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**BAT Project Activity – Best Available Techniques (BAT) to Prevent and Control Mercury
Releases to Land and Water**

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NO. 72

BAT Project Activity – Best Available Techniques (BAT) to Prevent and Control
Mercury Releases to Land and Water

IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

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Environment Directorate

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Paris 2022

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Foreword

The OECD has been working on a Best Available Techniques (BAT) project since 2016 to help governments to prevent and control industrial pollution. The project aims to identify and exchange best practices amongst countries that already have a BAT-based policy in place and to assist those that are considering adopting this approach for the first time. Furthermore, the BAT project is designed to contribute towards meeting the United Nations' Sustainable Development Goals (SDGs), especially Target 12.4 on the environmentally sound management of chemicals, which relates to SDG 12 on ensuring sustainable consumption and production patterns.

The OECD's BAT project is overseen by an Expert Group (i.e. EG on BAT) which consists of members from governments in OECD member and non-member countries, along with environmental non-governmental organisations (NGOs), industry, academia and inter-governmental organisations.

The project has addressed five work areas with these associated publications, which are available on [oe.cd/bat](https://www.oecd.org/bat/):

- i. Activity 1, Policies on BAT or Similar Concepts Across the World (OECD, 2017^[1]), describing how BAT are defined and embedded in national legislation in different countries and regions;
- ii. Activity 2, Approaches to Establishing BAT Around the World (OECD, 2018^[2]), presenting various jurisdictions' procedures to determine BAT;
- iii. Activity 3, Measuring the Effectiveness of BAT Policies (OECD, 2019^[3]), analysing methodologies and data for the evaluation of the effectiveness of BAT-based policies in a range of countries and regions;
- iv. Activity 4, Guidance document on determining BAT, BAT-associated emission and environmental performance levels, and BAT-based permit conditions (OECD, 2020^[4]); and
- v. Activity 5, A study report on value chain approaches to determining BAT for industrial installations (OECD, 2021^[5]), identifying potential challenges and opportunities related to considering environmental implications across different stages of the value chain when determining BAT for a given industrial activity.

This study presents the results of a cross-country comparison of best available techniques or emission standards to prevent or reduce mercury releases to land or water. This study was undertaken to inform the development of guidance on best available techniques and environmental practices for controlling or reducing anthropogenic mercury releases to water and land under Article 9 of the Minamata Convention on Mercury¹, as well as guidance or mitigation strategies covered under other Articles. Guidance on BAT to control emissions to air under Article 8 has already been published and addresses cross-media effects

¹ Article 8, 2(a): "Emissions" means emissions of mercury or mercury compounds to the atmosphere; Article 9, 2(a): "Releases" means releases of mercury or mercury compounds to land or water.

(UNEP, 2017⁽⁶⁾). This document focuses on the use of BAT to control releases to water and soil. This report is published under the responsibility of the Chemicals and Biotechnology Committee of the OECD.

The OECD BAT project has been produced with the financial assistance of the European Union. The views expressed herein can in no way be taken to reflect the official opinion of the European Union.

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Acronyms

AMAP	Arctic Monitoring and Assessment Programme
BAT	Best Available Techniques
BAT-AEPL	BAT-Associated Environmental Performance Levels
BAT-AE(P)Ls	BAT-Associated Emission Levels and/or Environmental Performance Levels
BEP	Best Environmental Practice
BREF	BAT Reference Document
CAK	Production of Chlor-alkali
CWW	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector
EC	European Commission
EIPPCB	European Integrated Pollution Prevention and Control Bureau
EU	European Union
EPA	Environmental Protection Agency
GATPPC	Guidelines of Available Technologies for Pollution Prevention and Control
IFC	International Finance Corporation, World Bank Group
LCP	Large Combustion Plant
LVOC	Production of Large Volume Organic Chemicals
MEE	Ministry of Ecology and Environment, People's Republic of China
NFM	Non-ferrous Metals Industries
NIER	National Institute of Environmental Research of South Korea
OECD	Organisation for Economic Co-Operation and Development
REF	Refining of Mineral Oil and Gas
SDG	Sustainable Development Goal
UNEP	UN Environment Programme
US	United States
VCM	Vinyl Chloride Monomer
WI	Waste Incineration

Executive Summary

A growing number of countries use Best Available Techniques (BAT) to set evidence-based industrial emission levels following a multi-stakeholder dialogue. BAT policies are a trusted means to prevent or reduce emissions from polluting industries. In the process of the identification of BAT for a particular industry sector or type of industry, BAT Reference Documents (BREFs) are usually prepared to collect and evaluate candidate techniques. Thereby BREFs contribute to the transparency of the BAT determination process. Given that much information on the available techniques is gathered under the multi-stakeholder involvement, BREFs are unique and rich sources of information on available techniques. The OECD has prepared and published online a list² of BREFs gathered from Member and Partner countries.

The Minamata Convention is a multilateral environmental agreement that was adopted in 2013 and came into force in August 2017. It aims to control and, where feasible, reduce the use, release and emission of mercury from anthropogenic sources and, therewith, human exposure to mercury from anthropogenic activities. The Convention highlights the impact of mercury emissions and releases on the environment as a whole and the use of BAT to control and reduce impacts. Particularly, Article 9 on releases requires adoption of guidance on best available techniques and best environmental practices which the Conference of Parties (COP) have started to discuss recently, resulting in the need for relevant information.

Therefore, this study was conducted by the Expert Group on BAT with the aim to:

- compile the best available technical approaches for reducing or controlling mercury releases to water and land across countries;
- contribute information needed for the development of Guidance on Best Available Techniques and Best Environmental Practices for reducing or controlling mercury releases to water and land under Article 9 of the Minamata Convention; and
- support other articles of the Minamata Convention in addition to Article 9 that address specific practices and are potential sources of releases to water and land.

Seven target sector categories were selected: large-scale mining, non-ferrous metal, waste (waste treatment, incineration, storage, and disposal), organic chemicals, chlor-alkali production, oil refining and thermal power plant (TPP) For these sectors, relevant BREFs from the OECD BREF list as well as other documents were gathered. The study identifies and summarises common techniques to control or reduce mercury releases to water and land.

Four common techniques are identified and described for mercury removal from wastewater:

- Precipitation of metals
- Adsorption on ion-exchange resins
- Adsorption on activated carbon
- Biological treatment

² [List of Best Available Techniques Reference Documents by sectors and activities covered by each jurisdiction](#)

Five common techniques for mercury removal from soil and waste are identified:

- Mechanical/physical treatment
- Chemical treatment
- Thermal treatment
- Solidification and stabilisation

This study also describes other techniques and provides direct links to descriptions in the source document. The practices summarised in this report are thus expected to contribute toward the development of the Guidance on Best Available Techniques and Best Environmental Practices for reducing or controlling mercury releases to water and land in the context of Article 9 of the Minamata Convention on Mercury and in supporting the objectives of other articles.

1. Introduction

1.1. Mercury– Global issue on human health

Mercury (Hg) and its compounds are well-known global pollutants that affect human health and the environment (UNEP, 2008^[7]). All forms of mercury lead to severe health impacts, such as irreversible damage to the central nervous system, thyroid, lungs, kidneys, eyes, gums, skin and the immune system. The principal target organs differ according to forms of mercury (UNEP, 2017^[8]; UNEP, 2008^[7]). There is no known safe level of exposure to mercury, so adverse health effects can be observed at relatively low exposure levels (UNEP, 2017^[8]; UNEP, 2008^[7]; Bose-O'Reilly, 2010^[9]). (UNEP, 2017^[8]; UNEP, 2008^[7]). The most vulnerable groups to mercury exposure and its toxic effects are fetuses, new-borns and children (UNEP, 2017^[8]). These subpopulations are not only more likely to be exposed to mercury, but they are also more sensitive to the toxic effects, particularly toxicity to the central nervous system, since their body organs and blood brain barrier are not fully developed (Needham, 2010^[10]). The main source of environmental exposure to mercury occurs through dietary consumption of seafood and fish containing mercury and inhalation of mercury vapour (Eunhee Ha, 2017^[11]; UNEP, 2017^[6]).

Overall emissions of mercury and its compounds to air have been drastically reduced over the years due to implementation of best available techniques and best environmental practices at industrial facilities. However, estimated emissions of mercury to the air associated with global human activity increased by nearly 20% between 2010 and 2015 (UNEP, 2020^[12]; UNEP, 2019^[13]). For 2010, anthropogenic emissions were estimated to be 1960 metric tonnes of mercury to the atmosphere and at least 1000 metric tonnes of releases to the oceans (EC, 2017^[14]).

Sector-wise the majority of the global anthropogenic releases of mercury to aquatic systems are relatively equally distributed between **ore mining and processing (41%)** and **waste treatment sectors (42%)**, **followed by the energy sector (16%)**. Currently, major sectors contributing to releases to water are primary non-ferrous metal production, such as aluminum, copper, lead and zinc, and municipal wastewater, as well as large scale gold mining for direct releases to soil/land (AMAP/UNEP, 2019^[15]). For non-ferrous metals, primary production involving the smelting process is a large source of anthropogenic mercury emissions.

Atmospheric mercury and its forms are monitored on the basis of provisions of either national legislations or by international agreements, such as the Minamata Convention. Technological advancements are used for monitoring and tracking mercury transport in air. Global monitoring programmes such as the Arctic Monitoring and Assessment Programme (AMAP) are in place to assess the presence of mercury in wastewater and waste, in addition to emissions to air (AMAP, 2021^[16]). However, according to (AMAP/UNEP, 2019^[15]). collaborations to reinforce and expand existing monitoring networks are needed for more comprehensive geographic coverage of mercury presence in the atmosphere. Further, monitoring developments should inform and better characterise the gaps in the anthropogenic releases of mercury to water (AMAP/UNEP, 2019^[15]).

1.2. How has the OECD addressed the issue?

The OECD is carrying out various activities to address the global issue of emissions and releases of mercury and its compounds. In 2007, the OECD published a report on Instrument Mixes Addressing Mercury Emissions to Air (OECD, 2007^[17]). Since its publication, the OECD proceeded with extensive work on Best Available Techniques in preventing and controlling industrial emissions and conducting trend analyses of mercury emissions data from seven different Pollutant Release and Transfer Registers (PRTRs) across the world. The data pertain to emissions of mercury to air and releases to water from 2008 to 2017 from facilities in manufacturing sectors (OECD, 2021^[18]). In 2022, the OECD is planning to hold a Global Forum on Environment (GFENV) dedicated to mercury. The GFENV is a platform where member and non-member governments exchange experiences and explore common policy issues for one or two priority issues on the global environmental agenda per year³. The GFENV in 2022 is planned to focus on mercury and encourage the exchange of common challenges in implementing the Minamata Convention between Member and Partner countries.

1.3. Minamata Convention and BAT/BEP guidance

The Minamata Convention is a multilateral environmental agreement that was adopted in 2013 and came into force in August 2017. It aims to control, and, where feasible, reduce the use, release and emission of mercury from anthropogenic sources, and, therewith, human exposure to mercury from anthropogenic sources.

The Convention recognises that mercury is a chemical of global concern owing to its ability to undergo long-range atmospheric transport, persist in the environment, bioaccumulate in aquatic organisms, biomagnify throughout the food chain, and cause significant negative effects on human health and the environment. The Minamata Convention is legally binding for all its Parties⁴ (UNEP, 2019^[19]). The provisions in the agreement cover the entire life cycle of mercury and mercury compounds to accomplish the objective of the Convention, including

- Supply sources and trade (Article 3)
- Mercury-added products (Article 4)
- Manufacturing processes that use mercury or mercury compounds (Article 5)
- Artisanal and small-scale gold mining (Article 7)
- Emissions to air (Article 8)
- Releases to land or water from sources not addressed in other provisions of the Convention (Article 9)
- Environmentally sound interim storage of mercury, other than waste mercury (Article 10)
- Mercury wastes (Article 11)
- Contaminated sites (Article 12)

Article 8 of the Minamata Convention covers control and reduction of emissions of mercury to the *atmosphere* from new and existing point sources (Annex D) (UNEP, 2017^[6]). At the first Conference of the Parties (COP) meeting in September 2017, the parties adopted the guidance on best available techniques and on best environmental practices (BAT/BEP) to aid parties in fulfilling their obligations under Article 8

³ <https://www.oecd.org/environment/gfenv.htm>

⁴ Article 31 of the Convention provides that it shall enter into force on the ninetieth day after the date of deposit of the fiftieth instrument of ratification, acceptance, approval or accession

(UNEP, 2017^[6]). It describes best available techniques and practices for controlling emissions of mercury and mercury compounds to air from point sources (UNEP, 2017^[6]).

Article 9 involves 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 (UNEP, 2019^[19]). After COP-2 in 2018 (UNEP, 2018^[20]) and COP-3 in 2019 (UNEP, 2019^[21]), the parties agreed to prepare guidance on releases and a roadmap to developing guidance on best available techniques and on best environmental practices (BAT/BEP) focusing on reducing or controlling releases of mercury and mercury compounds to water and land from point sources.

Other articles relate to the interim storage of mercury, mercury wastes, and mercury contaminated sites, respectively covered in Articles 10, 11, and 12. Article 11 provides that Parties take appropriate measures to ensure that mercury waste is managed in an environmentally sound manner, taking into account the guidelines developed under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 1992^[22]).

1.4. Overview of Sectors contributing to Releases

According to the technical background document for the Global Mercury Assessment developed by AMAP/UN Environment (AMAP/UNEP, 2019^[15]), the following sectors mainly contribute to mercury **releases to water**:

- Non-ferrous metal production (primary production of aluminum, copper, lead and zinc) (30%)
- Mercury releases with municipal wastewater (25%)
- Mercury-added products⁵ – use and waste disposal, e.g. batteries, thermometers (17%)
- Large scale gold mining (10%)
- Coal-fired power plants (10%) – covered under Thermal Power Plants.
- Oil refining (<1%)

Sectors contributing mercury **releases directly to land/soil** are identified as follows:

- Large-scale gold mining
- Primary mercury mining⁶
- Chlor-alkali production
- Metal production, non-ferrous metal production, vinyl chloride monomer (VCM) production, and disposal of mercury-added products also generate mercury-containing wastes released to land/soil. (AMAP/UNEP, 2019^[15]).

This study focuses on seven sector categories for which BREFs are available and are relevant for the sectors listed above, i.e. large-scale mining, non-ferrous metal, waste (wastewater and products, waste treatment, incineration, storage, and disposal), organic chemicals (e.g. LVOC production), chlor-alkali production, oil refining, and thermal power plant (TPP). Relevant sectoral BREFs were gathered for this mercury study.

Article 9 addresses releases to land and water generally, while other Articles in the Convention address specific situations or practices commonly undertaken by industry such as mercury storage, handling of

⁵ Article 4 defines it as : “Mercury-added product” means a product or product component that contains mercury or a mercury compound that was intentionally added.

⁶ According to the Convention: “Primary mercury mining” means mining in which the principal material sought is mercury

wastes, or clean up of contaminated sites. As such, this study recognises that some of the BAT/BEP highlighted to prevent and control mercury releases have applicability beyond Article 9.

1.5. Objectives of this study

This study aims to

- compile the best available techniques for reducing or controlling mercury releases to water and land in place across countries;
- contribute information needed for the development of Guidance on Best Available Techniques and Best Environmental Practices for reducing or controlling mercury releases to water and land under Article 9 of the Minamata Convention on Mercury; and
- support other articles of the Convention that address specific practices and are potential sources of releases to water and land.

This document focuses on releases to water and land under Article 9; however, many potential sources of releases to water and land are addressed under other articles of the Minamata Convention. Releases of mercury from these sources covered elsewhere more accurately reflect technical, process, and/or situational instances that fall under these other articles, and that overlap and could benefit from waste management practices identified in this study. At COP-4 in November 2021, meeting documents on these points were not discussed due to the limited scope of the meeting held virtually. However, COP-4 will resume in early 2022 to consider the remaining agenda items for adoption by the parties (UNEP, 2021^[23]; UNEP, 2021^[24]). If the roadmap to developing a BAT/BEP guidance on releases is adopted, the draft is planned to be submitted for adoption by the parties at the COP-5 in 2023.

2. Compilation of BAT descriptions from BREFs on Mercury release to water and land

2.1. OECD BAT project and activities on BREF compilation and comparison

OECD's Best Available Techniques (BAT) project is a platform established to exchange experience and knowledge between countries that have existing BAT-based policies and those that have commenced the initial design and establishment of BAT-based policies.

Much work has focused on understanding the BAT regulatory frameworks across the world, data driven processes for establishing best available technique emission standards and understanding control approaches. To aid with increased harmonisation of standards and emission limits across countries, recent efforts have focused on the compilation of BREFs (BAT Reference Documents) to facilitate information access and comparison, recommendation of permitting conditions, as well as on the study of select sectors. BAT information gathered over the years was used to inform the present comparison of mercury standards and emission limits specific to land and water.

This report on mercury releases leverages information submitted to the OECD in the context of the BAT project, and supplements it with additional BREF and BAT-like documents. A list of available BREFs from different jurisdictions according to various industrial sectors and activities was developed as part of the OECD Guidance Document on Determining Best Available Techniques (BAT), BAT-Associated Environmental Performance Levels and BAT-Based Permit Conditions (OECD, 2020^[4]).

2.2. Materials – Sectoral BREFs

Sectoral BREFs provided by the OECD Expert Group on BAT are compiled in a BREF database, accessible from the OECD website (OECD, 2020^[25]). Following the focus sectors described above, the relevant sectoral BREFs from the database were examined for descriptions of mercury release to water and land as well as descriptions on techniques for controlling its release. Table 1 lists the BREFs examined for relevant descriptions of mercury release and its prevention techniques.

Table 1. BREFs with descriptions and/or techniques of controlling mercury release to water and land

Sector	Country/ Organisation	Abbreviation (EU BREF)	Descriptions on mercury release to water and/or land	Descriptions on techniques of controlling its release	Reference
Large-scale mining	EU	MWEI	Yes	Yes	(EIPPCB, 2018 ^[26])

	Russia	-	No	No	(Rosstandart, 2016 ^[27] ; Rosstandart, 2017 ^[28] ; Rosstandart, 2017 ^[29] ; Rosstandart, 2017 ^[30] ; Rosstandart, 2017 ^[31])
	US	-	Yes	No	(US EPA, 1988 ^[32])
	China	-	Yes	Yes	(MEE, 2010 ^[33])
Non-ferrous metal	EU	NFM	Yes	Yes	(EIPPCB, 2017 ^[34])
	Russia	-	No	No	(Rosstandart, 2019 ^[35] ; Rosstandart, 2019 ^[36] ; Rosstandart, 2019 ^[37] ; Rosstandart, 2016 ^[38] ; Rosstandart, 2016 ^[39] ; Rosstandart, 2017 ^[40])
	Korea	-	Yes	Yes	(NIER, 2017 ^[41])
	US	-	Yes	No	(US EPA, 1990 ^[42])
	China	-	Yes	Yes	(MEE, 2015 ^[43] ; MEE, 2015 ^[44] ; MEE, 2015 ^[45] ; MEE, 2015 ^[46] ; MEE, 2012 ^[47])
	IFC	-	Yes	No	(IFC, 2007 ^[48])
Waste	EU	WT	Yes	Yes	(EIPPCB, 2018 ^[49])
		WI	Yes	Yes	(EIPPCB, 2019 ^[50])
		CWW	Yes	Yes	(EIPPCB, 2016 ^[51])
	Russia	-	Yes	No	(Rosstandart, 2016 ^[52] ; Rosstandart, 2019 ^[53])
	Korea	-	Yes	Yes	(NIER, 2017 ^[54])
	US	-	Yes	No	(US EPA, 2003 ^[55])
		-	Yes	Yes	(US EPA, 2000 ^[56] ; US EPA, 2000 ^[57])
		-	Yes	Yes	(US EPA, 2003 ^[58])
		-	Yes	Yes	(US EPA, 1998 ^[59])
	China	-	Yes	Yes	(MEE, 2010 ^[60])
	IFC	-	Yes	No	(IFC, 2007 ^[61])
Organic chemical	EU	LVOC	Yes	Yes	(EIPPCB, 2017 ^[62])
	Korea	-	Yes	Yes	(NIER, 2017 ^[63])
Chor-alkali	EU	CAK	Yes	Yes	(EIPPCB, 2014 ^[64])
	US	-	Yes	No	(US EPA, 1982 ^[65])
Oil refining	EU	REF	Yes	Yes	(EIPPCB, 2015 ^[66])
	Russia	-	No	No	(Rosstandart, 2017 ^[67] ; Rosstandart, 2017 ^[68])
	IFC	-	Yes	No	(IFC, 2016 ^[69])
Thermal Power Plant	EU	LCP	Yes	Yes	(EIPPCB, 2017 ^[70])
	Korea	-	Yes	Yes	(NIER, 2016 ^[71])
	Russia	-	No	No	(Rosstandart, 2017 ^[72])
	US	-	Yes	No	(US EPA, 2020 ^[73])
	China	-	No	No	(MEE China, 2017 ^[74])
	IFC	-	Yes	No	(IFC, 2008 ^[75])
Cross-sectorial	US	-	Yes	Yes	(US EPA, 2007 ^[76])

2.3. Compilation and comparison of BATs in the BREFs

Initial reviews of sectoral BREFs indicated that the BAT descriptions to prevent or control mercury releases to water and land were much less prominently covered compared to BAT descriptions for mercury

emissions to air. Regardless, there were several common techniques identified among the sectoral BREFs. These BAT descriptions were extracted and summarised as a list of techniques for reducing mercury releases to water and land in the following chapter.

3. Summary of BATs on mercury release to water and land

Techniques for mercury removal could be primarily classified by its form in the environment, whether mercury is dissolved in water or adsorbed in particles. Dissolved mercury such as in wastewater from industrial point sources, can be removed by techniques including precipitation and adsorption, whilst removal of mercury adsorbed to soil or solid wastes first involves separation (also known as desorption) from the materials to which it is adsorbed by physical, chemical, or thermal treatment. This chapter is divided into two sub-chapters which summarise the BATs described in BREFs to remove mercury from wastewater and remove mercury from soil and waste.

3.1. Mercury removal from wastewater

Wastewater treatment for mercury removal is the primary measure to prevent or reduce the release of mercury to surface waters. Some facilities generate mercury-containing wastewater including those that handle mercury and those that use mercury-containing raw materials. Some techniques to control mercury emission to air use water to remove mercury from emitted gas resulting in mercury-containing wastewater. We thus first focus on describing how sectors generate mercury-containing wastewater, followed by a discussion on common techniques to remove mercury from the wastewater as described in the BREFs.

3.1.1. How mercury-containing wastewater is generated?

Effluent containing mercury is generated in various ways depending on the applied manufacturing processes and raw materials used in the relevant sectors. Mercury-containing raw materials are the primary sources of mercury contaminants.

Some organic chemical production routes use mercury-based catalysts or amalgams including for the production of vinyl chloride monomers (VCM), acetaldehyde, and alcoholates (EIPPCB, 2017_[62]). While many of these production routes are aimed to be phased out under the Minamata Convention (under Article 5), some existing plants continue to use mercury-based catalysts and materials (e.g., mercury cell where it acts as the cathode in an electrolytic cell) (EIPPCB, 2014_[64]), and may still be major sources of mercury contamination.

Pollution control techniques sometimes generate mercury-containing wastewater, for example, combustion plants capture mercury by certain end-of-pipe techniques, including wet scrubbers, resulting in the generation of mercury-containing wastewater (under Article 8). EU Refining of Mineral Oil and Gas (REF) BREF mentions that the process of refining natural gas which contains mercury might lead to generating wastewater with mercury (EIPPCB, 2015_[66]). Coal cleaning 'by washing' with water is another technique used to remove mercury which is performed prior to combustion that generates contaminated wastewater (EIPPCB, 2017_[70]). The same situation arises from cleaning contaminated solid material during decommissioning of chlor-alkali plants, as washing with water is one of the techniques used (EIPPCB, 2014_[64]).

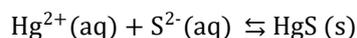
3.1.2. Common techniques

Mercury contained in wastewater can be removed by several techniques using physico-chemical and biological treatments. Removal techniques may reduce or oxidise mercury to make it more amenable to adsorptive techniques or biological treatments using microorganisms.

Several commonly seen techniques in the BREFs are summarised below:

Precipitation of metals

Precipitation is a process to form insoluble particulates (i.e. solid precipitate) that is followed by an additional process of separating the water portion (EIPPCB, 2018_[49]). 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. At a specific pH, the addition of sulfide reagents to an aqueous solution of mercury ion (Hg^{2+}) results in the formation of mercury sulfide, which is insoluble and precipitates from the solution. Typical chemicals used to precipitate mercury sulfide are sodium sulfide and polyorganosulphides (EIPPCB, 2016_[51]). It is noted that hydrogen sulfide, which can cause harmful effects to occupational health, may be generated during the metal sulfide precipitation (MEE, 2012_[47]). The chemical reaction is illustrated below (EIPPCB, 2018_[26]):



EU CAK BREF indicates that removing mercury from wastewater initially starts by a settling technique to remove large mercury droplets. After that, oxidising agents, such as hypochlorite, chlorine or hydrogen peroxide are used to fully convert mercury into its oxidised form (metallic cation) which is followed by sulfide precipitation of the wastewater and then filtration (EIPPCB, 2014_[64]). The precipitate is then managed as solid waste (EIPPCB, 2014_[64]).

Table 2 shows the list of BREFs which includes this technique as a mercury removal technique.

Table 2. BREFs with precipitation of metals for mercury removal from wastewater

Country/Organisation	BREFs	Chapter	Page	Reference	Note
EU	Management of Waste from Extractive Industries (MWEI)	4.3.2.2.3.3	P435	(EIPPCB, 2018 _[26])	Technique to consider in the determination of BAT
	Waste Treatment (WT)	2.3.6.2.4.1	P197	(EIPPCB, 2018 _[49])	
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[64])	Technique to consider in the determination of BAT
		5.2 BAT 3	P254		BAT Conclusion
	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	3.3.2.3.4.2	P208	(EIPPCB, 2016 _[51])	Technique to consider in the determination of BAT
US	Development Document for Waste Combustors Effluent Guidelines	6.1.1.5	6-7	(US EPA, 2000 _[56])	Wastewater treatment technologies
		6.4.2	6-48	(US EPA, 2000 _[56])	Rationale Used for Selection of BAT
	Treatment Technologies for Mercury in Soil, Waste, and Water	7.0	7-1	(US EPA, 2007 _[76])	
China	Mining and Mineral Processing of the Iron and Steel Industry	3.4.5	P11	(MEE, 2010 _[33])	
	Copper Smelting	3.2.5	P164	(MEE, 2015 _[43])	
	Cobalt Smelting	3.2.5	P47	(MEE, 2015 _[44])	
	Nickel Smelting	3.2.5	P85	(MEE, 2015 _[45])	
	Lead Smelting	3.3.3	P8	(MEE, 2012 _[47])	
	Secondary Lead Smelting	3.4.2	P21	(MEE, 2015 _[46])	

Korea	Waste Incineration	5.8	P415	(NIER, 2017 _[54])	
	Electricity and Steam Production	4.7.3	P310	(NIER, 2016 _[71])	

Adsorption on ion-exchange resins

Ion exchange is the removal of undesired or hazardous ionic constituents of wastewater and their replacement by more acceptable ions from an ion exchange resin. The undesirable ions are temporarily retained by the resin and then released into a regeneration or backwashing liquid (EIPPCB, 2016_[51]; EIPPCB, 2019_[50]). For removal by ion exchange, mercury must first be oxidised to the mercuric cation (Hg^{2+}) with oxidising agents such as hypochlorite, chlorine, or hydrogen peroxide (EIPPCB, 2014_[64]). Table 3 shows the list of BREFs which presents the adsorption on ion-exchange resins as a technique for mercury removal.

Table 3. BREFs with adsorption on ion-exchange resins for mercury removal from wastewater

Country/Organisation	BREFs	Chapter	Page	Reference	Note
EU	Waste Incineration (WI)	4.6.8	P446	(EIPPCB, 2018 _[49])	Technique to consider in the determination of BAT
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[64])	Technique to consider in the determination of BAT
		5.2 BAT 3	P254		BAT Conclusion
	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	3.3.2.3.4.11	P258	(EIPPCB, 2016 _[51])	Technique to consider in the determination of BAT
US	Waste Specific Evaluation of RMERC Treatment Standard	D.7	P32	(US EPA, 1998 _[59])	

Adsorption on activated carbon

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 (EIPPCB, 2017_[34]). For instance, granular activated carbon (GAC) has a wide efficiency range and is not restricted to polar or non-polar compounds (EIPPCB, 2016_[51]). As a pretreatment, reducing agents such as hydroxylamine can be used to fully convert ionic mercury into its elemental form, with subsequent removal by coalescence and recovery of metallic mercury, followed by adsorption on activated carbon (EIPPCB, 2014_[64]). Table 4 shows the list of BREFs which include this technique as a mercury removal technique.

Table 4. BREFs with adsorption on activated carbon as a technique for mercury removal from wastewater

Country/Organisation	BREFs	Chapter	Page	Reference	Note
EU	Non-ferrous Metals Industries (NFM)	2.12.6.2.9	P185	(EIPPCB, 2017 _[34])	General processes and techniques
	Large Combustion Plants (LCP)	10.8.6	P810	(EIPPCB, 2017 _[70])	BAT Conclusion
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[64])	Technique to consider in the determination of BAT
		5.2 BAT 3	P254		BAT Conclusion
		8.2.6	P286		Annex
	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	3.5.1.2.3	P352	(EIPPCB, 2016 _[51])	Technique to consider in the determination of BAT
	Development Document for Waste Combustors Effluent Guidelines	6.1.1.8	6-19	(US EPA, 2000 _[56])	Wastewater treatment technologies

US		6.4.1.3	6-44	(US EPA, 2000 ^[56])	Performance of EPA Sampled Treatment Processes
	Treatment Technologies for Mercury in Soil, Waste, and Water	8.1	8-1	(US EPA, 2007 ^[76])	
China	Mining and Mineral Processing of the Iron and Steel Industry	3.4.5	P11	(MEE, 2010 ^[33])	

Biological treatment

Biological reduction of organic pollutants utilises the metabolism of microorganisms to perform redox reactions rather than using chemical treatments to achieve the same end. Biological treatment involves the use of microorganisms that act directly on contaminants or alter the surrounding conditions which lead to contaminant leaching from the soil or precipitating from water (US EPA, 2007^[76]). While mercury is an inorganic contaminant, biological treatment can be used to reduce hazardous soluble mercury compounds to less soluble forms in the wastewater, which can then be removed by additional techniques such as adsorption or precipitation (US EPA, 2007^[77]; EIPPCB, 2017^[70]). This technique is based on reducing oxidised species of mercury to elemental mercury using microbial metabolism in anoxic or anaerobic conditions.

Biological treatment is typically carried out in fixed-film bioreactors using activated carbon as a carrier for wastewater generated from the use of wet abatement systems in LCP plants. The anoxic/anaerobic biological treatment for the removal of mercury is applied in combination with other techniques, such as adsorption on activated carbon (EIPPCB, 2017^[70]). Some coal-fired power plants use anoxic/anaerobic biological systems to reduce certain pollutants including ionic mercury and reported it to be more effective than sedimentation, chemical precipitation or aerobic biological treatment processes (EIPPCB, 2017^[70]). On the contrary, biological treatment of mercury in the wastewater from chlor-alkali plants showed higher residual mercury concentrations than those of the other common abatement techniques (EIPPCB, 2014^[64]).

Activated sludge systems combined with sludge incineration or waste gas treatment is another technique reported in the EU CWW BREF to reduce the mercury emissions to wastewater (EIPPCB, 2016^[51]). Chlorine production using mercury cell technique along with contaminated sites may be critical sources of mercury for wastewater treatment plants. Mercury can easily adsorb onto the sludge, which needs to be controlled if sludge is to be incinerated (EIPPCB, 2016^[51]). However, there is no further information about the technique provided in the BREF. Table 5 shows the list of BREFs that include biological treatment as a mercury removal technique.

Table 5. BREFs with biological treatment of mercury in wastewater

Country/Organisation	BREFs	Chapter	Page	Reference	Note
EU	Management of Waste from Extractive Industries (MWEI)	6.3.1.3	P597	(EIPPCB, 2018 ^[26])	Emerging technique
	Large Combustion Plants	3.2.4.9	P292	(EIPPCB, 2017 ^[70])	Technique to consider in the determination of BAT
		10.8.6	P810		
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 ^[64])	Technique to consider in the determination of BAT
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	2.4.3.6	P67	(EIPPCB, 2016 ^[51])		
US	Treatment Technologies for Mercury in Soil, Waste, and Water	10.0	10-1	(US EPA, 2007 ^[76])	

Innovative techniques

There are a number of innovative techniques outlined in some of the BREFs that can be used alternatively to treat mercury and mercury-compounds in the wastewater than the common practices described above. These practices are grouped under filtration for solids removal techniques. Monitoring and process control of wastewater treatment are also important practices for appropriate functioning of the treatment plants and keeping up the removal rates. The EU CAK BREF presented methods for monitoring mercury in water that are in accordance with the EN ISO standards⁷ (EIPPCB, 2014^[64]). Several process control techniques are listed in the EU Non-ferrous Metals Industries (NFM) BREF (EIPPCB, 2017^[34]).

Solid Removal/Filtration techniques

- **Nanofiltration (NF)** is a membrane permeation process, which allows water, single valence ions (e.g. fluoride, sodium, potassium, and chloride) and nitrates to pass through while retaining polyvalent ions [e.g. mercury II ion (Hg^{2+}), sulphate and phosphates]. The salts become concentrated and are discharged as a concentrated brine. The EU CWW BREF reported over 90 % of abatement efficiency for organic/inorganic mercury (EIPPCB, 2016^[51]; NIER, 2017^[63]).
- **Ultrafiltration (UF)** is another membrane permeation process, which has a different pore size of membrane. This technique is usually preceded by precipitation/coprecipitation to cause the mercury species to form or adsorb onto a suspended solid. UF is primarily used to remove high-molecular weight contaminants and solids. 54.5% reduction in the concentration of mercury is reported in the US BREF (US EPA, 2007^[76]; US EPA, 2000^[56]).
- **Iron filtration** involves treating mercury-containing wastewater with iron filings after pre-treating with sand filtration to reduce the mercury ions to metallic mercury at pH 3.0~3.5, and then removal by filtration. This technique is described in the GATPPC Mining document (MEE, 2010^[33]).
- Waste incineration plants commonly use **filtration and sand filtration, sedimentation, flocculation, and coagulation** as well as chemical precipitation, ion exchange, and adsorption (EIPPCB, 2019^[50]).

In addition to the filtration and preventive techniques, microbial mats or algae usage is described as an emerging technique in the EU MWEI BREF. Microbial mats are composed of living organisms, primarily of cyanobacteria. They can grow rapidly and survive extreme environmental conditions such as high concentrations of metals and organic contaminants. Algal biomass treatment occurs via enhanced cyanobacterial and algal growth through nutrients addition. Certain studies reported this technique achieved the removal of dissolved mercury (EIPPCB, 2018^[26]). Since microbial mats are biofilms where both aerobic and anoxic metabolisms take place, this emerging technique provides opportunities to study the microbial mercury transformations compared to redox conditions (Vigneron, 2021^[78]).

Table 6 shows the list of BREFs which include these other techniques as a way of removing mercury from wastewater.

Table 6. BREFs with innovative techniques of mercury removal (including its monitor and process control) from wastewater

Country/Organisation	BREFs	Chapter	Page	Reference	Note
<i>Nanofiltration</i>					
EU	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	3.3.2.3.4.7	P236	(EIPPCB, 2016 ^[51])	Technique to consider in the determination of BAT

⁷ European Standard (EN) (EN ISO 12846 or EN ISO 17852) is referred as a BAT for monitoring of a particular substance.

Korea	Organic Chemical Industry	3.2.4	P99	(NIER, 2017 ^[63])	
<i>Ultrafiltration</i>					
US	Development Document for Waste Combustors Effluent Guidelines	6.1.1.7.3	6-17	(US EPA, 2000 ^[56])	
	Treatment Technologies for Mercury in Soil, Waste, and Water	9.0	9-1	(US EPA, 2007 ^[76])	
<i>Ion filtration</i>					
China	Mining and Mineral Processing of the Iron and Steel Industry	3.4.5	P11	(MEE, 2010 ^[33])	
<i>Reduction with hydrazine</i>					
EU	Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	2.4.3.6	P67	(EIPPCB, 2016 ^[51])	Technique to consider in the determination of BAT
<i>filtration and sand filtration, sedimentation, flocculation, and coagulation</i>					
EU	Waste Incineration (WI)	5.2.3	P506	(EIPPCB, 2018 ^[49])	BAT Conclusion
<i>Monitoring</i>					
EU	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 ^[64])	Technique to consider in the determination of BAT
<i>Process control</i>					
	Non-ferrous Metals Industries (NFM)	2.12.3.3	P117	(EIPPCB, 2017 ^[34])	General processes and techniques

3.2. Mercury removal from soil and waste

This subsection highlights techniques used to remove mercury adsorbed to soil and waste, which were found in BREFs listed in Table 1. While some of those techniques are derived from the sectors that are addressed under other Articles than Article 9 of the Minamata Convention, particularly, interim storage in Article 10, waste in Article 11⁸, contaminated sites in Article 12, these techniques identified are included for reference and completeness. Table 7 shows the list of BREFs which include techniques described in the following sections.

3.2.1. How is the contaminated soil and waste generated?

Examples of materials that contain mercury can be certain types of batteries, catalysts, thermometers, fluorescent tubes, and flat panel displays. These uses of mercury also lead to the generation of mercury-containing wastes. The mercury removal processes from waste water may produce mercury-containing waste such as sludge, precipitate and activated carbon filters (EIPPCB, 2018^[49]; MEE, 2010^[60]). Dismantling and demolition of chlor-alkali plants result in the generation of various contaminated waste, including asphalt and wooden floorboards. Chlor-alkali plants can also generate contaminated soil on the site of the plant's location. (EIPPCB, 2014^[64]). The information in the following section also supports the implementation of Article 11 of the Minamata convention.

Improper treatment or disposal of these mercury-containing materials/waste can lead to contamination of land with mercury. For example, EU CAK BREF mentions that the contamination of soil with mercury is due to the historical disposal of graphite sludge from the use of graphite anodes and of other wastes on

⁸ Article 11 of Minamata Convention states that parties shall take appropriate measures so that mercury wastes are managed in an environmentally sound manner taking into account the guidelines set by the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2019^[89]). The Basel Convention COP in 2019 decided to update the technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds as well (UNEP, 2019^[90]).

and around the site (EIPPCB, 2014^[64]). The decontamination techniques presented in the following section are developed in support of Article 12 of the Minamata convention.

3.2.2. Common techniques

Decontamination processes aim to separate mercury from one or several other fraction(s) of solid material. This can be done mechanically, chemically or thermally. The safe management of these processes involves the avoidance of mercury emissions in order to protect health and the environment. In some cases, mercury can also be recovered for allowed uses (EIPPCB, 2018^[49]).

Mechanical or physical treatment for decontamination

Mercury contained in certain wastes can be separated by mechanical or physical treatment including sorting or breaking, centrifuging, and shredding or sieving. These techniques are particularly applicable for wastes in which the mercury-using parts are identified, such as mercury lamps, thermometers, LCD, and batteries (EIPPCB, 2018^[49]).

Mechanical or physical treatment also includes washing with water (with or without pressure), ultrasonic vibration, and vacuum cleaners with appropriate adsorption or condensation systems. These treatments are suitable if significant quantities of metallic mercury are present and they are applicable for contaminated solid materials, such as those that arise during decommissioning of chlor-alkali plants (including dismantled waste) (EIPPCB, 2014^[64]).

Ex situ Soil Washing

Soil washing has been used to treat soils contaminated with heavy metals including mercury. This *ex situ* technique takes advantage of the behaviour of some contaminants to preferentially adsorb onto the fines fraction of soil. The contaminated soil is suspended in a wash solution of water or water enhanced with chemical additives such as leaching agents, surfactants, acids, or chelating agents to help remove organic compounds and heavy metals, and the fines are separated from the suspension, thereby reducing the contaminant concentration in the remaining soil (US EPA, 2007^[76]).

Chemical treatment for decontamination

Chemical treatment for decontamination uses oxidising agents such as hypochlorite, chlorinated brine and hydrogen peroxide, which converts elemental and other forms of mercury into its cationic form that can dissolve in water. The liquid streams are then treated for removing mercury from the wastewater generated (see Section 3.1) (EIPPCB, 2014^[64]).

Ex situ acid extraction

Acid extraction is regarded as an *ex situ* technique for contaminated soil that uses an extracting chemical, such as hydrochloric acid or sulfuric acid to extract mercury from a solid matrix by dissolving it in the acid. The mercury is then recovered from the acid leaching solution using techniques such as aqueous-phase electrolysis (US EPA, 2007^[76]).

Thermal treatment for decontamination

Thermal desorption consists of heating excavated mercury-contaminated soil (on site or off site) to volatilise the mercury with subsequent treatment of the resulting waste gases. Operating temperatures for thermal desorption typically range from 320 °C to more than 800 °C. Thermal desorption can be carried out with the help of a vacuum or vibrating equipment (EIPPCB, 2014^[64]).

Vitrification technology is a high-temperature treatment designed to immobilise metals by incorporating them into a vitrified end-product, which is chemically durable and leach resistant. The primary residue generated by this technique is typically glass cullet or aggregate. Secondary residues generated are air emissions, scrubber liquor, carbon filters, and used hood panels. This technique may also cause contaminants to volatilise or undergo thermal destruction, thereby reducing their concentration in the soil. (US EPA, 2007^[76]; EIPPCB, 2014^[64]). During vitrification, the organic content of the mercury-containing waste releases heat during its combustion which reduces the external energy requirements. This process may be beneficial for treating waste with a combination of mercury and organic contaminants or for treating organo-mercury compounds, however, high concentrations of organic compounds and moisture may result in high volumes of off-gas emissions that affect the function of the emission control systems (US EPA, 2007^[77]).

Many mercury cell chlor-alkali plants use distillation or retorting in specially designed units at the plant or externally. This practice is used for high mercury wastes (hazardous wastes that contain greater than 260 mg/kg total mercury hazardous) (US EPA, 2003^[58]). The mercury is recovered as metallic mercury (EIPPCB, 2014^[64]).

In the process of vacuum distillation, waste containing mercury is evaporated under reduced pressure at approximately 300–650 °C. The liquid components (e.g. mercury, water and oil) are distilled from the waste and condensed. In the condensation, the mercury and the distillate are separated. The metallic mercury is drained and possibly refined. The mercury can be recycled as a secondary raw material (EIPPCB, 2018^[49]).

Solidification and Stabilisation (including Amalgamation)

Solidification and stabilisation (S/S) is used to treat elemental mercury and mercury-contaminated soil and sludge. S/S reduces the mobility of contaminants in the media by physically binding them within a stabilised mass (such as cement) or inducing chemical reactions.

Amalgamation involves dissolving and solidifying mercury in other metals such as copper, nickel, zinc and tin, to result in a solid, non-volatile product. This technology falls under solidification methods and does not involve a chemical reaction (US EPA, 2007^[76]).

Two generic processes are used for amalgamating mercury in wastes: *aqueous* and *non-aqueous replacement*. The *aqueous* process involves mixing a finely divided base metal, such as zinc or copper, into wastewater that contains dissolved mercury salts; the base metal reduces mercury cations to elemental mercury, which dissolves in the metal to form a solid mercury-based metal amalgam. The *non-aqueous* process involves mixing finely divided metal powders into waste liquid mercury, forming a solidified amalgam (US EPA, 2007^[76]).

3.3. Mercury-containing waste management

Proper management of mercury and mercury-containing waste is crucial in controlling and preventing its release to the environment in any form. This section covers three good environmental governance practices that may serve as BATs for the Articles 10, 11 and 12 of the Minamata Convention.

3.3.1. Short-term storage of metallic mercury on site

Prior to transport, further treatment and disposal, it may be necessary to store metallic mercury for a short term on site in facilities. This section on interim storage supports the implementation of Article 10 of the Minamata Convention. EU CAK BREF (EIPPCB, 2014^[64]) lists desirable features at a facility for purposes of storing mercury as follows:

- well-lit;

- weatherproof to avoid corrosion;
- secured against unauthorised access;
- equipped with a floor capable of carrying the heavy weight;
- free of substances that are flammable or may react with mercury;
- equipped with a suitable secondary containment capable of retaining 110 % of the liquid volume of any single container (e.g. metal or plastic spill trays; crack-free, smooth, impervious floor with slopes and gutters leading to a collection sump);
- free of obstructions and debris that may absorb mercury and/or hinder the clean-up of spills (e.g. wooden pallets);
- equipped with aspiration equipment with activated carbon filters to rapidly clean up spills;
- periodically inspected, both visually and with mercury-monitoring equipment.

Standards for the storage of mercury waste are also described in 40 CFR Part 262.15 of the US Code of Federal Regulations (US EPA, 2016^[79]).

3.3.2. *Monitoring mercury concentration in applied sludge*

Since sludge application to agricultural land potentially causes land contamination, stability tests and analysis of heavy metal content including mercury are required prior to the widespread application of sludge (US EPA, 1993^[80]). Regular monitoring of the mercury concentration in applied sludge and post-application site is also needed (MEE, 2010^[60]). This section supports the implementation of Article 11 of the Minamata Convention.

3.3.3. *Containment of contaminated soil*

This technique applies to contaminated sites, such as sites contaminated by a chlor-alkali plant. Containment methods are essentially cutting off the exposure pathway from a contaminated site towards receptors. This is achieved by confinement of the contaminated material, either at the original location or after removal. For the containment of contaminated soil at the original location, barriers such as cappings or cut-off walls are frequently used, either during emergency preliminary activities or as permanent techniques. Alternatively, the polluted soil or sediment is removed and confined in a permanent storage facility at a different location. If necessary, the incurring groundwater is treated. The excavated soil is then replaced with uncontaminated soil (EIPPCB, 2014^[64]). This section supports the implementation of Article 12 of the Minamata Convention.

Table 7. BREFs with techniques for the reduction of mercury release to land

Country/Organisation	BREFs	Chapter	Page	Reference	Note
<i>Mechanical/physical treatment for decontamination</i>					
EU	Waste Treatment (WT)	5.8.2	P696	(EIPPCB, 2018 _[649])	Technique to consider in the determination of BAT
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
		5.2	P253		
<i>Chemical treatment for decontamination</i>					
EU	Production of Chlor-alkali (CAK)	5.2	P253	(EIPPCB, 2014 _[641])	BAT Conclusion
US	Waste Specific Evaluation of RMERC Treatment Standard	D 1	P28	(US EPA, 1998 _[59])	
<i>Soil washing and extraction</i>					
EU	Production of Chlor-alkali (CAK)	4.4.4	P242	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
US	Treatment Technologies for Mercury in Soil, Waste, and Water	4.0	P4-1	(US EPA, 2007 _[76])	
<i>Thermal treatment for decontamination</i>					
EU	Waste Treatment (WT)	5.8.2	P696	(EIPPCB, 2018 _[49])	Technique to consider in the determination of BAT
	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
		4.4.4	P242		Technique to consider in the determination of BAT
US	Treatment Technologies for Mercury in Soil, Waste, and Water	5.0	P5-1	(US EPA, 2007 _[76])	
		6.0	P6-1		
	Waste Specific Evaluation of RMERC Treatment Standard	D 5	P31	(US EPA, 1998 _[59])	
<i>Solidification and Stabilisation (Including Amalgamation)</i>					
EU	Production of Chlor-alkali (CAK)	4.4.4	P242	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
US	Treatment Technologies for Mercury in Soil, Waste, and Water	3.0	P3-1	(US EPA, 2007 _[76])	
		Waste Specific Evaluation of RMERC Treatment Standard	D 3		
<i>Short-term storage of metallic mercury on site</i>					
EU	Production of Chlor-alkali (CAK)	4.1.3	P142	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
US	Satellite accumulation area regulations for small and large quantity generators	262.15	-	(US EPA, 2016 _[81])	
<i>Containment of contaminated soil</i>					
EU	Production of Chlor-alkali (CAK)	4.4.3	P241	(EIPPCB, 2014 _[641])	Technique to consider in the determination of BAT
<i>Monitoring mercury concentration in applied sludge</i>					
China	Treatment and Disposal of Sludge from Municipal Wastewater Treatment Plant	8.5.5	P18	(MEE, 2010 _[60])	Best Environmental Management Practices
	Medical waste treatment and disposal	4.4.1	P13	(MEE, 2012 _[62])	Best Environmental Management Practices
	Cement industry	7	P16	(MEE, 2014 _[83])	Best Environmental Management Practices

4. Other resources of BAT

In addition to the BREFs provided by the OECD Expert Group on BAT, this study identifies other resources with technologies on mercury removal. This chapter aims to list those relevant sources of information, which may be useful in the development of Guidance on Best Available Techniques and Best Environmental Practices for reducing or preventing mercury releases to water and land.

Guidance on the Identification, Management and Remediation of Mercury Contaminated Sites

This document is intended as preliminary guidance in relation to sites contaminated with mercury and mercury compounds. It is aligned with the description of Article 12, *contaminated site*, of the Minamata Convention. Chapter 6 of this guidance outlines remediation technologies and techniques, including emerging technologies (IPEN, 2016^[84]).

Technical guidelines for the environmentally sound management of wastes consisting of elemental mercury and wastes containing or contaminated with mercury

Current guidelines for the environmentally sound management (ESM) of wastes consisting of elemental mercury and wastes containing or contaminated with mercury are in line with the decisions made under the Basel Convention. It contains lists of techniques on reduction of mercury releases from thermal treatment and disposal of waste, remediation of contaminated sites (UNEP, 2011^[85]).

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