or to uncontrolled landfills. Releases from the management of mercury wastes is addressed in article 11, which requires parties to manage, in an environmentally sound manner, mercury waste as defined in paragraph 2 of that article, taking into account the guidelines developed under the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal.

57. When mercury is intentionally used in industrial processes or is contained in the raw materials or fuels, conversion to the use of mercury-free processes or raw materials or fuels that have a low mercury content contributes to reducing releases of mercury to land and water.

4. TECHNIQUES FOR SPECIFIC SOURCES OF RELEASE

4. TECHNIQUES FOR SPECIFIC SOURCES OF RELEASE

4.1. RELEASES FROM AIR POLLUTION CONTROL SYSTEMS

58. Air pollution control systems that are used in facilities in the list of potentially relevant point sources include:

    (a) Electrostatic precipitators

    (b) Fabric filters

    (c) Wet particulate matter scrubbers

    (d) Wet flue-gas desulfurization

    (e) Dry flue-gas desulfurization

    (f) Selective catalytic reduction.

59. All wet-type flue-gas cleaning systems in combustion plants produce wastewater that, owing to the fuel and materials used, contains mercury, among other components. One of the main sources of wastewater in this context is the wet limestone scrubber used in a large number of combustion plants for the desulfurization of the flue gas.

60. Among the techniques for preventing and controlling the pollution of water with mercury owing to emissions from plants operating flue-gas treatment are techniques such as precipitation, ion exchange and biological treatment. Dissolved metals are usually removed by precipitation with hydroxide and (organo-)sulfides. Although mercury cannot be precipitated with hydroxide, it can with (organo-)sulfides.

61. Filtration with membranes such as silicon carbide ceramic membranes can be used for the treatment of wastewater from wet scrubbers (furnace flue-gas condensate).

62. The technique of seawater scrubbing utilizes the inherent properties of seawater to absorb and neutralize sulfur dioxide in flue-gases. The injection of activated carbon in the flue-gas stream, together with the use of a bag filter, before seawater flue-gas desulfurization, enables mercury emissions to water to be reduced. The seawater will remove soluble oxidized mercury from the flue gas, but unlike in limestone flue-gas desulfurization, where the mercury is retained in the gypsum by-product, the seawater is released back into the environment along with the mercury captured from the flue gas. The discharge to water will contain also sulfate and chlorine ions, which are natural constituents of seawater. It is either channelled into the sea with the water flow or may be sparged from the water and released to the local atmosphere in the vicinity of the water aeration basins used for cooling.

63. Dry abatement techniques like fabric filters produce solid waste such as dust and ash. Such waste needs to be disposed of in an environmentally sound manner to prevent releases of mercury through leaching.

4.2. COAL COMBUSTION

64. The techniques used in the air pollution control systems described in subsection 4.1 can be applied to coal combustion facilities.

65. The pretreatment of fuel before combustion is often conducted for reasons of pollution abatement, including mercury-emission control. Such pretreatment can involve cleaning, blending with another fuel and/or the use of additives. The effectiveness of mercury removal from coal during conventional coal cleaning varies widely and depends on the source of the coal and on the nature of the mercury within it.

66. Wet coal cleaning transfers mercury to wastewater. The dissolved mercury can be precipitated with sulfides like in the usual flue-gas desulfurization technique used on wastewater, but dissolved organic carbon will not be reduced by the usual techniques employed in a power plant.

4.3. OIL AND GAS

67. Crude oil and natural gas are composed primarily of hydrocarbons. They also contain a wide range of elements, including mercury, in varying concentrations depending on the reservoir, the stage of processing and how they are used. Mercury, in its chemical forms, is present in crude oil and natural gas in low concentrations, between 0.1 and 20,000 parts per billion in crude oil and between 0.05 and 5,000 micrograms per Normal cubic metre in natural gas.[1]

68. As a natural constituent of crude oil and natural gas, mercury is detrimental to petroleum processing systems. In gas processing, mercury may contaminate and damage equipment such as cryogenic heat exchangers. In chemical manufacturing and refining, it may poison certain catalysts, contaminate process chemicals (such as triethylene glycol, which can be reused in gas processes) and enter wastewater.

69. The disposal of the mercury collected by a mercury removal system (mercury waste) varies depending on the type of system used. The most commonly used media for mercury removal units are metal sulfides on an inert support material (e. alumina) or sulfur-impregnated carbon. These can be regarded as non-regenerative sorbents. The spent adsorbent should be disposed of in an environmentally sound manner and thus, if the waste is combusted, then the mercury needs to be condensed, captured and disposed of.

70. Regenerative mercury adsorbents that utilize the high affinity of mercury for precious metals such as gold and silver are used less. The mercury removal unit is regenerated by hot regeneration gas, typically at temperatures around 290°C, with the cycle being repeated on a preset timeline that depends on capacities. The mercury is removed from the main process stream and is concentrated in the regeneration stream. The regeneration stream then requires the mercury to be removed. This is typically achieved with a smaller non-regenerative mercury removal unit that may then need the adsorbent to undergo appropriate treatment. A typical refinery wastewater-treatment plant employs techniques for the removal of undesired substances that include oil removal, further oil/water/solid separation, biological treatment and additional treatments such as sand filtration and/or ultrafiltration followed by activated carbon filtration and/or reverse osmosis for salt removal. Other techniques, such as adsorption with sulfur-impregnated carbon columns and precipitation with ferric chloride, are also used for removal of mercury from water in the petroleum industry. Sludges, demolition waste and other waste are to be managed in an environmentally sound manner to prevent mercury releases.

4.4. PRIMARY MERCURY-METAL PRODUCTION

71. Mercury mines pose an environmental concern because of the presence of mine tailings, commonly termed “calcines”, that contribute mercury-enriched sediment to watersheds. At some mines, mine drainage, which is often acidic and contains elevated levels of mercury and other toxic metals, also has an impact on water quality and biota. Mercury ores consisting primarily of cinnabar are processed in rotary furnaces and retorts, and elemental mercury is recovered from condensing systems. During the roasting process, mercury phases more soluble than cinnabar are formed and concentrated in the calcines. Differences in mineralogy and in trace-metal geochemistry are reflected in the composition of the mine drainage. Mercury and methylmercury concentrations in mine drainage are relatively low at the point of discharge from mine workings, but the concentration of both mercury species increases significantly in mine drainage that flows through and reacts with calcines.

72. In addition, during the process of mercury purification, wastewater and sludge are generated and discharged to primary treatment (sedimentation). Overflow is further discharged to an evaporation pond. After liquid components have been removed, mercury-rich solids are returned to the rotary kiln, from both the sedimentation process and the evaporation pond, for mercury extraction. Wastewater and sludge from metallurgical production are separated from the other industrial effluents of the plant and treated using the techniques explained in section 3 and subsection 4.1.

4.5. NON-FERROUS-METAL PRODUCTION

73. Mercury exists as a trace element in many ores of non-ferrous metals, and the mining and processing of these ores has the potential to mobilize mercury and to emit it to the atmosphere or release it to land and water. The concentration of mercury in ore and concentrates can vary according to the geological conditions. The creation of tailings during mining and beneficiation can lead to the exposure of mercury-bearing minerals to oxygen and water and to leaching processes, which can result in mercury releases to water systems or soil.

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[1] David Lang, Murray Gardner and John Holmes, Mercury arising from oil and gas production in the United Kingdom and UK continental shelf (Department of Earth Sciences, University of Oxford, 2012).

74. Within non-ferrous metal production, the thermal processing (such as smelting, roasting and other high-temperature operations) of metallurgical raw materials has the potential to emit mercury to the atmosphere or to release it to land and water. The main aim of the smelting and roasting processes is to convert the metals from their native state in ores to pure metal form. Metals commonly exist in nature as oxides, sulfides or carbonates, and the smelting process requires a chemical reaction in the presence of a reducing agent to liberate the metal. At high temperatures, mercury becomes highly volatile and is released to the gas phase or condenses on fine particles produced during the processing. Thermal processing therefore necessitates the use of appropriate air pollution control techniques to capture the mercury in various liquid or solid forms. Such waste needs to be treated and/or disposed of in an environmentally sound manner to prevent releases of mercury to land or to water.

75. The production of non-ferrous metals by pyrometallurgical and hydrometallurgical methods is associated with the generation of various liquid effluents. Techniques described in subsection 4.1 can be used to treat these effluents to remove toxic metals, including mercury.

76. Non-recyclable or non-reusable water can be treated in order to minimize the concentration of pollutants such as metals, acidic substances and solid particles in the final effluent discharged to the aquatic environment. To reduce the concentration of the pollutants in the water, several techniques may be used, such as chemical precipitation, sedimentation or flotation and filtration and ion exchange. These techniques may be used together in series or in parallel, depending on the water-management plan of the site. Efforts can also be made to settle solids and/or precipitate metals before the process stream is mixed with other effluents.

4.6. CHLOR-ALKALI PRODUCTION

77. In accordance with article 5 of and annex B to the Minamata Convention, mercury-cell chlor-alkali production is to be phased out by 2025, or by 2030 if parties have registered an exemption. The present subsection is intended to support parties in controlling the release of mercury to land and water until mercury-cell chlor-alkali facilities have been converted or decommissioned.

78. Mercury used as electrode in chlor-alkali production can be emitted to air or released to land and water. The techniques described in section 3 apply to wastewater. In two examples of plants reviewed by Euro Chlor, the industry association that represents the interests of chlor-alkali producers in Europe, wastewater was treated with hydrazine and then subjected to sedimentation, sand filtration and activated-carbon filtration processes.

4.7. WASTE INCINERATION

79. The mercury in effluent from waste incineration originates from the mercury contained in the initial waste. It is common practice for incinerators to apply a limit on the amount of mercury in the waste to be incinerated.

80. The techniques described in section 3 and subsection 4.1 apply to wastewater.

81. In the process of mercury separation using ion exchange, the raw acids and the ionically bound metals in the wastewater from the first, acidic stage of the wet scrubber are passed through a mercury ion exchanger. The mercury is separated by means of a resin filter. The acid is then neutralized using milk of lime.

82. Plants fitted with ion-exchange and/or adsorption technologies generally achieve lower emission levels. From an economic point of view, ion exchange is reported to be expensive in relation to the alternatives.

4.8. WASTE LANDFILLING

83. Sources of wastewater at landfill facilities include contaminated rainfall run-off, leachate, landfill gas condensate and site management activities such as drainage from the site, wheel washing and activities carried out at hard standing areas.

84. Without adequate controls, leachate has the potential to cause significant groundwater and surface-water pollution. A landfill should be designed so as to minimize the generation of leachate and the possibility of untreated leachate escaping from the site. The quantity and nature of leachate varies considerably and is influenced by the nature of the waste, the compaction, the use of landfill covers and weather (rainfall).

85. The technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds under the Basel Convention provide further guidance in relation to waste landfilling.

5. MONITORING

5. MONITORING

86. The monitoring of mercury releases to the environment is an essential part of implementing best available techniques and best environmental practices for controlling those mercury releases and for maintaining high levels of operating efficiency in terms of the abatement techniques used. The monitoring of mercury releases should be conducted according to overall best practices using approved or accepted methods. Representative, reliable and timely data obtained from mercury release monitoring are needed to evaluate and ensure the effectiveness of the mercury-release control techniques in use at a facility.

87. The first step in conducting mercury-release monitoring is to establish a performance baseline, either by taking direct measurements of the mercury concentrations in the wastewater or by using indirect measurements to estimate releases. International standards, such as ISO 12846[2] and ISO 17852[3], exist for the measurement of mercury in water. Subsequently, more measurements are to be taken at specific time intervals (for example, daily, weekly and/or monthly) to ascertain the mercury concentration in the wastewater or the mercury releases at the given point in time. Monitoring is then conducted by compiling and analysing the measurement data to determine trends in releases and operating performance. Should the measurement data indicate any areas of concern, such as increasing mercury concentrations over time or peaks in mercury releases associated with certain plant operations, the facility should take swift action to rectify the situation.

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2 Standard ISO 12846:2012 – Water quality – Determination of mercury – Method using atomic absorption spectrometry (AAS) with and without enrichment.

3 Standard ISO 17852:2006 – Water quality – Determination of mercury – Method using atomic fluorescence spectrometry.

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