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**Conference of the Parties to the Basel Convention  
on the Control of Transboundary Movements of  
Hazardous Wastes and Their Disposal  
Twelfth meeting**

Geneva, 4–15 May 2015  
Agenda item 4 (b) (i)

**Matters related to the implementation of the Convention:  
scientific and technical matters: technical guidelines**

## **Technical guidelines**

### **Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds**

#### **Note by the Secretariat**

At its twelfth meeting, the Conference of the Parties to the Basel Convention adopted, in decision BC-12/4, the technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds on the basis of the draft technical guidelines contained in document UNEP/CHW.12/5/Add.8. The technical guidelines referred to above were prepared by the Government of Japan, in consultation with the small intersessional working group on the development of technical guidelines on the environmentally sound management of mercury wastes. The technical guidelines were further revised taking into account comments received from parties and others by 21 March 2015 (see document UNEP/CHW.12/INF/8). The text of the final version of the technical guidelines, as adopted, is set out in the annex to the present note.

## **Annex**

### **Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds**

**Revised final version (15 May 2015)**

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## Abbreviations and acronyms

ASGM	artisanal and small-scale gold mining
ASTM	American Society for Testing and Materials
AOX	absorbable organic halides
BAT	best available techniques
CCME	Canadian Council of Ministers for the Environment
CEN	European Committee for Standardization
CETEM	Centre for Mineral Technology (Brazil)
CFLs	compact fluorescent lamps
CH <sub>3</sub> Hg <sup>+</sup> or MeHg <sup>+</sup>	monomethylmercury, commonly called methylmercury
Cl	chlorine
EMS	environmental management system
EN	European standard
EPA	Environmental Protection Agency (United States of America)
EPR	extended producer responsibility
ESM	environmentally sound management
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GMP	Global Mercury Project
HCl	hydrochloric acid
HF	hydrofluoric acid
Hg	mercury
HgCl <sub>2</sub>	mercury dichloride
HgO	mercury (II) oxide
HgS	mercury sulphide or cinnabar
HgSO <sub>4</sub>	mercury sulphate
HNO <sub>3</sub>	nitric acid
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IIED	International Institute for Environment and Development
ILO	International Labour Organization
IMERC	Interstate Mercury Education and Reduction Clearinghouse
IMO	International Maritime Organization
ISO	International Organization for Standardization
J-Moss	Japan marking of specific substances (Japanese standard JIS C 0950, titled “the marking for presence of the specific chemical substances for electrical and electronic equipment”)
JIS	Japanese Industrial Standard
JLT	Japanese standardized leaching test
JSA	Japanese Standards Association
LCD	liquid crystal displays
LED	light emitting diode
MMSD	Mining, Minerals and Sustainable Development (IIED/WBCSD project)
MSW	municipal solid waste
NEWMOA	Northeast Waste Management Officials’ Association
NGO	non-governmental organization
NIP	national implementation plan
NIMD	National Institute for Minamata Disease
NO <sub>x</sub>	nitrogen oxide
OEWG	Open-ended Working Group (of the Basel Convention)
OECD	Organisation for Economic Co-operation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
QA/QC	quality assurance/quality control
PAC	powdered activated carbon
PACE	Partnership for Action on Computing Equipment
PBB	polybrominated biphenyls
PBDE	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
PM	particulate matter
POPs	persistent organic pollutants
PRTR	pollutant release and transfer register
PVC	polyvinyl chloride
RoHS	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive)
SAICM	Strategic Approach to International Chemicals Management

SETAC	Society of Environmental Toxicology and Chemistry
SO <sub>2</sub>	sulphur dioxide
SOP	standard operational procedure
SPC	sulphur polymer cement
S/S	stabilization and/or solidification
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon
TS	technical specification
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
VCM	vinyl chloride monomer
WBCSD	World Business Council for Sustainable Development
WEEE	waste electrical and electronic equipment
WHO	World Health Organization

## Units of measurement

µg	microgram
mg	milligram
g	gram
kg	kilogram
mg/kg	milligram(s) per kilogram. Corresponds to parts per million (ppm) by mass.
L	liter
m <sup>3</sup>	cubic meter
cm <sup>3</sup>	cubic centimeter
°C	degree Celsius

## I. Introduction

### A. Scope

1. The present guidelines provide guidance on the environmentally sound management (ESM) of wastes consisting of, containing, or contaminated with mercury<sup>1</sup> or mercury compounds,<sup>2</sup> hereinafter referred to as “mercury wastes”, pursuant to decisions VIII/33, IX/15, BC-10/7, BC-11/5 and BC-12/4 of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal and decisions VII/7 and OEWG-9/4 of the Open-ended Working Group of the Basel Convention. This document supersedes the Basel Convention *Technical guidelines for the ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury*, adopted by the Conference of the Parties at its tenth meeting.

2. In paragraph 1 of Article 2 (“Definitions”), the Basel Convention defines wastes as “substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law”. The following mercury wastes<sup>3</sup> are covered by the present guidelines (see table 3 for additional examples):

A: Wastes consisting of mercury or mercury compounds (e.g., excess mercury from the decommissioning of chlor-alkali facilities, mercury recovered from wastes containing mercury or mercury compounds or wastes contaminated with mercury or mercury compounds or surplus stock of mercury or mercury compounds designated as waste);

B: Wastes containing mercury or mercury compounds;

B1: Wastes of mercury-added products<sup>4</sup> that easily release mercury into the environment, including when they are broken (e.g., mercury thermometers, fluorescent lamps);

B2: Wastes of mercury-added products other than those listed in B1 (e.g., batteries);

B3: Wastes containing mercury or mercury compounds that result from a the treatment of mercury wastes listed as A, B1, B2 or C;

C: Wastes contaminated with mercury or mercury compounds (e.g., residues generated from mining processes, industrial processes or waste treatment processes).

3. The present guidelines focus on mercury wastes categorized as hazardous wastes.

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<sup>1</sup> “Mercury” means elemental mercury (Hg(0), CAS No. 7439-97-6) (see Article 2 (d) of the Minamata Convention on Mercury (hereinafter referred to as “Minamata Convention”).

<sup>2</sup> “Mercury compound” means any substance consisting of atoms of mercury and one or more atoms of other chemical elements that can be separated into different components only by chemical reactions (see Article 2 (e) of the Minamata Convention).

<sup>3</sup> Under Article 11, paragraph 2, of the Minamata Convention, only those wastes consisting of, containing or contaminated with mercury or mercury compounds in a quantity above the relevant thresholds defined by the Conference of the Parties to the Convention are defined as mercury wastes. This definition excludes overburden, waste rock and tailings from mining, except from primary mercury mining, unless they contain mercury or mercury compounds above thresholds defined by the Conference of the Parties.

<sup>4</sup> “Mercury-added product” means a product or product component that contains mercury or a mercury compound that was intentionally added (see Article 2 (f) of the Minamata Convention).

## B. About mercury<sup>5</sup>

4. Mercury is or has been widely used in products such as measuring devices (barometers, hygrometers, manometers, thermometers, sphygmomanometers), switches and relays, fluorescent lamps, batteries, cosmetics, pesticides, biocides, topical antiseptics and dental amalgam, and in manufacturing processes, such as those involving the production of chlor-alkali, acetaldehydes, vinyl chloride monomers (VCM), sodium or potassium methylates or ethylates, polyurethane, and mercury-added products.

5. Mercury may also be a by-product of raw material refining or production processes, such as oil and gas refining and non-ferrous metal production. Mercury is recognized as a global hazardous pollutant.<sup>6</sup> Mercury emissions and releases can be caused by human activities (i.e., they may be anthropogenic) but may also result from natural sources such as volcanic eruptions and forest fires. Once mercury is emitted or released into the environment, it persists in the atmosphere (e.g., as mercury vapour), soil (e.g., as ionic mercury) and water bodies (e.g., methylmercury (MeHg<sup>+</sup>, or CH<sub>3</sub>Hg<sup>+</sup>)). Some of the mercury that is released or emitted into the environment ends up in the food chain, mainly due to the biomagnification of bioavailable mercury.

6. Improper handling, collection, transportation or disposal of mercury wastes can lead to emissions or releases of mercury, as can the use of some disposal technologies.

7. The discharge of wastewater containing mercury into Minamata Bay, Japan, from 1932 to 1968 (Ministry of the Environment of Japan, 2002), the illegal dumping of mercury-contaminated waste in Cambodia in 1998 (Honda et al., 2006; NIMD, 1999) and the case involving Thor Chemicals in South Africa (Lambrecht, 1989) are but a few examples of cases in which wastes containing or contaminated with mercury or mercury compounds were not managed in an environmentally sound manner.

8. The provisions of the Minamata Convention on Mercury (hereinafter referred to as “Minamata Convention”) are intended to reduce mercury supply and demand. The growing global trend towards phasing out mercury-added products and processes using mercury will soon result in the generation of an excess of mercury if mercury supplies remain at the current level. In addition, the coming years are expected to see increased use of some mercury-added products such as fluorescent lamps, which are being used to replace incandescent lamps as part of a strategy to move towards low-carbon societies, and mercury-added liquid crystal display (LCD) backlights. Ensuring ESM, particularly of mercury wastes, will be critical for most countries.

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<sup>5</sup> Further information on mercury, including its chemical properties, sources, behaviour in the environment and effects on human health, as well as mercury risks and pollution, is available from the following sources (see bibliography below for full references):

- For chemical properties: Japan Public Health Association, 2001; Steffen, 2007; WHO, 2003; Spiegel and Veiga, 2006; ILO, 2000 and 2001; Oliveira et al, 1998; and Tajima, 1970.
- For sources of anthropogenic emissions: UNEP, 2008a; and the Zero Mercury Working Group, 2009;
- For behaviour in the environment: Japan Public Health Association, 2001; and Wood, 1974;
- For human health risks: Ozonoff, 2006; Sanbom and Brodberg, 2006; Sakamoto et al, 2005; WHO, 1990; Kanai and Endou, 2003; Kerper et al, 1992; Mottet et al, 1985; Sakamoto et al, 2004; Oikawa et al, 1983; Richardson, 2003; Richardson and Allan, 1996; Gay et al, 1979; Boom et al, 2003; Hylander and Meili, 2005; Bull, 2006; WHO, 1972, 1990, 1991, 2003 and 2008; Japan Public Health Association, 2001; Canadian Centre for Occupational Health and Safety, 1998; Asano et al, 2000; and UNEP, 2008.
- For mercury pollution: Ministry of the Environment of Japan, 1997 and 2002; Amin-Zaki et al, 1978; Bakir et al, 1973; Damluji and Tikriti, 1972; UNEP, 2002; Lambrecht, 1989; GroundWork, 2005; The School of Natural Resources and Environment, University of Michigan, 2000; and Butler, 1997.

<sup>6</sup> The preamble of the Minamata Convention recognizes that mercury is a chemical of global concern owing to its long-range atmospheric transport, its persistence in the environment once anthropogenically introduced, its ability to bioaccumulate in ecosystems and its significant negative effects on human health and the environment.



## II. Relevant provisions of the Basel Convention and international linkages

### A. Basel Convention

#### 1. General provisions

9. The Basel Convention aims to protect human health and the environment against adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes.

10. Article 2, paragraph 4, of the Convention defines disposal as “any operation specified in Annex IV” to the Convention. Annex IV contains two categories of operations: those leading to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative uses (R operations) and those not leading to this possibility (D operations).

11. Article 4 (“General obligations”), paragraph 1, establishes the procedure by which parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal are to inform the other parties of their decision. Paragraph 1 (a) states: “Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13.” Paragraph 1 (b) states: “Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such waste when notified pursuant to subparagraph (a).”

12. Article 4, paragraphs 2 (a)–(e) and 2 (g), set out key provisions pertaining to ESM, waste minimization, reduction of transboundary movement, and waste disposal practices aimed at mitigating adverse effects on human health and the environment:

“Each Party shall take appropriate measures to:

- (a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social, technological and economic aspects;
- (b) Ensure the availability of adequate disposal facilities, for ESM of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;
- (c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;
- (d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement;
- (e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting;”
- “(g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner.”

#### 2. Mercury-related provisions

13. Article 1 (“Scope of the Convention”) defines the types of waste that are covered by the Basel Convention. Subparagraph 1 (a) sets out a two-step process for determining whether a “waste” is a “hazardous waste” covered by the Convention: first, the waste must belong to one of the categories listed in Annex I to the Convention (“Categories of wastes to be controlled”), and second, it must possess at least one of the characteristics listed in Annex III to the Convention (“List of hazardous characteristics”).

14. Annex I wastes are presumed to exhibit one or more of the hazardous characteristics listed in Annex III. These may include H6.1 “Poisonous (acute)”, H11 “Toxic (delayed or chronic)”, or H12

“Ecotoxic”, unless, through “national tests”, they can be shown not to exhibit such characteristics. National tests may be useful for identifying a particular hazardous characteristic listed in Annex III until such time as the hazardous characteristic is fully defined. Guidance papers for some Annex III hazardous characteristics have been drafted under the Convention.

15. List A of Annex VIII describes wastes that are “characterized as hazardous under Article 1, paragraph 1 (a) of this Convention” although “their designation on this Annex does not preclude the use of Annex III [hazard characteristics] to demonstrate that a waste is not hazardous” (Annex I, paragraph (b)). List B of Annex IX includes wastes that “will not be wastes covered by Article 1, paragraph 1 (a), of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic.”

16. As stated in Article 1, paragraph 1 (b), “Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit” are also subject to the Basel Convention.

17. Mercury wastes listed in annexes I and VIII to the Convention are listed in table 1 below.

**Table 1:** Mercury wastes listed in annexes I and VIII to the Basel Convention (emphasis added)

<b>Entries with direct reference to mercury</b>	
Y29	Wastes having as constituents: <b><i>Mercury, mercury compounds</i></b>
A1010	Metal wastes and waste consisting of alloys of any of the following: ... - <b><i>Mercury</i></b> ... but excluding such wastes specifically listed on list B.
A1030	Wastes having as constituents or contaminants any of the following: ... - <b><i>Mercury; mercury compounds</i></b> ...
A1180	Waste electrical and electronic assemblies or scrap <sup>7</sup> containing components such as accumulators and other batteries included on list A, <b><i>mercury-switches</i></b> , glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g. cadmium, <b><i>mercury</i></b> , lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110) <sup>8</sup>
<b>Other entries related to wastes which may contain or be contaminated with mercury</b>	
A1170	Unsorted waste batteries excluding mixtures of only list B batteries. Waste batteries not specified on list B containing Annex I constituents to an extent to render them hazardous
A2030	Waste catalysts but excluding such wastes specified on list B
A2060	Coal-fired power plant fly-ash containing Annex I substances in concentrations sufficient to exhibit Annex III characteristics (note the related entry on list B B2050)
A3170	Wastes arising from the production of aliphatic halogenated hydrocarbons (such as chloromethane, dichloro-ethane, vinyl chloride, vinylidene chloride, allyl chloride and epichlorhydrin)
A4010	Wastes from the production, preparation and use of pharmaceutical products but excluding such wastes specified on list B
A4020	Clinical and related wastes; that is wastes arising from medical, nursing, dental, veterinary, or similar practices, and wastes generated in hospitals or other facilities during the investigation or treatment of patients, or research projects
A4030	Wastes from the production, formulation and use of biocides and phytopharmaceuticals, including waste pesticides and herbicides which are off-specification, outdated, or unfit for their originally intended use
A4080	Wastes of an explosive nature (but excluding such wastes specified on list B)
A4100	Wastes from industrial pollution control devices for cleaning of industrial off-gases but excluding such wastes specified on list B

<sup>7</sup> This entry does not include scrap assemblies from electric power generation.

<sup>8</sup> PCBs are at a concentration level of 50 mg/kg or more.

A4140	Waste consisting of or containing off specification or outdated <sup>9</sup> chemicals corresponding to Annex I categories and exhibiting Annex III hazard characteristics
A4160	Spent activated carbon not included on list B (note the related entry on list B B2060)

## B. International linkages

### 1. Minamata Convention on Mercury

18. The objective of the Minamata Convention, which was adopted on 10 October 2013, is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. To achieve this objective, the Minamata Convention aims:

- (a) To reduce the supply of mercury and control the international trade in mercury;
- (b) To reduce the demand for mercury in products, manufacturing processes and artisanal and small-scale gold mining;
- (c) To reduce emissions and releases of mercury to air, land and water;
- (d) To ensure environmentally sound interim storage of mercury and mercury compounds;
- (e) To ensure ESM of mercury wastes and remediation of contaminated sites; and
- (f) To promote capacity-building, technical assistance and technology transfer, including through specific financial and other arrangements.

19. Article 11 (“Mercury wastes”) of the Minamata Convention sets forth the following waste-related provisions:

“1. The relevant definitions of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal shall apply to wastes covered under this Convention for Parties to the Basel Convention. Parties to this Convention that are not Parties to the Basel Convention shall use those definitions as guidance as applied to wastes covered under this Convention.

2. For the purposes of this Convention, mercury wastes means substances or objects:

- (a) Consisting of mercury or mercury compounds;
- (b) Containing mercury or mercury compounds; or
- (c) Contaminated with mercury or mercury compounds,

in a quantity above the relevant thresholds defined by the Conference of the Parties, in collaboration with the relevant bodies of the Basel Convention in a harmonized manner, that are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law or this Convention. This definition excludes overburden, waste rock and tailings from mining, except from primary mercury mining, unless they contain mercury or mercury compounds above thresholds defined by the Conference of the Parties.

3. Each Party shall take appropriate measures so that mercury waste is:

(a) Managed in an environmentally sound manner, taking into account the guidelines developed under the Basel Convention and in accordance with requirements that the Conference of the Parties shall adopt in an additional annex in accordance with Article 27. In developing requirements, the Conference of the Parties shall take into account Parties’ waste management regulations and programmes;

(b) Only recovered, recycled, reclaimed or directly re-used for a use allowed to a Party under this Convention or for environmentally sound disposal pursuant to paragraph 3 (a);

(c) For Parties to the Basel Convention, not transported across international boundaries except for the purpose of environmentally sound disposal in conformity with this Article and with that Convention. In circumstances where the Basel Convention does not apply to transport across international boundaries, a Party shall allow such transport only after taking into account relevant international rules, standards, and guidelines.

<sup>9</sup> “Outdated” means unused within the period recommended by the manufacturer.

4. The Conference of the Parties shall seek to cooperate closely with the relevant bodies of the Basel Convention in the review and update, as appropriate, of the guidelines referred to in paragraph 3 (a).
5. Parties are encouraged to cooperate with each other and with relevant intergovernmental organizations and other entities, as appropriate, to develop and maintain global, regional and national capacity for the management of mercury wastes in an environmentally sound manner.”
20. Paragraphs 21 to 27 below describe other provisions of the Minamata Convention that are relevant to mercury wastes.
21. Article 3, paragraph 5 (b), of the Minamata Convention provides that “each Party shall take measures to ensure that, where the Party determines that excess mercury from the decommissioning of chlor-alkali facilities is available, such mercury is disposed of in accordance with the guidelines for environmentally sound management referred to in paragraph 3 (a) of Article 11, using operations that do not lead to recovery, recycling, reclamation, direct re-use or alternative uses.”
22. Article 4, paragraph 1, of the Convention provides that “each Party shall not allow, by taking appropriate measures, the manufacture, import or export of mercury-added products listed in Part I of Annex A after the phase-out date specified for those products, except where an exclusion is specified in Annex A or the Party has a registered exemption pursuant to Article 6.” Part I of Annex A provides that by 2020 the manufacture, import or export of the mercury-added products subject to paragraph 1 of Article 4 shall not be allowed (i.e., phase-out date). Those products are listed in table 2 below. The following products are excluded from Annex A:
- “(a) Products essential for civil protection and military uses;
  - (b) Products for research, calibration of instrumentation, for use as reference standard;
  - (c) Where no feasible mercury-free alternative for replacement is available, switches and relays, cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for electronic displays, and measuring devices;
  - (d) Products used in traditional or religious practices; and
  - (e) Vaccines containing thiomersal as preservatives.”

**Table 2:** Mercury-added products listed in Part I of Annex A (“Products subject to Article 4, paragraph 1”) to the Minamata Convention

Batteries, except for button zinc silver oxide batteries with a mercury content < 2 per cent and button zinc air batteries with a mercury content < 2 per cent.
Switches and relays, except very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge, switch or relay.
Compact fluorescent lamps (CFLs) for general lighting purposes that are ≤ 30 watts with a mercury content exceeding 5 mg per lamp burner.
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Triband phosphor < 60 watts with a mercury content exceeding 5 mg per lamp; (b) Halophosphate phosphor ≤ 40 watts with a mercury content exceeding 10 mg per lamp.
High-pressure mercury vapour lamps (HPMV) for general lighting purposes.
Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for electronic displays: (a) short length (≤ 500 mm) with mercury content exceeding 3.5 mg per lamp; (b) medium length (> 500 mm and ≤ 1 500 mm) with mercury content exceeding 5 mg per lamp; (c) long length (> 1 500 mm) with mercury content exceeding 13 mg per lamp.
Cosmetics (with mercury content above 1ppm), including skin lightening soaps and creams, and not including eye area cosmetics where mercury is used as a preservative and no effective and safe substitute preservatives are available. <sup>14</sup>
Pesticides, biocides and topical antiseptics.
The following non-electronic measuring devices, except non-electronic measuring devices installed in large-scale equipment or those used for high precision measurement, where no suitable mercury-free alternative is available: (a) barometers; (b) hygrometers;

- |  |
|--|
| <ul style="list-style-type: none"> <li>(c) manometers;</li> <li>(d) thermometers;</li> <li>(e) sphygmomanometers.</li> </ul> |
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<sup>17</sup>The intention is not to cover cosmetics, soaps or creams with trace contaminants of mercury.

23. Article 4, paragraph 3, of the Minamata Convention provides that “each Party shall take measures for the mercury-added products listed in Part II of Annex A in accordance with the provisions set out therein.” Part II of Annex A provides that “measures to be taken by a Party to phase down the use of dental amalgam shall take into account the Party’s domestic circumstances and relevant international guidance and shall include two or more” of the measures listed therein.

24. Article 5, paragraph 2, of the Minamata Convention provides that “each Party shall not allow the use of mercury or mercury compounds in the manufacturing processes listed in Part I of Annex B after the phase-out date specified in that Annex for the individual processes, except where the Party has a registered exemption pursuant to Article 6.” Part I of Annex B lists chlor-alkali production and acetaldehyde production in which mercury or mercury compounds are used as a catalyst. In addition, Article 5, paragraph 3, provides that “each Party shall take measures to restrict the use of mercury or mercury compounds in the processes listed in Part II of Annex B in accordance with the provisions set out therein”. Part II of Annex B lists vinyl chloride monomer production, sodium or potassium methylate or ethylate, and production of polyurethane using mercury containing catalysts. Measures to reduce or control mercury emissions and releases from manufacturing or production processes in which mercury or mercury compounds are used may result in the capture and generation of residues and substances contaminated with mercury or mercury compounds that should be managed appropriately as waste.

25. Article 8, paragraph 3, of the Minamata Convention provides that “[a] Party with relevant sources shall take measures to control emissions.” “Relevant source” means a source falling within one of the categories listed in Annex D to the Convention. Relevant sources listed in Annex D include waste incineration facilities, coal-fired power plants, coal-fired industrial boilers, smelting and roasting processes used in the production of non-ferrous metals, and cement clinker production facilities. Article 8, paragraph 4, provides that “for its new sources, each Party shall require the use of best available techniques and best environmental practices to control and, where feasible, reduce emissions, as soon as practicable but no later than five years after the date of entry into force of the Convention for that Party.” Article 8, paragraph 5, provides that “for its existing sources, each Party shall include in any national plan, and shall implement, one or more of the following measures, taking into account its national circumstances, and the economic and technical feasibility and affordability of the measures, as soon as practicable but no more than ten years after the date of entry into force of the Convention for it:

- (a) A quantified goal for controlling and, where feasible, reducing emissions from relevant sources;
- (b) Emission limit values for controlling and, where feasible, reducing emissions from relevant sources;
- (c) The use of best available techniques and best environmental practices to control emissions from relevant sources;
- (d) A multi-pollutant control strategy that would deliver co-benefits for control of mercury emissions; and
- (e) Alternative measures to reduce emissions from relevant sources.”

These mercury emission control measures and practices may generate solid wastes contaminated with mercury or mercury compounds.

26. Lastly, Article 12 of the Minamata Convention provides that “each Party shall endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds” and that “the Conference of the Parties shall adopt guidance on managing contaminated sites.” Remediation activities for mercury-contaminated sites are likely to generate mercury waste.

## 2. UNEP Global Mercury Partnership

27. In decision 25/5, Part III, the UNEP Governing Council requested the Executive Director of UNEP, coordinating as appropriate with Governments, intergovernmental organizations, stakeholders and the Global Mercury Partnership, to continue and enhance, as part of the international action on mercury, existing work in a number of areas. The Global Mercury Partnership currently has eight

identified priorities for action or “partnership areas”.<sup>10</sup> One such partnership area is the mercury waste management partnership area, launched in 2008 with the Ministry of the Environment of Japan as lead. Among others things, the partnership area has identified and grouped country-level projects by waste stream and created a list of experts on mercury waste.

### 3. **Rotterdam Convention**

28. Annex III to the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade lists “mercury compounds, including inorganic mercury compounds, alkyl mercury compounds and alkyloxyalkyl and aryl mercury compounds.” Annex III lists chemicals that have been banned or severely restricted for health or environmental reasons in at least two regions and that are subject to the prior informed consent procedure.

### 4. **Heavy Metals Protocol**

29. The objective of the 1998 Protocol on Heavy Metals to the 1979 Convention on Long-Range Transboundary Air Pollution, which was amended in 2012, is to control anthropogenic emissions of heavy metals, including mercury, that are subject to long-range transboundary atmospheric transport and are likely to have significant adverse human health or environmental effects. Parties to the Protocol are required to reduce emissions of target heavy metals below 1990 levels (or an alternative year between 1985 and 1995) by applying best available techniques for stationary sources and imposing emissions limit values for certain stationary sources. Parties are also required to develop and maintain emission inventories for heavy metals covered under the Protocol. Annex VII to the Protocol lists mercury-containing electrical components, measuring devices, fluorescent lamps, dental amalgam, pesticides, paint and batteries for recommended product management measures, including substitution, minimization, labelling, economic incentives, voluntary agreements, and programmes for collection, recycling or disposal.

### 5. **SAICM**

30. The Strategic Approach to International Chemicals Management (SAICM) is made up of a ministerial declaration (the “Dubai Declaration on International Chemicals Management”), an overarching policy strategy, and a global plan of action. Mercury is specifically addressed in the SAICM global plan of action, under work area 14, as follows: “Mercury and other chemicals of global concern; chemicals produced or used in high volumes; chemicals subject to wide dispersive uses; and other chemicals of concern at the national level”; specific activities under the work area pertain to risk reduction, the need for further action and the review of scientific information. A quick start programme (QSP) was established under SAICM in 2006 to support initial enabling capacity-building and implementation activities in developing countries, least developed countries, small island developing states and countries with economies in transition (UNEP, 2006a). As of February 2014, seven projects including mercury components such as campaign on minimization of mercury use and inventory development of mercury products, mercury releases, and mining sites have been implemented under the quick start programme (UNEP, 2014a).

## III. **Guidance on environmentally sound management (ESM)**

### A. **General considerations**

31. ESM is a broad policy concept that is understood and implemented in various ways by different countries, organizations and other stakeholders. International guidance documents and core performance elements pertaining to ESM of hazardous wastes have been developed by the Basel Convention and by the Organisation for Economic Co-operation and Development (OECD) and should help stakeholders to implement the ESM of hazardous wastes, including mercury wastes.

#### 1. **Basel Convention**

32. In Article 2, paragraph 8, the Basel Convention defines ESM of hazardous wastes or other wastes as taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner that will protect human health and the environment against the adverse effects which may result from such wastes.

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<sup>10</sup> For further information, <http://www.unep.org/chemicalsandwaste/Mercury/GlobalMercuryPartnership/tabid/1253/language/en-US/Default.aspx>.

33. In Article 4, paragraph 2 (b), the Convention requires each party to take the appropriate measures to “ensure the availability of adequate disposal facilities for the environmentally sound management of hazardous or other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal”, while in paragraph 2 (c) it requires each party to “ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment.”

34. In Article 4, paragraph 8, the Convention requires that “hazardous wastes or other wastes, to be exported, be managed in an environmentally sound manner in the State of import or elsewhere. Technical guidelines for the environmentally sound management of wastes subject to this Convention shall be decided by the Parties at their first meeting.” The present guidelines are intended to provide a more precise definition of ESM when applied to mercury wastes, including by defining appropriate treatment and disposal methods for mercury waste streams that constitute ESM.

35. At its eleventh meeting in 2013, the Conference of the Parties to the Basel Convention adopted a *Framework for the environmentally sound management of hazardous wastes and other wastes*. The framework establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM. It is intended as a practical guide for Governments and other stakeholders participating in the management of hazardous wastes and other wastes and constitutes the most comprehensive ESM guidance produced thus far, complementing the various technical guidelines adopted under the Basel Convention.

36. Under the Basel Convention, ESM is the subject of multiple provisions (refer to section II A.1 above) and the following two declarations:

(a) The 1999 Basel Declaration on Environmentally Sound Management, which was adopted by the Conference of the Parties to the Basel Convention at its fifth meeting and calls on parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention, taking into account social, technological and economic concerns, and through further reduction of transboundary movements of hazardous and other wastes subject to the Convention.

(b) The 2011 Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes, which was adopted by the Conference of the Parties to the Basel Convention at its tenth meeting and reaffirms that the Basel Convention is the primary global legal instrument for guiding the ESM of hazardous wastes and other wastes and their disposal.

37. ESM criteria recommendations for computing equipment have been developed under the Basel Convention Partnership for Action on Computing Equipment (PACE).

## 2. Organisation for Economic Co-operation and Development

38. OECD has adopted a recommendation on ESM of waste that covers such items as the core performance elements of ESM guidelines applying to waste recovery facilities, including: elements of performance that precede collection, transport, treatment and storage; and elements subsequent to storage, transport, treatment and disposal of pertinent residues (OECD 2004).

39. Further information may be found in the guidance manual for the implementation of the OECD recommendation on ESM of waste (OECD 2007).

## 3. Life cycle management of mercury

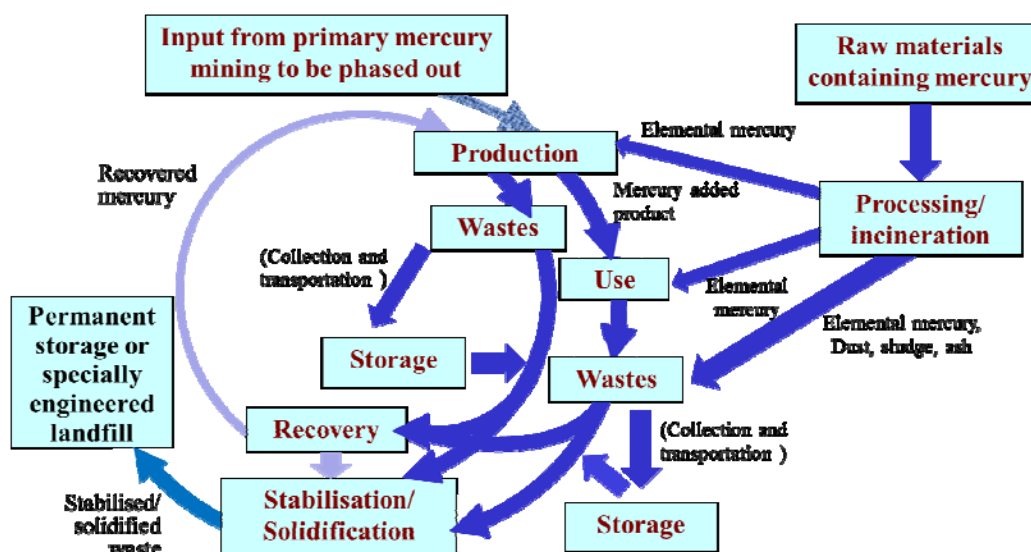
40. The concept of life cycle management can serve as a useful approach to promote the ESM of mercury wastes. Life cycle management provides a framework for analysing and managing the sustainability performance of goods and services. Global businesses are using it, for instance, to reduce the carbon, raw material and water footprints of their products, improve their social and economic performance, and make value chains more sustainable (UNEP and SETAC, 2009). When a life cycle management approach is applied to mercury, performance should be assessed during the following stages: production of mercury-added products or of other products using mercury; use of such products; collection and transportation of wastes; and disposal of wastes.

41. In life cycle management of mercury, it is important to give priority to reducing the use of mercury in products and industrial processes, thereby reducing the mercury content of wastes resulting from such products and processes. When using mercury-added products, special care should be taken not to emit or release mercury into the environment. Mercury-containing wastes should be

treated to either recover the mercury in them or to immobilize it in an environmentally sound manner. In those cases where mercury is recovered, the recovered mercury should be disposed of, after stabilization and/or solidification (S/S), at a permanent storage site or at a specially engineered landfill site. Alternatively, the recovered mercury may be used as an input in products for which mercury-free alternatives do not exist or are unavailable, or in cases in which it would take a long time to replace mercury-added products; such reuse could help to reduce the production of new mercury from primary mining. Mercury wastes may be stored pending further treatment or disposal or until export to other countries for disposal is possible (see figure 1 below).

**Figure 1:** Basic concept of mercury management

“Prevent and minimize mercury release to the environment at each stage”



42. Waste management covers source separation, collection, transportation, storage and disposal (e.g., recovery, solidification, stabilization, permanent storage and disposal in a specially engineered landfill). When a Government plans to collect mercury wastes, it also needs to plan for the subsequent waste management step, such as storage and disposal.

## B. Legislative and regulatory framework

43. Parties to the Basel Convention should examine their national controls, standards and procedures to ensure that they are in agreement with their obligations under the Convention, including those pertaining to the transboundary movement and ESM of mercury wastes; if they are also parties to the Minamata Convention they should further examine such controls, standards and procedures to ensure that they are in agreement with their waste-related obligations under that Convention.

44. Implementing legislation should give Governments the power to enact and enforce specific rules and regulations, conduct inspections and establish penalties for violations. Legislation on hazardous wastes should define hazardous wastes in accordance with the Basel Convention and include mercury wastes in the definition of hazardous wastes. The legislation could define ESM and require adherence to ESM principles, thus ensuring that countries comply with the provisions on ESM of mercury wastes. The specific components and features of a regulatory framework that would meet the requirements of the Basel Convention and other international agreements are discussed below.<sup>11</sup>

### 1. Registration of waste generators

45. One approach to facilitate ESM of mercury waste involves the establishment, through regulation, of registers of generators of this type of waste. Such registers should include large-scale

<sup>11</sup> Further guidance on Basel Convention regulatory frameworks can be found in the following documents: Model National Legislation on the Management of Hazardous Wastes and Other Wastes as well as on the Control of Transboundary Movements of Hazardous Wastes and Other Wastes and their Disposal (UNEP 1995), Manual for Implementation of the Basel Convention (UNEP, 2015) and Basel Convention: Guide to the Control System (UNEP, 2015b).



mercury waste generators such as power plants, industrial establishments (e.g., chlor-alkali plants using mercury cell technology, VCM production facilities using a mercury catalyst or smelting operations), as well as hospitals, medical and dental clinics, research institutes, mercury waste collectors, etc. A register of mercury waste generators would make it possible to determine the origins, types and volumes of various kinds of mercury waste, as well as the quantities of mercury-added products being used by various waste generators.

46. Regulations on registries of generators of mercury wastes could require waste generators to provide their name, address, the name of the responsible person, their type of business, the amounts and kinds of mercury waste generated, and information on collection schemes applicable to such wastes and how the wastes are to be handed over to collectors and disposed of. Waste generators could be required to transmit and provide regular updates on this information to the authorities (central or local governments). Based on the amounts and kinds of waste obtained through registries, parties could also develop waste inventory programmes.

47. Mercury waste generators should have a duty to prevent mercury emissions and releases to the environment until the wastes are handed over to collectors or sent to a disposal facility. They should strictly comply with national and local legal requirements regarding the management of mercury wastes and be held liable for remediating or compensating any environmental or health damages that they might cause when handling such wastes, to the degree required by applicable legislation.

## 2. Reduction and phase-out of mercury in products and industrial processes

48. The reduction and phase-out of mercury use in products and industrial processes is one of the most effective ways of reducing emissions and releases of mercury to the environment.

49. Minamata Convention parties should develop and enforce a legislative or regulatory framework for a reduction and phase-out programme and measures according to the provisions of the Minamata Convention (see paragraphs 22-24 above). One approach for a phase-out programme involves the establishment, through legislation or regulations, of a cut-off date by which the manufacture, export and import of products containing mercury or mercury compounds and the use of mercury or mercury compounds in processes, except for those for which there are no technically or practically viable alternatives or for which exemptions apply, would no longer be allowed. This approach would require that producers, importers and exporters of mercury and mercury-added products to comply with the requirement to embark on a mercury phase-out programme.

50. Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, known as the “RoHS Directive”, is an example of a regulation phasing out the use of mercury in certain products. The RoHS Directive restricts the use of mercury and other substances in electrical and electronic equipment and, while exemptions may be granted in cases where no satisfactory alternatives are available (e.g., some types of mercury-added lamps), most mercury-containing electrical and electronic equipment has been phased out in the European Union market since the Directive entered into force on 1 July 2006. A revised version of the RoHS Directive, known as the “RoHS 2 Directive”, was adopted in May 2011 and entered into force on 21 July 2011.

51. Another example from the European Union is Directive 2006/66/EC of the European Parliament and of the Council on batteries and accumulators and waste batteries and accumulators, which prohibits the placing on the market of all batteries, whether or not incorporated into appliances, that contain more than 0.0005 per cent of mercury by weight. Button cells with a mercury content of no more than 2 per cent by weight were exempt from this prohibition until 1 October 2015, while batteries and accumulators lawfully placed on the market prior to the date of application of the prohibitions set out in Article 4 of the Directive may continue to be marketed until stocks run out (European Union, 2006).

52. Norway’s imposes a general ban on the use of mercury in products to ensure that mercury is not used in products where alternatives exist.<sup>12</sup> The regulation prohibits the manufacture, import,

<sup>12</sup> Norwegian Product Regulations (Section 2.3 on mercury and mercury compounds in Chapter 2 on regulated substances, preparations and products), unofficial English translation, available from: <http://www.miljodirektoratet.no/en/Legislation1/Regulations/Product-Regulations/Chapter-2/> Special exemptions apply:

- Limited use (concentration limits specified) in packaging, batteries, some components in vehicles and in some electrical and electronic equipment according to the European Union Regulations implemented in Norway.
- Substances/preparations and solid processed products where the content of mercury or mercury compounds is lower than 0.001 per cent by weight.
- Thimerosal as a preservative in vaccines.

export, sale and use of substances or preparations that contain mercury or mercury compounds, and the manufacture, import, export and sale of solid processed mercury-added products or mercury compounds. The regulation therefore is expected to reduce the number of mercury-added products on the market, in addition to discharges from products that have inadvertently failed to be disposed of as hazardous waste.

53. Canada's *Products Containing Mercury Regulations* prohibit the manufacture and import of products containing mercury or any of its compounds, with some exemptions for essential uses for which there are no technically or economically viable alternatives (e.g., certain medical and research applications and dental amalgam).

### 3. Transboundary movement requirements

54. Under the Basel Convention, mercury wastes are listed in Annex I, under category Y29 (wastes having mercury or mercury compound as constituents), and are thus considered hazardous waste unless, through national tests, they can be shown not to exhibit any of the characteristics listed in Annex III (List of hazardous characteristics).

55. If a party to the Convention has national legislation banning the import of mercury wastes, and has reported the information in accordance with Article 4, paragraph 1 (a), other parties shall prohibit or shall not permit the export of such wastes to that party. In addition, in cases where the State of import has not prohibited the import of mercury wastes, parties to the Convention shall prohibit or shall not permit the export of such wastes if the State of import does not consent in writing to the specific import.

56. The Minamata Convention also includes a provision on transboundary movements of mercury waste in Article 11, paragraph 3 (c) (see paragraph 19 above).

57. Transboundary movements of hazardous wastes and other wastes must be kept to a minimum consistent with their environmentally sound and efficient management and conducted in a manner that protects human health and the environment from any adverse effects that may result from such movements. Transboundary movements of these wastes are permitted only under the following conditions:

(a) If the country of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner;

(b) If the wastes in question are required as a raw material for recycling or recovery industries in the country of import; or

(c) If the transboundary movements in question are in accordance with other criteria decided by the parties.

58. Any transboundary movements of hazardous and other wastes are to be notified in writing to the competent authorities of all countries concerned by the movement (country of export, country of import and, if applicable, country of transit). This notification is to contain the declarations and information requested in the Convention and shall be written in a language acceptable by the State of import. Prior written consent from the importing and the exporting country and, if appropriate, from transit countries, in addition to a confirmation of the existence of a contract specifying ESM of the wastes between the exporter and the owner of the disposal facility are required before any transboundary movements of hazardous and other wastes can take place. Parties are to prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes. The Convention also requires that information regarding any consignment be accompanied by a movement document from the point where the transboundary movement commences to the point of disposal. Some countries have implemented national prohibitions following decision III/1 of the Conference of the Parties, which contains an amendment to the Convention that has not yet entered into force and bans the export of hazardous wastes from the countries listed in Annex VII (OECD and EU countries and Liechtenstein) to non-Annex VII countries.

59. Hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards.<sup>13</sup>

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The Regulations do not apply to the use of products for analysis and research purposes. However, the prohibition applies to mercury thermometers to be used for analysis and research purposes.

<sup>13</sup> See, e.g., *United Nations Recommendations on the Transport of Dangerous Goods – Model Regulations* (18th revised edition) (United Nations, 2013).

60. When a transboundary movement of hazardous or other wastes to which the consent of the countries concerned has been given cannot be completed in accordance with the terms of the contract, the country of export must ensure that the wastes in question are taken back into the country of export by the exporter if alternative arrangements cannot be made for their disposal in an environmentally sound manner. This is to be done within 90 days of the importing country's notification to the country of export and the secretariat, or within another period of time on which the countries involved agree (Article 8). In the case of illegal traffic (as defined in Article 9, paragraph 1), the country of export shall ensure that the wastes in question are returned to the country of export for disposal or are disposed of in accordance with the provisions of the Convention.

61. When required by the country of import or any transit country that is a party to the Convention, transboundary movements of hazardous or other wastes are to be covered by insurance, bonds or other guarantees.

62. No transboundary movements of hazardous wastes or other wastes are permitted between a party and a non-party to the Convention unless a bilateral, multilateral or regional arrangement exists, as required under Article 11 of the Convention. Existing bilateral and multilateral agreements that have been notified to the Secretariat are listed on the Basel Convention webpage.<sup>14</sup>

63. It is worth noting that the export from the European Union of metallic mercury and certain mercury compounds and mixtures has been banned since 15 March 2011, through Regulation (EC) No 1102/2008 (European Commission, 2010b). Similarly, through the Mercury Export Ban Act of 2008, the United States of America severely restricts the export of mercury since January 2013.

#### **4. Authorization and inspection of disposal facilities**

64. Mercury wastes should be disposed of in facilities that practise ESM.

65. Most countries have legislation or sector-specific regulations that require waste disposal facilities to obtain approvals or operating permits to commence their operations. Approvals or operating permits may include specific conditions (e.g., facility design and operating conditions) that must be maintained in order for the approval or permit to remain valid. It may be necessary to add requirements specific to mercury waste to meet the requirements of ESM, to comply with specific requirements of the Basel Convention and to take into account recommendations and guidelines on best available techniques (BAT), such as guidelines on BAT and provisional guidance on best environmental practices produced under the Stockholm Convention, reference documents on BAT produced by the European Union (known as "BREFs"), and guidelines for the chlor-alkali sector produced by the World Chlorine Council and Eurochlor.<sup>15</sup> Approvals or operating permits should be reviewed periodically and if necessary should be updated in order to improve occupational and environmental safety through the use of improved or new technologies.

66. Disposal facilities should be periodically inspected by independent authorities or technical inspection associations in order to verify their compliance with the requirements set out in their permits. Legislation should enable authorities to conduct extraordinary inspections if there is evidence of non-compliance with permit requirements by disposal facilities.

### **C. Identification and inventory**

67. To enable effective action to prevent, minimize and manage mercury wastes it is important that parties identify the sources of mercury waste generation and quantify the amount of mercury wastes generated and the mercury concentrations in such wastes.

#### **1. Identification of sources of mercury wastes**

68. While the sources of mercury waste generation vary across countries, globally the major sources of mercury waste include industrial processes using mercury or mercury compounds and mercury devices that have become waste. Another major source of mercury releases is the processing or use of natural resources (e.g., non-ferrous metals ore processing and coal combustion). Figure 2 shows estimated global mercury use by application in 2007. The largest use sector was artisanal and

<sup>14</sup> For bilateral agreements, see:

<http://www.basel.int/Countries/Agreements/BilateralAgreements/tabid/1517/Default.aspx>;

for multilateral agreements, see:

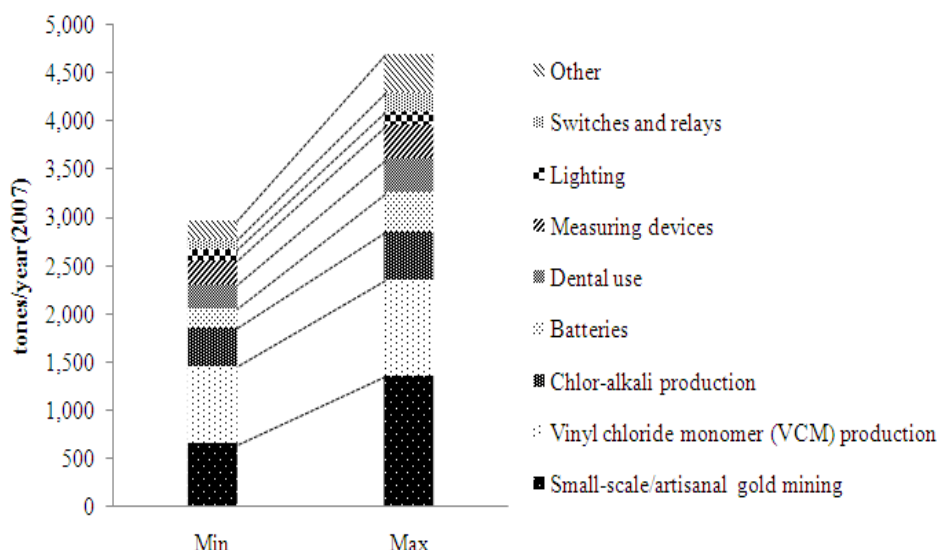
<http://www.basel.int/Countries/Agreements/MultilateralAgreements/tabid/1518/Default.aspx>

<sup>15</sup> See compilation at:

<http://www.unep.org/chemicalsandwaste/Mercury/PrioritiesforAction/ChloralkaliSector/Reports/tabid/4495/language/en-US/Default.aspx>.

small-scale gold mining, followed by vinyl chloride monomer VCM/polyvinyl chloride (PVC) production and chlor-alkali production. Mercury is also used in products such as batteries, dental amalgams, measuring devices, lamps, and electrical and electronic devices, although the amounts of mercury used in these categories varies between countries. The total amount of mercury used globally in 2007 was between 3,000 tonnes and 4,700 tonnes (Maxson, 2010).

**Figure 2:** Estimated global mercury uses in 2007 (Maxson, 2010)



69. The sources, categories and examples of mercury wastes are summarized in table 3 below.

70. It should be noted that in some countries some of the industrial sources presented in table 3 (sources 1, 2, 3, 4 and 7, except for production processes using mercury) neither used mercury nor generated mercury wastes. Industrial processes depend on a country’s technological and social conditions, and these will determine whether mercury-free processes are used.

**Table 3:** Sources, categories and examples of mercury wastes (UNEP 2002; 2005; 2006b; 2006c).

Source	Cate-gories*	Examples of waste types	Remarks
<b>1. Extraction and use of fuels/energy sources</b>			
1.1. Coal combustion in power plants	C	Flue gas cleaning residues (fly ash, particulate matter, wastewater / sludge, etc.)	• Accumulation in bottom ashes and flue gas cleaning residues.
1.2. Other coal combustion	C		
1.3. Extraction, refining and use of mineral oil	C		
1.4. Extraction, refining and use of natural gas	C		
1.5. Extraction and use of other fossil fuels	C		
1.6. Biomass fired power and heat generation	C		
<b>2. Primary (virgin) metal production</b>			
2.1. Primary extraction and processing of mercury	C	Smelting residue	• Pyrometallurgy of mercury ore
2.2. Metal (aluminium, copper, gold, lead, manganese,	C	Tailings, extraction process residues, flue gas cleaning residues, wastewater treatment residues	• Industrial processing; • Thermal treatment of ore; and • Amalgamation.

mercury, zinc,  
primary ferrous  
metal, other non-  
ferrous metals)  
extraction and  
initial processing

### 3. Production processes with mercury impurities

3.1.	Cement production	C	Process residues, flue gas cleaning residues, sludge	<ul style="list-style-type: none"> <li>Pyroprocessing of raw materials and fuels with naturally occurring mercury impurities</li> </ul>
3.2.	Pulp and paper production			<ul style="list-style-type: none"> <li>Combustion of raw materials with naturally occurring mercury impurities</li> </ul>
3.3.	Lime production and lightweight aggregate kilns			<ul style="list-style-type: none"> <li>Calcination of raw materials and fuels with naturally occurring mercury impurities</li> </ul>

### 4. Intentional use of mercury in industrial production

4.1.	Chlor-alkali production with mercury-technology	A/C	Solid waste contaminated with mercury, waste electrodes, process residues, soil	<ul style="list-style-type: none"> <li>Mercury cell;</li> <li>Mercury recovery units (retort).</li> </ul>
4.2.	Production of alcoholates (e.g. sodium or potassium methylate or ethylate), dithionite and ultrapure potassium hydroxide solution	A/C	Solid waste contaminated with mercury, waste electrodes, process residues, soil	<ul style="list-style-type: none"> <li>Mercury cell;</li> <li>Mercury recovery units (retort).</li> </ul>
4.3.	VCM production with mercuric chloride (HgCl <sub>2</sub> ) catalyst	A/C	Process residues, waste catalyst	<ul style="list-style-type: none"> <li>Mercury catalyst process</li> </ul>
4.4.	Acetaldehyde production with mercury sulphate (HgSO <sub>4</sub> ) catalyst	A/C	Wastewater, waste catalysts	<ul style="list-style-type: none"> <li>Mercury catalyst process</li> </ul>
4.5.	Other production of chemicals and pharmaceuticals with mercury compounds and/or catalysts	A/C	Process residues, wastewater, waste catalysts	<ul style="list-style-type: none"> <li>Mercury catalyst process</li> </ul>
4.6.	Production of products referred to in 5. below	C	Process residues, wastewater	

### 5. Products and applications with intentional use of mercury

5.1.	Thermometers and other measuring devices with mercury	B1	Used, obsolete or broken products	<ul style="list-style-type: none"> <li>Mercury</li> </ul>
5.2.	Electrical and electronic switches, contacts and relays with			

5.3.	mercury Light sources with mercury	B1		<ul style="list-style-type: none"> <li>• Vapour-phase mercury;</li> <li>• Divalent mercury adsorbed on phosphor powder.</li> </ul>
5.4.	Batteries containing mercury	B2		<ul style="list-style-type: none"> <li>• Mercury, mercury oxide</li> </ul>
5.5.	Biocides and pesticides	B1	Stockpiles of obsolete pesticides, soil and solid waste contaminated with mercury	<ul style="list-style-type: none"> <li>• Mercury compounds (mainly ethylmercury chloride)</li> </ul>
5.6.	Paints	B1	Stockpiles of obsolete paints, solid waste contaminated with mercury, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Phenylmercuric acetate and similar mercury compounds</li> </ul>
5.7.	Pharmaceuticals for human and veterinary uses	B1	Stockpiles of obsolete pharmaceuticals, medical waste	<ul style="list-style-type: none"> <li>• Thimerosal;</li> <li>• Mercuric chloride;</li> <li>• Phenyl mercuric nitrate;</li> <li>• Mercurochrome, etc.</li> </ul>
5.8.	Cosmetics and related products	B2	Stockpiles of cosmetics and related products	<ul style="list-style-type: none"> <li>• Mercury iodide;</li> <li>• Ammoniated mercury, etc.</li> </ul>
5.9.	Dental amalgam fillings	B2/C	Stockpiles of dental amalgam, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Alloys of mercury, silver, copper and tin</li> </ul>
5.10.	Manometers and gauges	B1	Used, obsolete or broken products	<ul style="list-style-type: none"> <li>• Mercury</li> </ul>
5.11.	Laboratory chemicals and equipment	A/B1/B2/C	Stockpiles of laboratory chemicals and equipment, wastewater treatment residues, laboratory wastes	<ul style="list-style-type: none"> <li>• Mercury;</li> <li>• Mercury chloride, etc.</li> </ul>
5.12.	Polyurethane elastomers	B2/C	Defective and excess product waste, used or end-of-life products	<ul style="list-style-type: none"> <li>• Elastomer waste containing mercury compounds</li> </ul>
5.13.	Sponge gold/gold production from ASGM sources	C	Flue gas residues, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Thermal treatment of gold;</li> <li>• Industrial processing.</li> </ul>
5.14.	Mercury metal use in religious rituals and folklore medicine	A/C	Solid waste, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Mercury</li> </ul>
5.15.	Miscellaneous product uses, mercury metal uses and other sources	B1/B2/C	Stockpiles, wastewater treatment residues, solid wastes	<ul style="list-style-type: none"> <li>• Infra-red detection semiconductors with mercury;</li> <li>• Bougie and Cantor tubes;</li> <li>• Educational uses, etc.</li> </ul>

## 6. Secondary metal production

6.1.	Recovery of mercury	A/C	Spillage during recycling processes, extraction process residues, flue gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Dismantling of chlor-alkali facilities;</li> <li>• Recovery from mercury meters used in natural gas pipelines;</li> <li>• Recovery from manometers, thermometers, and other equipment.</li> </ul>
6.2.	Recovery of ferrous metals	C		<ul style="list-style-type: none"> <li>• Shredding;</li> <li>• Smelting of materials containing mercury.</li> </ul>
6.3.	Recovery of gold	A/C		<ul style="list-style-type: none"> <li>• Mercury;</li> </ul>

	from e-waste (printed circuit boards)			<ul style="list-style-type: none"> <li>• Thermal process.</li> </ul>
6.4.	Recovery of other metals, such as copper and aluminium	C		<ul style="list-style-type: none"> <li>• Other mercury-added materials or products /components</li> </ul>
<b>7. Waste incineration</b>				
7.1.	Incineration of municipal solid waste	C	Flue gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Mercury-added products and process waste;</li> </ul>
7.2.	Incineration of hazardous waste			<ul style="list-style-type: none"> <li>• Natural mercury impurities in high volume materials (plastics, paper, etc.) and minerals.</li> </ul>
7.3.	Incineration of medical waste			
7.4.	Sewage sludge incineration			
<b>8. Waste deposition/landfilling and wastewater treatment</b>				
8.1.	Controlled landfills/deposits	C	Wastewater, wastewater treatment residues, solid waste contaminated with mercury	<ul style="list-style-type: none"> <li>• Mercury-added products and process waste;</li> </ul>
8.2.	Diffuse deposition under some control			<ul style="list-style-type: none"> <li>• Natural mercury impurities in bulk materials (plastics, tin cans, etc.) and minerals.</li> </ul>
8.3.	Uncontrolled local disposal of industrial production waste			
8.4.	Uncontrolled dumping of general waste			
8.5.	Wastewater system/treatment		Wastewater treatment residues, slurries	<ul style="list-style-type: none"> <li>• Intentionally used mercury in spent products and process waste;</li> <li>• Mercury as an anthropogenic trace pollutant in bulk materials.</li> </ul>
<b>9. Crematoria and cemeteries</b>				
9.1.	Crematoria	C	Flue gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> <li>• Dental amalgam fillings</li> </ul>
9.2.	Cemeteries		Soil contaminated with mercury	

\*A: Waste consisting of mercury or mercury compounds; B: Wastes containing mercury or mercury compounds; C: Wastes contaminated with mercury or mercury compounds.

71. More detailed information on mercury-added products (e.g., names and manufacturers of specific products) is available from the following sources:

(a) UNEP, 2008. *Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury-free products and processes*. Available at: [http://www.chem.unep.ch/mercury/OEWG2/documents/g7/English/OEWG\\_2\\_7.doc](http://www.chem.unep.ch/mercury/OEWG2/documents/g7/English/OEWG_2_7.doc);

(b) European Commission, 2008. *Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society*. Available at: [http://ec.europa.eu/environment/chemicals/mercury/pdf/study\\_report2008.pdf](http://ec.europa.eu/environment/chemicals/mercury/pdf/study_report2008.pdf);

(c) UNEP Global Mercury Partnership – Mercury-Containing Products Partnership Area. Reports and publications available from: <http://www.unep.org/chemicalsandwaste/Mercury/InterimActivities/Partnerships/Products/tabid/3565/language/en-US/Default.aspx>;

(d) Lowell Center for Sustainable Production, 2003. "An Investigation of Alternatives to Mercury-Containing Products". Available at: <http://www.chem.unep.ch/mercury/Sector-Specific-Information/Docs/lcspfina.pdf>; and

(e) The Interstate Mercury Education and Reduction Clearinghouse (IMERC). Mercury-Added Products Database. Available at: <http://www.newmoa.org/prevention/mercury/imerc/notification>.

## 2. Inventories

72. Inventories are an important tool for identifying, quantifying and characterizing wastes. National inventories may be used:

- (a) To establish a baseline for quantities of mercury-added products produced, circulated, traded or in use, commodity mercury, mercury-containing by-products and mercury wastes;
- (b) To establish an information registry to assist with safety and regulatory inspections;
- (c) To obtain the accurate information needed to draw up plans for lifecycle management of mercury;
- (d) To assist with the preparation of emergency response plans; and
- (e) To track progress towards reducing and phasing out mercury.

73. After identifying the sources and types of mercury wastes, process-specific information and quantities should be used to estimate the amounts of waste from the identified sources for different types of waste in a given country (or area, community, etc.) (UNEP, 2005).

74. It is in some cases very difficult to collect the necessary data to estimate the quantities of mercury waste generated, particularly in developing countries and countries with economies in transition, due to a lack of data, particularly where small-scale facilities are concerned. In cases where actual measurements are not feasible, data collection could be carried out using questionnaire-based surveys.

75. The *Methodological guide for the undertaking of national inventories of hazardous wastes under the Basel Convention* (UNEP, 2015d) should be used when producing inventories of mercury wastes. A previous version of the methodological guide has been tried out, including in a pilot project on national inventories of hazardous waste developed by the Basel Convention Regional Centre for South-East Asia, whose final report can be used as a practical reference.<sup>16</sup>

76. The *Toolkit for Identification and Quantification of Mercury Releases* (UNEP, 2013) can also be applied. There are two versions of the toolkit, which correspond to two levels of inventory development (i.e., simplified and comprehensive). The toolkit is intended to help countries to develop national inventories of mercury releases and provides a standardized methodology and accompanying database enabling the development of consistent national and regional mercury inventories. The toolkit has been applied in a number of countries (UNEP, 2008c) and GEF-funded projects.

77. In keeping with a lifecycle management approach, channels or pathways through which mercury in wastes may be released into the environment should also be identified. In view of the potential risks of mercury releases into the environment, the various types of mercury waste should be ranked in order of priority for action. Information about possible measures to mitigate releases should then be collected, especially with regard to sources and types of mercury waste involving large quantities of mercury and presenting higher risk of mercury release into the environment. Measures must then be evaluated in terms of the magnitude of environmental mercury releases that they could help to prevent, their administrative and social costs, the availability of techniques and facilities associated with them, their social acceptability, etc.

78. In some countries, a Pollutant Release and Transfer Registry (PRTR) is used to collect data about specific mercury content in wastes and its transfer by each facility (Kuncova et al., 2007). PRTR data are publicly available.<sup>17</sup>

<sup>16</sup> See "National Inventories of Hazardous Waste Demonstration Project in Philippines" (December 2006). Available from: <http://www.brcr-sea.org/?content=publication&cat=2>.

<sup>17</sup> For example, the Czech Republic PRTR (available at <http://www.irz.cz>; in Czech only) collects specific data on mercury and mercury compounds transferred to environmental media from wastes, as well as data on how mercury wastes are handled.



## D. Sampling, analysis and monitoring

79. Sampling, analysis and monitoring are critical components of mercury waste management. Waste sampling, analysis and monitoring should be conducted by trained professionals in accordance with well-designed programmes using internationally accepted or nationally approved methods and should be carried out using the same methods throughout the lives of such programmes. They should also be subjected to rigorous quality assurance and quality control measures. Mistakes in sampling, analysis or monitoring or deviation from standard operational procedures can result in meaningless data or even programme-damaging data. Each party, as appropriate, should therefore develop standards to ensure that training, protocols and laboratory capabilities are in place for sampling, monitoring and analytical methods and that those standards are enforced.

80. Because there are numerous reasons for sampling, analysing and monitoring and because waste comes in so many different physical forms, many different sampling, analysis and monitoring methods are available. Although it is beyond the scope of this document to discuss them specifically, the next three sections consider key elements that should be included in sampling, analysis and monitoring activities. Waste testing priorities should be set based on existing knowledge (or lack thereof) of the mercury content of different types of waste (e.g., testing waste mercury lamps is unlikely to be a high priority, as significant information about their mercury content is readily available).

81. For information on good laboratory practices, the OECD series on good laboratory practice (OECD, various years) may be consulted; on general methodological considerations, the UNEP/WHO *Guidance for identifying populations at risk from mercury exposure* contains helpful information and may be used.<sup>18</sup> Further guidance on global monitoring of mercury is being developed through a UNEP GEF-funded project that is also expected to establish an online databank of operational mercury laboratories.<sup>19</sup>

### 1. Sampling

82. The overall objective of any sampling activity is to obtain a sample that can be used for a targeted purpose, e.g., site characterization, compliance with regulatory standards or determination of the suitability of proposed treatment or disposal methods. This objective should be identified before sampling is started. It is indispensable that quality requirements for equipment, transportation and traceability be met.

83. Standardized sampling procedures should be established and agreed upon before the start of the sampling campaign (both matrix- and mercury-specific). Elements of these procedures include the following:

- (a) The number of samples to be taken, the sampling frequency, the duration of the sampling project and a description of the sampling method to be used (including quality assurance procedures put in place, e.g., use of appropriate sampling containers<sup>20</sup> and field blanks and of chain-of-custody procedures);
- (b) Selection of locations or sites at which mercury wastes are generated and time and date of sample-taking (including description and geographic localization);
- (c) Identity of person who took the sample and conditions during sampling;
- (d) Full description of sample characteristics – labelling;
- (e) Preservation of the integrity of samples during transport and storage (before analysis);
- (f) Close cooperation between the sampler and the analytical laboratory; and
- (g) Appropriately trained sampling personnel.

84. Sampling should comply with specific national legislation, where it exists, or with international regulations and standards. In countries where regulations do not exist, qualified staff should be appointed. Sampling procedures include the following:

<sup>18</sup> Available at: [http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Documents/IdentifyingPopnatRiskExposuretoMercury\\_2008Web.pdf](http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Documents/IdentifyingPopnatRiskExposuretoMercury_2008Web.pdf).

<sup>19</sup> Development of a Plan for Global Monitoring of Human Exposure to and Environmental Concentrations of Mercury (GEF ID 5409).

<sup>20</sup> Polyethylene bottles are permeable to mercury and should not be used. For details, see Parker et al., 2005.

- (a) Development of a standard operational procedure (SOP) for sampling each of the matrices for subsequent mercury analysis;
- (b) Application of well-established sampling procedures such as those developed by the International Organization for Standardization (ISO), the European Committee for Standardization (CEN), the United States Environmental Protection Agency (EPA), the Global Environment Monitoring System (GEMS) and the American Society for Testing and Materials (ASTM); and
- (c) Establishment of quality assurance and quality control (QA/QC) procedures.

85. All these steps should be followed if sampling programmes are to be successful. Similarly, documentation should be thorough and rigorous.

86. Mercury can occur and be sampled in liquids, solids, gases and biota:

- (a) Liquids:
  - (i) Leachate from dumpsites and landfills;
  - (ii) Liquid collected from spills;
  - (iii) Water (surface water, drinking water and industrial effluents);
- (b) Solids:
  - (i) Stockpiles of products and formulations consisting of, containing or contaminated with mercury or mercury compounds;
  - (ii) Solids from industrial sources and treatment or disposal processes (fly ash, bottom ash, sludge, still bottoms, other residues, clothing, etc.);
  - (iii) Containers, equipment or other packaging materials (rinse or wipe samples), including the tissues or fabric used in the collection of wipe samples;
  - (iv) Soil, sediment, rubble, sewage sludge and compost;
- (c) Gases:
  - (i) Air (indoor) of facilities handling mercury wastes;
  - (ii) Mercury releases to the air from treatment of mercury wastes;
  - (iii) Flue gas from waste incinerators;
- (d) Biota:
  - (i) Biological materials (blood, urine and hair, especially those obtained through worker health monitoring);
  - (ii) Plants and animals.

87. In environmental and human monitoring programmes, both biotic and abiotic matrices may be included:

- (a) Plant materials and food;
- (b) Human hair, urine, nails, breast milk or blood;
- (c) Air (ambient, wet or dry deposition or, possibly, snow).

## 2. Analysis

88. Analysis refers to the extraction, purification, separation, identification, quantification and reporting of mercury concentrations in the matrix of interest. In order to obtain meaningful and acceptable results, the analytical laboratory should have the necessary infrastructure (housing) and proven experience with the matrix and the mercury species (e.g., successful participation in inter-laboratory comparison studies and in external proficiency testing schemes).

89. Accreditation of the laboratory in accordance with ISO 17025 or other standards by an independent body is important. Essential criteria for obtaining high-quality results include:

- (a) Specification of the analytical technique used;
- (b) Maintenance of analytical equipment;
- (c) Validation of all methods used (including in-house methods); and

(d) Training of laboratory staff.

90. Mercury analysis is typically performed in a dedicated laboratory. For screening purposes, test kits are available and can be used in the field.

91. For the analysis of mercury, there is no single analytical method available. Methods of analysing the various matrices for mercury, either for total mercury content or speciation of mercury, have been developed by the International Organization for Standardization (ISO), the European Committee for Standardization (CEN) at the international level, and by EPA and the Japan Standards Association at the national level. Table 4 lists some examples of methods for analysing mercury in wastes, flue gas and wastewater. Most in-house methods are variations of these. As with all chemical analysis, laboratories should use only validated methods and performance should be evaluated through QA/QC programmes.

92. In addition, procedures and acceptance criteria for storage, handling and preparation of the sample in the laboratory, e.g., homogenization, should be established.

93. The individual steps in the analytical determination include:

(a) Extraction;

(b) Purification;

(c) Identification by suitable detectors such as inductively coupled plasma (ICP), atomic fluorescence spectroscopy (AFS), amino acid analysers (AAS) and compact instruments;

(d) Quantification and reporting as required; and

(e) Reporting in accordance with regulation(s).

### 3. Monitoring

94. In Article 10 (“International Cooperation”), paragraph 2 (b), the Basel Convention requires parties to “cooperate in monitoring the effects of the management of hazardous wastes on human health and the environment”. Monitoring programmes should provide an indication of whether a hazardous waste management operation is functioning in accordance with its design, and should detect changes in environmental quality caused by the operation.

95. The information obtained through monitoring programmes should be used to ensure that different types of hazardous wastes are properly managed, to identify potential issues relating to possible mercury releases or exposure to mercury and to determine whether amendments to the management approach might be appropriate. By implementing a monitoring programme, facility managers can identify problems and take appropriate measures to remedy them.

96. It should be noted that a number of continuous mercury measurement systems are commercially available for some types of mercury monitoring. Such monitoring may be required under national or local legislation.

**Table 4:** Chemical analysis of mercury in waste, flue gas and wastewater

Target		Method
Waste	To determine the mobility of mercury in waste	EN 12457-1 to 4: Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges (CEN, 2002a)
		EN 12920: Characterization of waste - Methodology for the determination of the leaching behaviour of waste under specified conditions (CEN, 2006)
		EN 13656: Characterization of waste - Microwave assisted digestion with hydrofluoric (HF), nitric (HNO <sub>3</sub> ) and hydrochloric (HCl) acid mixture for subsequent determination of elements in waste (CEN, 2002b)
		EN 13657: Characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements in waste (CEN, 2002c)
		TS 14405: Characterization of waste - Leaching behaviour test - Up-flow percolation test (CEN, 2004)
		EPA Method 1311: TCLP, Toxicity Characteristic Leaching Procedure (EPA, 1992)

Target		Method
To determine concentrations of mercury in waste		EN 13370: Characterization of waste - Analysis of eluates - Determination of Ammonium, AOX, conductivity, Hg, phenol index, TOC, easy liberatable CN-, F- (CEN, 2003)
		EN 15309: Characterization of waste and soil - Determination of elemental composition by X-ray fluorescence (CEN, 2007)
		EPA Method 7471B: Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique) (EPA, 2007d)
		EPA Method 7473: Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry (EPA, 2007e)
		EPA Method 7470A: Mercury in Liquid Waste (Manual Cold-Vapor Technique) (EPA, 1994)
Flue Gas		EN 13211: Air quality - Stationary source emissions - Manual method of determination of the concentration of total mercury (CEN, 2001) *This method determines the total mercury content (i.e., metallic/elemental Hg + ionic Hg).
		EN 14884: Air quality - Stationary source emissions - Determination of total mercury: Automated measuring systems (CEN, 2005)
		JIS K 0222: Analysis Method for Mercury in Flue Gas (JSA, 1997)
		EPA Method 0060: Determination of Metals in Stack Emissions (EPA, 1996)
	For the speciation of mercury	ASTM D6784 - 02(2008) Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method) (ASTM International, 2008)
Wastewater		ISO 5666: 1999: Water quality – Determination of mercury (ISO, 1999)
		ISO 16590: 2000: Water quality – Determination of mercury - Methods involving enrichment by amalgamation (ISO, 2000)
		ISO 17852: 2006: Water quality – Determination of mercury - Method using atomic fluorescence spectrometry (ISO, 2006)

## E. Waste prevention and minimization

97. The prevention and minimization of mercury wastes are the first and most important steps in the ESM of such wastes. In Article 4, paragraph 2, the Basel Convention calls on parties to “ensure that the generation of hazardous wastes and other wastes ... is reduced to a minimum”. Waste prevention should be the preferred option in any waste management policy so that the need for waste management is reduced, enabling resources for ESM to be used more efficiently. Paragraphs 100 to 122 below provide information on ways to prevent and minimize mercury wastes from important sources of mercury wastes.

98. Article 5 of the Minamata Convention requires parties to phase out mercury use in chlor-alkali and acetaldehyde production processes and to restrict mercury use in vinyl chloride monomer production, sodium or potassium methylate or ethylate, and production of polyurethane using mercury-containing catalysts (for details, see paragraph 24 of the present guidelines).

### 1. Waste prevention and minimization for industrial processes

99. There are several industrial processes using mercury; however, because of the large quantity of mercury used in artisanal and small-scale gold mining, vinyl-chloride monomer production and chlorine and caustic soda (chlor-alkali) production, this subsection discusses waste prevention and minimization measures only with respect to those three processes.

#### (a) Artisanal and small-scale gold mining

100. Mercury-free techniques such as gravimetric methods and in combination with non-mercury methods are available. In cases where feasible alternatives are unavailable, interim solutions that lead towards mercury-free techniques should be used. Such solutions could include mercury capture and recycling technologies such as retorts and fume hoods, mercury re-activation, and avoidance of mercury-intensive processing such as whole-ore amalgamation. Details on these interim solutions can be found in the following reference materials:

(a) GMP, 2006. Manual for Training Artisanal and Small-Scale Gold Miners, UNIDO, Vienna, Austria. Available at: [http://communitymining.org/attachments/221\\_training%20manual%20for%20miners%20GMP%20Mancelo%20Veiga.pdf?phpMyAdmin=cde87b62947d46938306c1d6ab7a0420](http://communitymining.org/attachments/221_training%20manual%20for%20miners%20GMP%20Mancelo%20Veiga.pdf?phpMyAdmin=cde87b62947d46938306c1d6ab7a0420);

(b) MMSD Project. 2002. Artisanal and Small-Scale Mining, Documents on Mining and Sustainable Development from United Nations and Other Organizations;

(c) UNEP, 2010. *Global Forum on Artisanal and Small Scale Gold Mining* (meeting report). Available from: <http://www.unep.org/chemicalsandwaste/GlobalForumonASGM/tabid/6005/Default.aspx>;

(d) UNEP, various dates. Global Mercury Partnership reports and publications. Available from: <http://www.unep.org/chemicalsandwaste/Mercury/PrioritiesforAction/ArtisanalandSmallScaleGoldMining/Reports/tabid/4489/language/en-US/Default.aspx>;

(e) United States EPA. 2008. Manual for the Construction of a Mercury Collection System for Use in Gold Shops. Available at: <http://www.epa.gov/oia/toxics/asgm.html>.

101. Artisanal miners, their families and communities in the vicinity of mining operations should be educated about the risks of exposure to mercury and related health hazards and the environmental impacts of mercury use in ASGM.

102. Once awareness of the environmental and health risks of mercury use in ASGM has increased, training in techniques and systems to prevent waste generation should be provided.

**(b) Vinyl chloride monomer (VCM) production**

103. VCM production using the acetylene process involves the use of mercuric chloride as a catalyst. Methods to prevent and minimize mercury waste in VCM production fall into two primary categories: (a) alternative, mercury-free manufacturing methods; and (b) methods to better manage mercury during the production process and to capture mercury environmental releases.

104. In mercury-free VCM manufacturing, VCM is manufactured using a variety of mercury-free methods, most commonly based on the oxychlorination of ethylene (The Office of Technology Assessment, 1983). While mercury-free methods are common worldwide, in several countries the acetylene process continues to be used because it is significantly less expensive in locations where coal is cheaper than ethylene (Maxson, 2011). Efforts to develop a mercury-free catalyst for the acetylene process have resulted in the development (by Johnson Matthey) of a mercury-free catalyst for the manufacture of VCM that includes gold in its formulation and is ready for commercialisation. It is economically viable and can be used as a direct replacement for catalysts in existing VCM reactors.<sup>21</sup>

105. Suggested measures to reduce the generation of wastes contaminated with mercury include better management of mercury and use of environmental controls to capture mercury releases; development and application of low-mercury catalysts; implementation of technological reforms to prevent mercuric chloride evaporation; prevention of catalyst poisoning; and delaying carbon deposition to reduce the use of mercury. Environmental control measures to capture mercury releases include the adsorption of mercury through the use of activated carbon in mercury removers and the use of deacidification systems such as foaming and washing towers; the recycling and reuse of mercury-containing effluents; the collection of mercury-containing sludge; and recovery of mercury from evaporated substances containing mercury; improved emission controls at catalyst recyclers and producers. For further information, the “Project Report on the Reduction of Mercury Use and Emission in Carbide PVC Production” (Ministry of Environmental Protection of China, 2010) should be consulted.

**(c) Chlor-alkali production**

106. As the mercury cell process is replaced by mercury-free processes in chlor-alkali facilities, mercury emissions and waste generation are eliminated at these facilities. Mercury-free chlor-alkali production employs either diaphragm or membrane processes. Membrane processes are more cost effective than diaphragm processes because they require less electricity (Maxson, 2011). Although the mercury cell process is being phased out, as of 2012 there were still 75 plants using the process in 40 countries. Solid waste from these chlor-alkali plants amounted to 163,465 tonnes in 2012 (UNEP Global Mercury Partnership, 2013). In 2010, mercury cell chlor-alkali installations represented about

<sup>21</sup> See [http://www.matthey.com/innovation/innovation\\_in\\_action/vcm-catalyst](http://www.matthey.com/innovation/innovation_in_action/vcm-catalyst).

10 per cent of global chlor-alkali production capacity. In Japan, the mercury cell process was no longer in use by 1986. At the beginning of 2013, 28 per cent of European chlorine production capacity was based on mercury cell technology. European chlorine manufacturers have voluntarily committed to replacing or closing down all chlor-alkali mercury cell plants by 2020 (Euro Chlor). In the United States, the use of the mercury cell process declined from 14 facilities in 1996 to two facilities in 2012 (Chlorine Institute, 2009; UNEP Global Mercury Partnership, 2013).

107. Waste contaminated with mercury generated from chlor-alkali plants may include semi-solid sludges from water, brine and caustic treatment, graphite and activated carbon from gas treatment, residues from retorting, and mercury collected in tanks or sumps. In addition to monitoring of possible leakages and good housekeeping, mercury waste generation can be reduced through reduction of mercury evaporation, better control of mercury emissions, recovery of mercury from wastewater and from flue gas and caustic treatment. For further information, the following documents or website should be consulted:

(a) European Commission, 2013. *Commission implementing decision of 9 December 2013 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, for the production of chlor-alkali (2013/732/EU)*.

(b) Global Mercury Partnership, Chlor-alkali sector reports and publications. Available from: <http://www.unep.org/chemicalsandwaste/Mercury/GlobalMercuryPartnership/ChloralkaliSector/Reports/tabid/4495/language/en-US/Default.aspx> (this link contains more than 20 guidelines for the chlor-alkali industry).

## 2. Waste prevention and minimization for mercury-added products

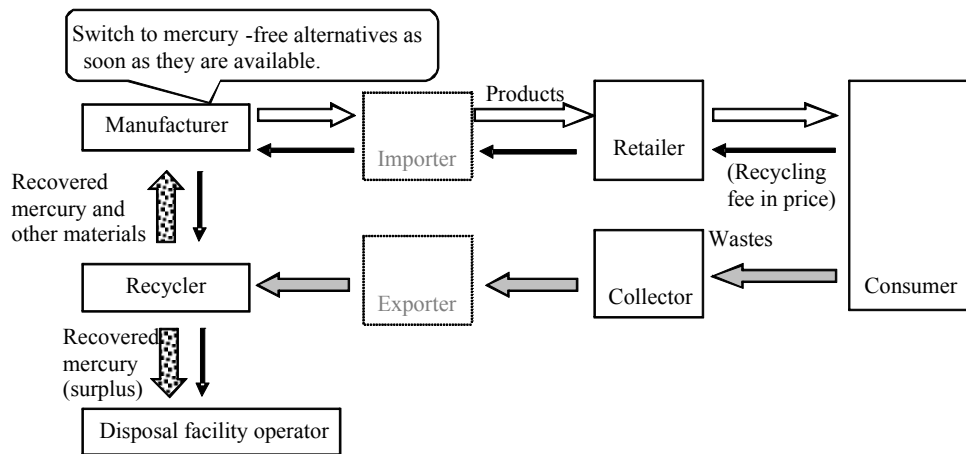
108. Introducing mercury-free alternatives and banning mercury-added products are important ways to prevent the generation of mercury wastes. Under the Minamata Convention, the manufacture, export and import of specific mercury-added products are prohibited starting in 2020 (see paragraph 22 above).

109. As a transitional measure, setting maximum limits of mercury content in products where mercury-free alternatives are not available in the foreseeable future would help to reduce the generation of mercury wastes from the mercury-added products sector. Replacement of such products with mercury-free or low-mercury alternatives can be facilitated through green purchasing.

110. Where mercury-added products are still in use, the establishment of a safe closed system for utilization of mercury is desirable. Mercury contamination of waste streams should be prevented through:

- (a) The use of mercury-free products;
- (b) Setting maximum limits of mercury content in products; and
- (c) Setting procurement standards to purchase mercury-free and low-mercury products.

111. Waste containing mercury should be separated from other wastes and collected and, when feasible, mercury should be recovered from the waste and re-used instead of primary mercury in production processes, or disposed of in an environmentally sound manner (see figure 3). Extended producer responsibility (EPR) schemes can be effective instruments to encourage the production of mercury-free or low-mercury products and the collection of such products after they have become waste. Other approaches could include paying a rebate for the collection of spent mercury-added products.

**Figure 3: Closed System for Utilization of Mercury**


**(a) Mercury-free products**

112. The substitution of mercury in products depends on factors such as efficacy or performance of substitutes, substitute and overall product costs, the environmental and human health impacts of substitutes, technology, government policies and economies of scale. Many kinds of mercury-free alternatives are now available. Detailed information about mercury-free alternatives is available in the following publications:

(a) *List of alternatives to mercury-added products* (UNEP, 2014b);

(b) *Replacement of mercury thermometers and sphygmomanometers in health care: Technical guidance* (WHO, 2010);

(c) *Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury-free products and processes* (UNEP, 2008b); and

(d) *Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society* (European Commission, 2008).

**(b) Setting maximum limits of mercury content in products**

113. Mercury content limits should be established for mercury-added products until such time as those products can be phased out. Such limits can result in less mercury being used per product in the production stage, which in turn could result in less mercury being emitted throughout the entire product lifecycle, including from accidental release or breakage, and reduce the total amount of mercury in wastes requiring mercury-specific management. The Minamata Convention sets mercury content limits for certain products that parties to the convention must follow (see paragraph 22 above).

114. Mercury content limits for products can be set through legislation (see examples in section III, B, 2 below) or through voluntary industry action under public environmental/mercury management plans. As stated previously, legal requirements for mercury content limits for batteries and fluorescent lamps have been established in the European Union, and several states of the United States have adopted mercury content limits for batteries. In Japan, mercury content limits for fluorescent lamps have been set by an industry association and the national government has used those limits as a criterion to select fluorescent lamps under green purchasing policies. In Canada, the *Products Containing Mercury Regulations* set limits on the amount of mercury that fluorescent and other types of lamps can contain.

115. In order to reduce the amount of mercury in fluorescent lamps, manufacturers have developed various technologies for injecting specific amounts of mercury into individual lamps that correspond to the minimum amounts of mercury required for adequate lamp performance. Examples of methods for injecting precise amounts of mercury in lamps include using mercury amalgam, a mercury alloy pellet, a mercury alloy ring, and a mercury capsule instead of injecting mercury (Ministry of the Environment of Japan, 2010).

116. The use of mercury amalgam dosing may have environmental and performance advantages over the use of mercury throughout the life cycle of compact fluorescent lamps (CFLs) and other types of mercury-added lamps. The strength of accurate mercury dosing methods is that they minimize worker and consumer exposure to, as well as environmental releases of, mercury vapour

during manufacturing, transportation, installation, storage and recycling and disposal, particularly when lamps break. In addition, accurate mercury dosing methods enable manufacturers to produce CFLs that contain very low mercury levels (two milligrams or less) while meeting important performance requirements such as high efficiency and long lamp life.

(c) **Procurement**

117. Procurement programmes for mercury-free products should be encouraged in order to pursue waste prevention and promote the use of mercury-free and low-mercury products. Purchasing practices should, where possible, be aimed at the purchase mercury-free products, except in the few cases where alternatives to mercury-added products are practically or technologically unavailable, or at the purchase of products whose mercury content is minimized.

118. Larger users of mercury-added products, such as government institutions and healthcare facilities, can play an important role in stimulating demand for mercury-free products by implementing green procurement programmes. In some cases, financial incentives could be used to encourage green procurement programmes. Some states in the United States, for instance, have subsidized the purchase of mercury-free thermometers.

**3. Extended producer responsibility**

119. Extended producer responsibility (EPR) is defined as “an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle”. “Producer”<sup>22</sup> is considered to be the brand owner or importer except in cases such as packaging, and in situations where the brand owner is not clearly identified, as in the case of electronics, in which the manufacturer (and importer) would be considered as the producer (OECD, 2001a). EPR programmes shift the responsibility for the end-of-life management of products from local government authorities and taxpayers to producers, and can create incentives for producers to incorporate environmental considerations into the design of their products and ensure that the cost of environmentally sound treatment and disposal of those products once they have become waste are reflected in product prices. EPR can be implemented through mandatory or voluntary approaches, or a combination of the two (e.g., via negotiated agreements). Take-back collection programmes can be incorporated into EPR programmes (see paragraph 147 below).

120. EPR programmes, depending on how they are designed, can achieve a number of objectives, including: (1) to relieve local governments of the financial and in some cases operational burden of disposing of waste/products/materials; (2) to encourage companies to design products for reuse and recyclability and to reduce both the quantity and hazardousness of materials used; (3) to incorporate waste management costs into product prices; and (4) to promote innovation in recycling technology. EPR therefore promotes a market in which prices reflect the environmental costs of products (OECD 2001a). Detailed descriptions of EPR schemes are available in several OECD publications on the issue.<sup>23</sup>

121. When EPR programmes are used, the environmental authorities should develop regulatory frameworks setting out the responsibilities of relevant stakeholders, standards for the management of products and the components that all EPR programmes should have, and encourage participation by relevant parties and the public. The environmental authorities should also monitor the performance of EPR programmes (e.g., amount of wastes collected, amount of mercury recovered and costs accrued for collection, recycling and storage) and make recommendations for improvement as necessary. The responsibility to implement EPR programmes should be shared by all producers of a given product and there should be no “free riders” (i.e., producers who do not have to implement EPR) in such programmes so as to avoid a situation in which certain producers are forced to bear a disproportionate share of the costs of EPR that goes beyond their product market share.

122. In the European Union, for example, fluorescent lamps, including CFLs, are one of the products subject to the requirements of the *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE)*. The directive requires extended producer responsibility for end-of-life management of electrical and electronic equipment that contain, *inter alia*, mercury. Other examples of EPR programmes are a European

<sup>22</sup> European Union Directive 2008/98/EC provides that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products has extended producer responsibility.

<sup>23</sup> Available from: <http://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm>.



Union programme for batteries and a programme on EPR for fluorescent lamps and batteries in the Republic of Korea.<sup>24</sup>

## F. Handling, separation, collection, packaging, labelling, transportation and storage

123. The procedures for the handling, separation, collection, packaging, labelling, transportation and storage of mercury wastes pending their disposal are similar to those applicable to other kinds of hazardous waste. However, because the physical and chemical properties of mercury make it very mobile in the environment, the ESM of mercury waste requires the use of additional precautions and handling techniques.

124. Specific technical guidance on the most appropriate handling of mercury wastes is provided in this section, but it is imperative that generators also consult and adhere to applicable national and local requirements. For transport and the transboundary movement of hazardous wastes, the following documents should be consulted to determine specific requirements:

- (a) UNEP, 2015a. *Manual for the Implementation of the Basel Convention*;
- (b) International Maritime Organization, 2014. *International Maritime Dangerous Goods Code*;
- (c) International Civil Aviation Organization, 2013. *Technical Instructions for the Safe Transport of Dangerous Goods by Air*;
- (d) International Air Transport Association, 2014. *Dangerous Goods Regulations Manual*; and
- (e) United Nations, 2013. *United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations*.

125. Product-specific guidance for handling, separation, collection, packaging, labelling, transportation and storage of mercury wastes is available in the following reference materials:

- (a) UNDP, 2010. *Medical devices: Guidance on the Clean-up, Temporary or Intermediate Storage, and Transport of Mercury Waste from Health Care Facilities*;
- (b) WHO, 2010. *Future Use of Materials for Dental Restoration* (Chapter 6, Best management practices (BMP) for amalgam waste); and
- (c) The Lamp Recycling Outreach Project, undated. *Training Module (1-hour version) for Generators and Handlers of Fluorescent and Mercury-Containing Lamps (and Ballasts)*.

126. Relevant information regarding the hazardous characteristics and risks of mercury wastes should be collected and analysed in order to plan the proper handling of such wastes, for example by consulting and following the instructions given on the chemicals they contain and related safety data sheets. For labelling and packaging, the United Nations Globally Harmonized System of the Classification and Labelling of Chemicals (GHS) should be taken into account, as appropriate.

### 1. Handling

127. Those who handle mercury waste should pay particular attention to the prevention of evaporation and spillage of mercury into the environment. Mercury waste should be placed in a gas- and liquid-tight containers that bear a distinctive mark indicating that they contain “toxic” mercury. The most appropriate containers to store mercury waste are especially designed steel containers, as mercury amalgamates with many other metals, including zinc, copper and silver. Some plastics are permeable to mercury vapours and should be avoided if possible.

128. End users should safely handle and prevent any breakage of or damage to waste mercury-added products such as fluorescent lamps, thermometers and electrical and electronic devices. Waste mercury-added products such as paints and pesticides should be handled safely and should not be discharged into sinks, toilets, storm sewers or other rainfall runoff collection systems. Waste mercury-added products should not be mixed with any other wastes. If such products are accidentally broken or spilled, clean-up procedures should be followed (see subsection III.K.2 below).

<sup>24</sup> Information is available at [http://eng.me.go.kr/content.do?method=moveContent&menuCode=pol\\_rec\\_pol\\_rec\\_sys\\_responsibility](http://eng.me.go.kr/content.do?method=moveContent&menuCode=pol_rec_pol_rec_sys_responsibility).

129. Those who handle wastes contaminated with mercury should not mix them with other wastes. Wastes contaminated with mercury should be placed in sealed containers to prevent the release of mercury to the environment.

## 2. Separation

130. Separation and collection of mercury wastes are key factors in ESM because if such wastes are simply disposed of as municipal solid waste (MSW) without any separation, the mercury content in them could be released into the environment as a result of landfilling or incineration.

131. Industrial mercury wastes should be managed as hazardous wastes separate from other wastes generated at industrial facilities in accordance with applicable national laws. Separate management of such wastes allows for appropriate treatment to either extract the mercury from them or to stabilize the wastes for proper disposal without diluting their mercury content. Dilution of the mercury in the waste by mixing it with other wastes could make treatment less effective, or could inappropriately reduce the mercury concentration to be below the threshold(s) to be established under paragraph 2 of Article 11 of the Minamata Convention, thereby hindering the proper management of such wastes.

132. The following issues should be considered when establishing and implementing collection programmes for mercury wastes, in particular waste mercury-added products from households and commercial and institutional entities:

- (a) Advertise the programmes, depot locations and collection time periods to all potential holders of mercury wastes;
- (b) Allow enough time for the operation of collection programmes for the complete collection of all mercury wastes included in the programmes;
- (c) Include, to the extent practical, the collection of all mercury wastes in collection programmes;
- (d) Make acceptable containers and safe-transport materials available to mercury waste owners for those wastes that need to be repackaged or made safe for transport;
- (e) Establish simple, low-cost mechanisms for collection;
- (f) Ensure the safety both of those delivering mercury wastes to depots and of workers at such depots;
- (g) Ensure that the operators of depots are using an accepted disposal method;
- (h) Ensure that programmes and facilities meet all applicable legislative requirements; and
- (i) Ensure the separation of mercury wastes from other waste streams.

133. Depending on national and local legislation, labelling of products that contain mercury can help to ensure the proper separation and consequently the environmentally sound disposal of mercury-added products at the end of their useful life. Labelling systems for mercury-added products should be implemented by producers during the manufacturing stage of such products to facilitate the identification of products that contain mercury and need special handling under collection and recycling programmes.<sup>25</sup> Labels may need to comply with national right-to-know regulations, which may require the disclosure of the identity and properties of toxic chemical ingredients in products. Labelling systems for mercury-added products could also require that labels include instructions on proper use of those products, as well as waste management instructions that encourage recycling and proper disposal.

134. Labelling systems for mercury-added products could help achieve the following objectives:<sup>26</sup>

- (a) Informing consumers at the point of purchase that such products contain mercury and may require special handling at the end of their lives;

<sup>25</sup> By way of example, guidelines are available at:

<http://www.newmoa.org/prevention/mercury/imerc/labelinginfo.cfm>


and the labelling scheme can be found at: <http://www.digitaleurope.org/Services/MercuryFreelogo.aspx>

<sup>26</sup> By way of example, guidelines on the four points are available at:

<http://www.newmoa.org/prevention/mercury/imerc/labelinginfo.cfm> (NEWMOA, 2004).

Under the Law for Promotion of Effective Utilization of Resources in Japan, manufacturers and importers must include a label bearing the J-Moss symbol (<http://home.jeita.or.jp/eps/200512jmoss/orange.jpg>) if any of the products (personal computers, air conditioners, television sets, refrigerators, washing machines, microwaves and home driers) contains lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and/or polybrominated diphenyl ethers (PBDEs).

- (b) Identifying mercury-added products at the point of disposal so that they can be kept out of waste streams destined for landfill or incineration and thus be recycled;
- (c) Informing consumers about the presence of mercury in products so that they have information that may lead them to seek safer alternatives; and
- (d) Promoting the public's right-to-know about toxic substances in products.

135. Manufacturers can indicate the presence of mercury in mercury-added products by using the international chemical symbol for mercury, "Hg", on product labels. For example, mercury-added products sold in certain states of the United States are required to carry this symbol:<sup>27</sup> . In the European Union, the chemical symbol "Hg" must be printed on mercury-added batteries under Directive 2006/66/EC (European Union, 2006). The use of a similar symbol on the packaging labels for mercury-added lamps traded internationally could promote global recognition that such lamps contain mercury. Additional information provided in local languages could further serve to explain the meaning of the symbol.

136. In the United States, the Lamp Section of the National Electrical Manufacturers Association (NEMA) maintains that a harmonized national or international approach to labelling mercury-added lamps is an essential component of the efficient and economic distribution of energy-efficient lighting.<sup>28</sup> On 19 July 2010, the United States Federal Trade Commission promulgated a rule<sup>29</sup> requiring that, starting in 19 July 2011, packaging for CFLs, light emitting diode (LED) lamps and traditional incandescent lamps include new labels to help consumers choose the most efficient lamps for their lighting needs. For mercury-added lamps, both their packaging and the lamps themselves must be labelled as follows:<sup>30</sup>

**Figure 4:** Example of product labelling (fluorescent lamp: left for packaging, right for product)



137. When mercury-added products are exported and become waste in importing countries, consumers, users and other stakeholders in those countries may be unable to read or understand product labels written in a foreign language. In such cases, importers, exporters, manufacturers or national agencies in charge of product labelling should make sure that product labels are locally appropriate and/or are written in the relevant local language(s).

### 3. Collection

#### (a) Collection of waste consisting of mercury or mercury compounds

138. Wastes consisting of mercury or mercury compounds, such as those generated during the closure of mercury cell chlor-alkali facilities, are different from other mercury wastes in terms of the hazards that they may pose if mishandled. Wastes consisting of mercury or mercury compounds may also be generated in higher volumes than other mercury wastes, making their safe collection more difficult. Mercury in bulk form must be carefully packaged in appropriate containers before shipping to designated storage or disposal facilities.<sup>31</sup>

<sup>27</sup> Available at: <http://www.newmoa.org/prevention/mercury/imerc/labelinginfo.cfm>

<sup>28</sup> Available at: <http://www.nema.org/Policy/Environmental-Stewardship/Lamps/Documents/Labeling%20White%20Paper%20Final%2010%2004.pdf> and <http://www.nef.org.uk/energysaving/lowenergylighting.htm>.

<sup>29</sup> Appliance Labeling Rule, 75 Fed. Reg. 41696 (July 19, 2010).

<sup>30</sup> Available at: <http://www.ftc.gov/os/2010/06/100618lightbulbs.pdf> (last visited on 29 May 2011). For information about recycling etc., see: <http://www.epa.gov/cfl/cflrecycling.html>.

<sup>31</sup> The United States Department of Energy provides detailed guidance on the safe handling and storage of mercury, which is available from: <http://energy.gov/em/services/waste-management/waste-and-materials-disposition-information>.

**(b) Collection of waste mercury-added products**

139. Waste mercury-added products, after becoming wastes, should be collected separately from other wastes with and efforts should be made to prevent as much breakage and contamination as possible. The quantity of waste generated by households on the one hand and by other waste generators such as companies, governments, schools and other organizations on the other hand differs. It is therefore recommended that the waste from the two groups be collected separately.

140. There are three options, discussed below, for collecting waste mercury-added products from households such as those referred to in table 2 above. Mercury batteries may be collected together with other types of batteries.

**(i) Waste collection stations or drop-off depots**

141. Mercury-containing wastes should be discarded in a specially designed container at waste collection stations or depots in order to avoid the mixing of such wastes with other wastes. Mercury-containing wastes should be collected exclusively by collectors authorised by local governments or other appropriate authorities.

142. Boxes or containers for mercury-containing wastes should be made available for public use at waste collection stations. Mercury-containing waste such as fluorescent lamps and mercury-added thermometers and batteries should only be placed in coloured, marked waste containers. Designated containers should all be the same colour and/or bear the same logo so as to facilitate public awareness. Breakage of fluorescent lamps and thermometers should be avoided, *inter alia* through appropriate box design and the provision of written information on collection procedures. Different containers should be used for tube bulbs and CFLs. For CFLs, it is important to minimize the “free fall” of lamps by installing soft, cascading baffles or flaps. Alternatively, a small open box could ask users to carefully place their spent bulbs inside the box without breaking them. Another option to minimize lamp breakage would be to ask consumers to hand fluorescent lamps over to qualified collection station staff members. In the event of lamp breakage, the affected area should immediately be ventilated and staff should be informed and apply clean up procedures.<sup>32</sup> Waste drop-off stations for lamps could be established outdoors to minimize worker exposure should lamp breakage occur.

**(ii) Collection at public places or shops**

143. Mercury-containing wastes, particularly used fluorescent lamps, thermostats, mercury batteries and thermometers may be collected by specially designed collection vehicles or at public places or shops such as town halls and other public buildings, electronics stores, and shopping malls and other retail outlets, provided that appropriate collection containers are used. Separate collection boxes or containers for mercury-containing wastes should be designed to accommodate the characteristics of such wastes and to minimize waste breakage. Only containers specifically designed to carry mercury-containing wastes and shown to be capable of containing mercury vapours from broken lamps should be used in public collection locations.<sup>33</sup> Consumers should be able to take used fluorescent lamps, mercury batteries, thermostats and mercury thermometers to such locations free of charge. Authorized collectors, such as municipal collectors or private sector collectors (e.g., collectors trusted by producers), should collect the wastes in the designated waste collection boxes or containers.

144. Boxes and containers for mercury-containing waste should be monitored to ensure that no other type of waste is deposited in them. They should be labelled and placed in areas where they can be monitored, either inside buildings, in well-ventilated areas, or outside, in covered and protected areas.

**(iii) Collection at households by collectors**

145. The collection of waste mercury devices from households by authorized collectors can be carried out to deal with certain mercury-containing wastes such as mercury-containing e-waste. In order to ensure the efficient collection of such wastes by local collectors, special arrangements or legal mechanisms will often be required; for example, government or other agencies and producers of mercury-added products may need to provide arrangements for the collection of mercury-containing waste by local collectors.

<sup>32</sup> See EPA, “Cleaning up a broken CFL,” available at: <http://www.epa.gov/cfl/cflcleanup.html>; Mercury Policy Project, 2008, *Shedding Light on Mercury Risks from CFL Breakage*, available at: [http://mpp.cclearn.org/wp-content/uploads/2008/08/final\\_shedding\\_light\\_all.pdf](http://mpp.cclearn.org/wp-content/uploads/2008/08/final_shedding_light_all.pdf); and German Environment Protection Agency, available from: <http://umweltbundesamt.de/energie/licht/hgf.htm> (in German).

<sup>33</sup> See Glenz et al, 2009.

**(iv) Collection coordinated by business associations**

146. The collection of waste mercury-added products from business and commercial entities could be carried out by business or commercial associations in an efficient manner. In Japan, for example, the Tokyo Medical Association established an ad hoc collection system for unnecessary mercury thermometers and sphygmomanometers that collected several thousands of these devices during a collection period of one month. During the collection period, each member medical institution was encouraged to bring the devices to a designated local association branch office and requested to pay specific fees for transportation and disposal. The Tokyo Medical Association coordinated with local association branches and waste transporters and managers to ensure the efficient collection and disposal of devices collected. Each member medical institution benefited from lower transportation fees because the system created economies of scale and efficient transport arrangements.

**(v) Take-back collection programme**

147. Take-back programmes can refer to a variety of programmes established to divert spent or waste products from the waste stream for the purpose of recycling, reuse, refurbishing, and in some cases recovery. Take-back programmes are often voluntary initiatives developed by the private sector (e.g., manufacturers and retailers) that offer consumers the opportunity to return used products at their points of purchase or at some other specified facilities. Some take-back programmes offer financial incentives to consumers, others are mandated or operated by governments (e.g., bottle deposits schemes), and some serve to partly finance disposal or recycling activities. Take-back collection programmes generally focus on consumer products that are widely used, such as batteries, switches, thermostats, fluorescent lamps and other mercury-added products (Honda, 2005).

148. In Japan, producers collect and recycle used fluorescent lamps through leasing systems for business establishments under the Akari Anshin Service (Panasonic, 2009) and the Hitachi Lighting Service Pack (Hitachi, 2006).

**(c) Collection of wastes contaminated with mercury or mercury compounds**

149. Sewage treatment plants and waste incinerators are generally designed to include equipment for collecting sewage sludge, ash and residues that might contain trace amounts of mercury and other heavy metals. Mercury air pollution control devices in incinerators may increase mercury concentrations in collected fly ash. If mercury concentrations in these wastes exceed the criteria for hazardous waste, the wastes should be collected separately.

**4. Packaging and labelling**

150. Mercury wastes being transported from the premises of generators or from public collection points to waste treatment facilities should be properly packaged and labelled. Packaging and labelling for transport is often controlled by national hazardous waste or dangerous goods transportation legislation, which should be consulted first. If such legislation is lacking or does not provide sufficient guidance, reference materials published by national governments, IATA, IMO and UNECE should be consulted. International standards for the proper labelling and identification of wastes have been developed, including the following reference materials:

(a) United Nations, 2003. *Globally Harmonized System of Classification and Labelling of Chemicals* (revised and improved every two years); and

(b) OECD, 2001. *Harmonised Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures*.

**5. Transportation**

151. Mercury wastes should be transported in an environmentally sound manner in order to avoid accidental spills; they should also be tracked during transport until they have reached their final destination. Prior to transportation, contingency plans should be prepared in order to minimize environmental impacts associated with spills, fires and other potential emergencies. During transportation, mercury wastes should be identified, packaged and transported in accordance with the *United Nations Recommendations on the Transport of Dangerous Goods: Model Regulations (Orange Book)*.

152. Companies transporting wastes within their own countries should be certified as carriers of hazardous materials and wastes, and their personnel should be qualified and certified as handlers of hazardous materials and wastes in accordance with applicable national and local. Transporters should manage mercury wastes in a way that prevents breakage, environmental releases and exposure to moisture.

153. Guidance on the safe transportation of hazardous materials can be obtained from IATA, IMO, UNECE and ICAO (see paragraph 124 above).

## **6. Storage**

### **(a) Storage of wastes containing mercury by waste generators pending collection**

154. Mercury-containing wastes should be stored temporarily at the premises of waste generators before they are collected for disposal. Wastes containing mercury should be stored safely and kept apart from other wastes until they are brought to waste collection stations or facilities or picked up by collection programmes or contractors. Bulk waste should be stored in such a manner as to minimize mercury releases to the environment, including, if feasible, through the use of closed containers, impermeable concrete pads with runoff controls, or waterproof tarp covers. Waste should be stored by generators for a limited period of time, as allowed by national standards or regulations, and should in any case be sent off-site for appropriate disposal as soon as is practical.

155. Household wastes containing mercury, mainly fluorescent and other lamps, mercury-added batteries and thermometers, should be appropriately packaged (e.g., using product packaging or boxes that fit the shape of the wastes) and temporarily stored. Any mercury devices that are broken during handling should be cleaned up and all clean-up materials should be stored outdoors until they are collected for further management.<sup>34</sup> Liquid wastes containing mercury such as paints and pesticides should be kept in their original containers, whose lids should be tightly closed. Containers and packages holding mercury-containing waste should not be placed together with other wastes; containers and packages should be marked and stored in a dry and secure place, such as a warehouse or other space that is not usually frequented by people.

156. In addition to following the guidance contained in paragraphs 154 and 155 above, large-scale users of mercury such as governments, businesses and schools will also need plans for storing large amounts of mercury-containing wastes. When original boxes or packages are not available, containers that are specially designed to store mercury-containing wastes (e.g., fluorescent lamp containers) should be purchased. Containers or boxes for storing mercury-containing wastes should be marked and dated and stored in a dry place. The use of an area or room separated from work areas or areas not open to the public for storing such wastes is recommended. Such areas should not share building ventilation systems with work or public areas and should have their own ventilation systems or be vented directly to the outdoors. Guidance developed by UNDP for mercury wastes generated by healthcare facilities<sup>35</sup> provides detailed advice in this regard and may be applicable to many commercial facilities that generate waste mercury devices.

### **(b) Storage of mercury wastes pending disposal operations**

157. Storage of mercury wastes at disposal facilities should also minimize the potential for mercury releases to the environment.

#### **(i) Technical and operational considerations for storage facilities**

158. In terms of siting and design, in principle storage facilities should not be built in sensitive locations whenever possible. Sensitive locations may include floodplains, wetlands, groundwater, earthquake zones, Karst terrain, unstable terrain and areas with unfavourable weather conditions and incompatible land uses in order to avoid any risk of mercury releases and possible human and environmental exposure to mercury. However, such location limitations may not apply in cases where technical design and legal requirements govern the environmentally sound management of storage facilities. Storage areas should be designed to ensure the security of the facilities and to prevent unnecessary chemical and physical reactions to mercury. The floors of storage facilities should be covered with mercury-resistant materials to prevent seepage or penetration of mercury from accidental leaks and spills. Storage facilities should have fire alarm and fire suppression systems, as well as negative pressure environments to avoid mercury emissions escaping from buildings. The temperature in storage areas should be maintained as low as feasibly possible, preferably at a constant temperature of 21 degrees Celsius. Storage areas for mercury wastes should be clearly marked with warning signs (FAO, 1985; EPA, 1997b; UNEP, 2015c; U.S. Department of Energy, 2009).

159. In terms of operation, storage facilities should be kept locked to avoid theft or unauthorized access. Access to mercury wastes should be restricted to those with adequate training in, among other

<sup>34</sup> Materials should be stored outdoors because many commonly available containers such as plastic bags are permeable to mercury vapour. See, Maine Department of Environmental Protection, 2008.

<sup>35</sup> UNDP (GEF Global Healthcare Waste Project), *Guidance on the Clean Up, Temporary or Intermediate Storage, and Transport of Mercury Waste from Healthcare Facilities*. Available from: <http://www.gefmedwaste.org/guidance-documents>.

things, the identification of types of mercury wastes, mercury-specific hazards and the handling of such wastes. It is recommended that storage buildings for all types of mercury wastes not be used to store other liquid wastes or materials. A full inventory of the wastes kept at the storage site should be created and updated as waste is added or removed. Regular inspections of storage areas should be undertaken, focusing particularly on damage, leaks, spills and deterioration. Clean-up and decontamination should be carried out speedily, but not without alerting the authorities concerned, and in compliance with national laws and regulations. (FAO, 1985; EPA, 1997b).

160. In terms of the safety of facilities, site-specific procedures should be developed to implement safety requirements identified for the storage of mercury wastes. A workable emergency plan, preferably with multiple procedures, should be in place and implemented immediately in the event of accidental spillage and other emergencies. The protection of human life and the environment is of paramount importance. In the event of an emergency, there should be a responsible person who can authorize modifications to safety procedures when necessary in order to allow emergency response personnel to act. Adequate security siting and access to the area should be ensured (Environmental Management Bureau, Republic of the Philippines, 1997; UNEP, 2015c; U.S. Department of Energy, 2009).

**(ii) Special considerations for storage of wastes consisting of mercury or mercury compounds**

161. Containers of wastes consisting of mercury or mercury compounds should be structurally sound and make possible the environmentally sound storing of such wastes. Containers should meet the following requirements: (1) they should not be damaged from any materials previously stored in them or have contained materials that could adversely react with mercury; (2) their structural integrity should be intact; (3) they should not be excessively corroded; and (4) they should have a protective coating (paint) to prevent against corrosion. Appropriate materials for mercury containers include carbon and stainless steel, which do not react with mercury at ambient temperatures. No protective coating is required for the inner surface of such containers as long as the mercury to be stored in them meets purity requirements and no water is present inside the container. Protective coatings (e.g., epoxy paint and electroplating) should be applied to all exterior carbon steel surfaces in a manner that does not leave any steel exposed. Coatings should be applied in a manner that minimizes paint blistering, peeling and cracking. Labels including information on the names of the suppliers of the mercury waste, the origin of the waste, the container number, gross weight, the date when the mercury was injected and a “corrosives” label indicating that the container contains corrosive materials, should be affixed to each container (U. S. Department of Energy, 2009). In addition, the label should show that the container meets specific technical requirements regarding tightness, pressure stability, shock resistance, behaviour when exposed to heat, etc..

162. Containers for wastes consisting of mercury or mercury compounds should be stored upright on pallets off the ground. Aisles in storage areas should be wide enough to allow the passage of inspection teams, loading machinery and emergency equipment. The floors of storage facilities should be coated with an epoxy coating and be light in colour to allow the detection of mercury droplets. The floor and floor coating should be inspected frequently to ensure that the floor has no cracks and the coating is intact. The floor should not be penetrated by any drains or plumbing, and sloped floors and open flow gutters with rounded-down edges (to avoid mercury trapping under gutter covers) could be used to facilitate the collection of spills. When choosing the materials from which to construct the walls of storage facilities, materials that do not readily absorb mercury vapour should be selected. It is important to include redundant systems to prevent mercury releases in the event of an unexpected occurrence (U.S. Department of Energy, 2009; World Chlorine Council, 2004).

163. When storing wastes consisting of mercury or mercury compounds, the mercury content of such wastes should be as pure as possible in order to avoid chemical reactions and the degradation of containers. A mercury content greater than 99.9 weight per cent is recommended. For purification techniques, see subsection III.G.1 (b) (v) below.

**(iii) Special considerations for storage of wastes contaminated with mercury or mercury compounds**

164. Liquid wastes in containers should be placed in containment trays or curved, leak-proof areas. The liquid containment volume should be at least 125 per cent of the maximum liquid waste volume, taking into account the space taken up by stored items in the containment area.

165. Solid wastes should be stored in sealed containers such as barrels or pails, steel waste containers or in specially constructed containers that do not release mercury vapour.

## G. Environmentally sound disposal

166. The following disposal operations, as provided for in Annex IV, parts A and B, of the Basel Convention, should be permitted for the purpose of environmentally sound management of mercury wastes:<sup>36</sup>

- D5 Specially engineered landfill;
- D9 Physico-chemical treatment;
- D12 Permanent storage;
- D13 Blending or mixing<sup>37</sup> prior to submission to operations D5, D9, D12, D14 or D15;
- D14 Repackaging prior to submission to operations D5, D9, D12, D13 or D15;
- D15 Storage pending operations D5, D9, D12, D13 or D14;
- R4 Recycling/reclamation of metals and metal compounds;
- R5 Recycling/reclamation of other inorganic materials;
- R8 Recovery of components from catalysts;
- R12 Exchange of wastes<sup>38</sup> for submission to operations R4, R5, R8 or R13;
- R13 Accumulation of material intended for operations R4, R5, R8 or R12.

167. In addition, a form of backfilling in underground facilities may also be permitted whereby waste is utilized in underground facilities for mining safety purposes taking advantage of the respective structural properties of the waste.<sup>39</sup> In Germany, for example, such a process is regulated by the *Ordinance on Underground Waste Stowage* (see: [http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/underground\\_waste\\_stowage.pdf](http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/underground_waste_stowage.pdf)), whose requirements are equivalent to those found in the European Union's *Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste* and include special licensing procedures and supervision.

168. Should one of the recovery operations described in subsection III.G.1 below be carried out and the mercury subsequently sent to a specially engineered landfill or permanent storage (i.e., operations D5 or D12), the recovery operation would fall under categories D13 and D9 (i.e., blending or mixing, or physico-chemical treatment). On the other hand, should one of the operations not leading to the recovery of mercury or mercury compounds described under subsection III.G.2 below (e.g., stabilization) be carried out and the mercury waste subsequently sent for one of the "R" operations listed in paragraph 166 above, the operation would also constitute an "R" operation. These two conclusions may not apply to all countries.

### 1. Recovery operations

169. Mercury recovery from solid waste generally comprises: (1) pre-treatment; (2) thermal treatment; and (3) purification, as shown in figure 5 below. In order to minimize mercury emissions from the mercury recovery process, facilities should employ closed systems. The entire process should take place under reduced pressure in order to prevent leakage of mercury vapour into processing areas (Tanel, 1998). The small amount of exhausted air that is emitted in the recovery process must pass through a series of particulate filters and a carbon bed that absorbs the mercury before the air is exhausted into the environment.

170. Examples for mercury wastes whose recovery can generate mercury emissions are waste mercury-added equipment that easily releases mercury into the environment when broken and wastes contaminated with high concentrations of mercury. The former include measuring devices containing mercury (thermometers, sphygmomanometers and manometers) and mercury switches and relays, and could also include mercury-added lamps. The latter include wastewater treatment sludges from wet scrubbers in non-ferrous metal smelters. In the United States, specific standards have been set for the treatment and recovery of mercury-bearing hazardous wastes, including those with a mercury content greater than or equal to 260 mg/kg, prior to land disposal of such wastes (see U.S. Code of Federal

<sup>36</sup> For information on storage pending disposal operations (operations R13 and D15), see section III, F, 6.

<sup>37</sup> Examples include pre-processing such as sorting, crushing, drying, shredding, conditioning or separating.

<sup>38</sup> Exchange of wastes is interpreted to cover pre-treatment operations unless another R code is appropriate.

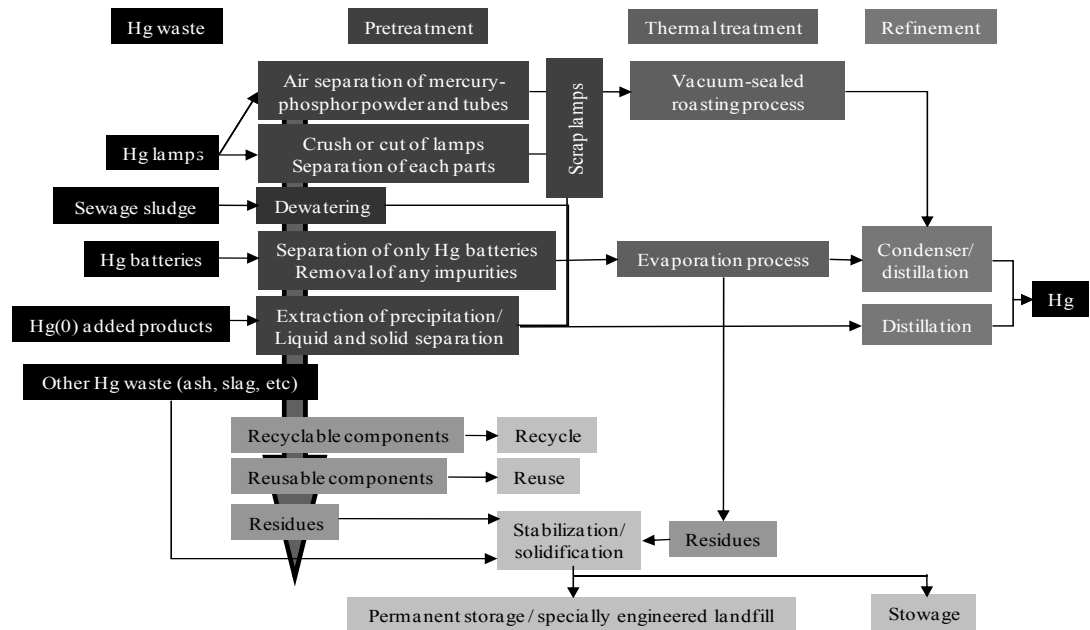
<sup>39</sup> Such backfilling of mercury sulphide resulting from the stabilization of wastes consisting of mercury is currently possible only in Germany.



Regulations (CFR), Title 40 (Protection of the Environment), Section 268.40: Applicability of treatment standards).

171. The Basel Convention *Technical guidelines on the environmentally sound recycling/reclamation of metals and metal compounds (R4)* focus mainly on the environmentally sound recycling and reclamation of metals and metal compounds, including mercury, that are listed in Annex I to the Convention (“Categories of wastes to be controlled”). It is possible to recycle mercury wastes, particularly wastes consisting of mercury or mercury compounds, in special facilities that have advanced mercury-specific recycling technologies. It should be noted that appropriate procedures should be employed in such recycling to prevent any releases of mercury into the environment. In addition, recycled mercury may be sold on the international commodities market, where it can be re-used. The recycling of mercury<sup>40</sup> will usually be determined by the degree of allowable use and a commercial evaluation as to whether it can be profitably recovered.

**Figure 5:** Flow of mercury recovery from solid waste (Nomura Kohsan Co. Ltd., 2007)



172. Mercury recovery from wastewater is generally achieved through chemical oxidation, chemical precipitation, or adsorption, followed by various treatment processes. Mercury exists in wastewater due to accidental or intentional discharging of mercury from thermometers, dental amalgams, or industrial processes using mercury or mercury compounds. Mercury may be found in wastewater from wet-type air pollution control devices and leachate from landfills and dumping sites where wastes containing mercury such as mercury thermometers are disposed of or dumped. Mercury in wastewater should not be released into the aquatic environment, where mercury is methylated and converted into methylmercury, which then bioaccumulates and biomagnifies in the food chain.

173. Pre-treatment prior to recycling/reclamation of mercury (operation R4) falls under operation R12 (see paragraph 166 above), while roasting, purification, chemical oxidation/precipitation and adsorption fall under operation R4.

**(a) Pre-treatment (exchange of wastes for submission to operations R4 or R13)**

174. Before undergoing thermal treatment, wastes that contain or are contaminated with mercury are treated in order to increase the efficiency of the thermal treatment; pre-treatment processes include, *inter alia*, removal of materials other than those containing mercury by crushing and air separation, dewatering of sludge, and removal of impurities. Examples of mercury waste-specific pre-treatment operations are summarized in table 5 below.

<sup>40</sup> See Article 11(3)(b) of the Minamata Convention. Furthermore, note that Article 3(5)(b) of that Convention prevents recycling of excess mercury (but not mercury wastes) from the decommissioning of chlor-alkali facilities.

**Table 5:** Examples of pre-treatment operations by type of waste

<b>Waste Type</b>	<b>Pre-treatment</b>
<i>Fluorescent lamps</i>	<p><b><i>Mechanical crushing</i></b></p> <p>Waste mercury-added lamps should be processed in a machine that crushes and separates the lamps into three categories: glass, end-caps and mercury-phosphor powder mixtures. This is accomplished by injecting the lamps into a sealed crushing and sieving chamber. Upon completion, the chamber automatically removes the end products to prevent cross-contamination. End-caps and glass should be removed and sent for reuse in manufacturing. However, the metal pins of the end caps should be removed and treated separately as their mercury content may be considerable. Mercury-phosphor powder may be disposed of or further processed to separate the mercury from the phosphor (Nomura Kohsan Co. Ltd., 2007).</p> <p>Lamp glass from crushed mercury-added lamps can contain significant amounts of mercury and should be treated thermally or in other ways to remove the mercury before sending the glass for recovery (Jang, 2005) or disposal. If the glass is sent to a melting unit for re-melting as part of the recovery process, the unit should have air pollution controls specifically directed at capturing released mercury (e.g., activated carbon injection).</p> <p>A high-performance exhaust air system should prevent the emission of any mercury vapours or dust during the entire process.</p> <p><b><i>Air separation</i></b></p> <p>The aluminium end caps of fluorescent lamps (straight, circular and compact tubes) are cut by hydrogen burners. Air is then blown into the cut lamps from the bottom of the lamps to remove mercury-phosphor powder adsorbed on lamp glass (Jang, 2005). Mercury-phosphor powder is collected in a precipitator and glass parts are crushed and washed with acid, thanks to which mercury-phosphor powder adsorbed on the glass is completely removed. In addition, the end-caps are crushed and aluminium, iron and plastics are magnetically separated for recycling (Kobelco Eco-Solutions Co. Ltd., 2001; Ogaki, 2004).</p>
<i>Mercury-added batteries</i>	<p><b><i>Removal of impurities</i></b></p> <p>In order to recycle mercury from mercury-added batteries, the batteries should be collected separately and stored in suitable containers before treatment and recycling. If mercury-added batteries are collected together with other types of batteries or with waste electrical and electronic equipment, the mercury-added batteries should be separated from other types of batteries. Before roasting treatment, impurities mixed with and adsorbed onto mercury-added batteries should be removed, preferably through a mechanical process. In addition, mechanical screening of the size of mercury-added batteries is necessary for an effective roasting process. (Nomura Kohsan Co. Ltd., 2007).</p>
<i>Sewage sludge</i>	<p><b><i>Dewatering</i></b></p> <p>Sewage sludge has a high water content of over 95 per cent. As a result, sludge contaminated with mercury and destined for destruction needs to be dewatered to about 20 to 35 per cent solids before any thermal treatment. After dewatering, sewage sludge should be treated through a roasting process (Nomura Kohsan Co. Ltd., 2007; EPA, 1997a). Extracted water will probably need to be managed as mercury waste.</p>
<i>Waste mercury-added products</i>	<p><b><i>Extraction</i></b></p> <p>Waste mercury-added products such as thermometers and barometers should be collected without any product breakage, to the degree feasible. After collection of waste mercury-added products, mercury in the products should be extracted and the extracted mercury distilled for purification under reduced pressure.</p>

Waste Type	Pre-treatment
<p>Wastes containing mercury attached to devices</p>	<p><b>Dismantling</b></p> <p>Wastes containing mercury, such as electric switches and relays, are usually attached to electric devices. Therefore, such wastes should be removed from such devices without breaking the devices' outer glass.</p> <p>Computer monitors and televisions with flat screen liquid crystal displays (LCD) contain one or more small lamps for illumination, usually located along the outside edge of screens. While newer technologies sometimes use light emitting diodes (LED) in these small lamps, most LCD screens contain fluorescent mercury vapour lamps. These mercury lamps will often break during handling and mechanized processing and release mercury vapour, so they should be carefully removed by hand<sup>41</sup> and should not be treated through mechanized processing such as shredding, unless shredding machines have the necessary pollution control equipment to manage such operations and are licensed and permitted for the processing of mercury lamps, such as at mercury treatment facilities. For further information, see section 7.3 of the Basel Convention Partnership for Action on Computing Equipment (PACE) <i>Guideline on environmentally sound material recovery and recycling of end-of-life computing equipment</i> (document UNEP/CHW.10/INF/23). Further information on the presence of mercury in LCD backlights is available in "Demonstration of flat panel display recycling technologies", a 2010 report produced by the Waste and Resources Action Programme (available from: <a href="http://www.wrap.org.uk">http://www.wrap.org.uk</a>).</p>

(b) **Recycling/reclamation of mercury or mercury compounds**

(i) **Thermal treatment**

175. Thermal treatment facilities for wastes containing or contaminated with mercury or mercury compounds such as sewage sludge, contaminated soils and other wastes from contaminated sites should be equipped with mercury vapour collection technology for the recovery of mercury (ITRC, 1998; Chang and Yen, 2006).

176. Thermal desorption is a process that uses either indirect or direct heat exchange to heat primarily organic contaminants to a high enough temperature to volatilize and separate them from a contaminated solid matrix and then either collect or destroy them. Thermal desorption using indirect heat exchange is the recommended option for mercury and its compounds. Air, combustion gas or an inert gas is used as a transfer medium for vaporized components. Thermal desorption systems involve physical separation processes that transfer contaminants from one phase to another. The systems have two major components, a desorber and an off-gas treatment/collection system.<sup>42</sup>

177. There are several evaporation processes for the treatment of mercury wastes, including rotary kiln distillation and vacuum thermal processing.

178. Rotary kiln distillation serves to remove and recover mercury in wastes such as mineral industrial slurries, slurries from the movement of natural gas, active carbons, catalysts, button cells and contaminated soil by means of evaporation and recycling of the resulting mercury-free products (e.g., glass, iron and non-ferrous metals, zeolites). Any pollutants or hydrocarbons and sulphur are removed in the treatment process.

179. In the rotary kiln distillation process, free-flowing and conveyable waste is fed evenly into a rotary kiln from a feed hopper with the use of a dosage system. The waste is treated at temperatures of up to 800°C, with an initial temperature of at least 356°C to cause the mercury in the waste to evaporate. The input waste are moved evenly through the rotary kiln. The required residence time of the waste in the rotary kiln depends on the input material but is usually between 0.5-1.5 hours. The treatment is carried out at under pressure to guarantee that the system operates safely. If necessary, nitrogen is added to create an inert atmosphere in the rotary kiln for a higher degree of safety. The

<sup>41</sup> See section III.J for details on worker safety precautions.

<sup>42</sup> The first large-scale thermal desorption unit for the treatment of mercury-containing wastes was constructed for the remediation of the Marktredwitz Chemical Factory (CFM) in Wölsau, Germany. The operation commenced in October 1993, including the first optimizing phase. Some 50,000 tons of mercury-contaminated solid wastes were treated successfully between August 1993 and June 1996. Thermal desorption units were also used to decontaminate the old chlor-alkali plant in Usti nad Labem in the Czech Republic and to decontaminate the soil in Taipei (Chang and Yen, 2006).

stream of exhaust air from the rotary kiln flows to two gas scrubbers through a hot gas dust filter in which the mercury, water and hydrocarbons condense. The exhaust gas is then fed to an active carbon filter system for final cleaning.<sup>43</sup>

180. Pre-treated waste, such as mercury-phosphor powder in fluorescent lamps, crushed lamp glass, cleaned mercury-added batteries, dewatered sewage sludge and screened soil, may be treated in roasting/retorting facilities equipped with mercury vapour collection technology through which mercury can be recovered. However, it should be noted that volatile metals, including mercury and organic substances (including persistent organic pollutants), are emitted during roasting and other thermal treatments and are transferred from the input waste to both the resulting flue gas and fly ash. Therefore, flue gas treatment devices should be used to capture volatilized pollutants and to prevent the pollutants from being emitted to the environment (see subsection III.H.1 below).

181. Vacuum thermal processing enables the treatment of thermometers, batteries, especially button cells, dental amalgam, electrical switches and rectifiers, fluorescent powder, exhaust tubes, crushed glass, soil, sludge, mining residues and catalyst materials, among others. The vacuum thermal process generally includes the following stages:

- (a) Heating the input waste in a special kiln or in a charging operation at temperatures of between 340°C and 650°C and pressures of a few millibars so that the mercury contained in the waste evaporates;
- (b) Applying thermal post-treatment to mercury-containing vapour at temperatures ranging from 800°C to 1000°C, where, for example, organic components can be destroyed;
- (c) Collecting and cooling of mercury-containing vapour;
- (d) Using distillation to generate pure liquid mercury.

182. The residue that remains at the end of the vacuum thermal processing is essentially mercury-free and is recycled or otherwise disposed of depending on its composition.<sup>44</sup>

**(ii) Chemical oxidation**

183. Chemical oxidation of mercury and organomercury compounds in waste is carried out to convert the mercury into mercury salts and to destroy the organomercury compounds. Chemical oxidation is an effective method for treating liquid and aqueous waste, such as slurry and tailings, containing or contaminated with mercury. Oxidizing reagents used in the chemical oxidation process include sodium hypochlorite, ozone, hydrogen peroxide, chlorine dioxide and free chlorine (gas). Chemical oxidation can be conducted as a continuous or batch process in mixing tanks or plug flow reactors. Mercury halide compounds formed in the oxidation process are separated from the waste matrix, treated and sent for subsequent treatment such as acid leaching and precipitation (EPA, 2007a).

**(iii) Chemical precipitation**

184. Precipitation uses chemicals to transform dissolved contaminants into insoluble solids that may precipitate or be removed by flocculation or filtration. In co-precipitation, the target contaminant may be in a dissolved, colloidal or suspended form. Dissolved contaminants do not precipitate but are adsorbed onto other species that are then precipitated. Colloidal or suspended contaminants become enmeshed with other precipitated species or are removed through processes such as coagulation and flocculation. Processes to remove mercury from wastewater can include a combination of precipitation and co-precipitation. The precipitated/co-precipitated solid is then removed from the liquid phase through clarification or filtration. More detailed information can be found in the report entitled "Treatment technologies for mercury in soil, waste, and water" (EPA, 2007b).

**(iv) Adsorption treatment**

185. Adsorption materials hold mercury on their surfaces through various types of chemical forces such as hydrogen bonds, dipole-dipole interactions and van der Waals forces. Adsorption capacity is affected by surface area, pore size distribution and surface chemistry. Adsorption materials are usually packed into a column, through which mercury or mercury compounds are adsorbed as liquid wastes pass. The column should be regenerated or replaced with new media when adsorption sites become filled (EPA, 2007b). The resulting spent adsorbent is mercury waste.

<sup>43</sup> See <http://www.nqr-online.de/index.php?id=17348&L=1>.

<sup>44</sup> See [www.gmr-leipzig.de/gbverfahren.htm](http://www.gmr-leipzig.de/gbverfahren.htm).

186. Examples of adsorption materials include activated carbon and zeolite. Activated carbon is a carbonic material that has many fine interconnected openings and typically has a wooden (coconut shells and sawdust), oil or coal base. It can be classified, based on its shape, into powdery activated carbon and granular activated carbon. Many activated carbon products are commercially available, offering the specific advantages of their individual materials. Mercury and other heavy metals, as well as organic substances, adsorb on activated carbon (Bansal, 2005). Zeolites are naturally occurring silicate minerals that can also be produced synthetically. Zeolites, in particular clinoptilolite, have a strong affinity for heavy metal ions where the adsorption mechanism is an ion exchange (Chojnacki et al., 2004). Ion exchange resins have proven to be useful in removing mercury from aqueous streams, particularly at mercury concentrations in the order of 1 µg/L to 10 µg/L. Ion exchange applications usually serve to treat mercuric salts, such as mercuric chlorides, that are found in wastewaters. The ion exchange process involves suspending a medium, which can be either a synthetic resin or mineral, into a solution where suspended metal ions are exchanged onto the medium. The anion exchange resin can be regenerated with strong acid solutions, but this is difficult since the mercury salts are not highly ionized and are not readily cleaned from the resin. The resin would therefore have to be disposed of. In addition, organic mercury compounds do not ionize, so they are not easily removed by using conventional ion exchange. If a selective resin is used, the adsorption process is usually irreversible and the resin should be disposed of as hazardous waste in a disposal facility not leading to recovery (Amuda, 2010).

187. Chelating resin is an ion exchange resin that has been developed as a functional polymer that selectively catches and removes ions, including various metals ions, from solutions. It is made of a polymer-based three-dimensional mesh construction, with a functional group that chelate-combines metal ions. The most commonly used chelating resin is polystyrene, followed by phenolic plastic and epoxy resin. Chelating resins are used to treat plating wastewater to remove mercury and other heavy metals remaining after neutralization and coagulating sedimentation, or to collect metal ions by adsorption from wastewater whose metal-ion concentration is relatively low. Chelating resin of the mercury adsorption type can effectively remove mercury in wastewater (Chiarle, 2000).

(v) **Distillation of mercury – purification**

188. Following waste treatment, collected mercury is purified by successive distillation (EPA, 2000). High purity mercury is produced by distillation through many steps, with each step enabling a higher purity grade to be achieved. High purity mercury is required for many uses of mercury, or if the mercury is to be stored for a number of years, since high purity will help to prevent chemical reactions between the container and impurities.

**2. Operations not leading to recovery of mercury or mercury compounds**

189. Before mercury wastes undergo final disposal in accordance with operations D5 and D12, they should be treated so that they meet the acceptance criteria of disposal facilities (see subsection III.G.2 (b) and (c) below). Wastes consisting of mercury or mercury compounds should be stabilized and/or solidified before final disposal and final disposal should be carried out in accordance with national and local laws and regulations. It is noted that a number of methods for final disposal are currently under development, e.g., the methods referred to in paragraphs 198 and 203. Treatment operations prior to D5 and D12 operations fall under operation D9 (see subsection III.G.2 (a) below).

(a) **Physico-chemical treatment**

(i) **Stabilisation and solidification**

190. Stabilisation processes include chemical reactions that may change the hazardous characteristics of waste by reducing the mobility and sometimes the toxicity of the waste constituents. Solidification processes only change the physical state of waste (e.g., converting a liquid into a solid) through the use of additives without changing the chemical properties of the waste (European Commission, 2003).

191. S/S is applied, for example, to waste consisting of mercury or mercury compounds and mercury-contaminated waste such as soil, sludge, ash and liquid. S/S reduces the mobility of contaminants in the waste media by physically binding them within a stabilized mass or by inducing chemical reactions that may reduce their solubility or volatility, or both, thereby reducing their mobility (EPA, 2007b). In the United States, only low-concentration mercury wastes (i.e., those with a mercury content lower than 260 mg/kg) can be stabilized, after which they may be landfilled.

192. Stabilization induces chemical reactions between a stabilizing agent and waste contaminants to reduce the mobility of the contaminants, and solidification involves physically binding or enclosing contaminants within a stabilized mass. Solidification is used to encapsulate or absorb waste, and

forms a solid material when free liquids other than mercury are present in the waste. Waste can be encapsulated in two ways: microencapsulation and macroencapsulation. Microencapsulation is the process of mixing the waste with an encasing material before solidification occurs. Macroencapsulation refers to the process of pouring an encasing material over and around a waste mass, thus enclosing it in a solid block (EPA, 2007b).

193. Generally speaking, the solidification process involves mixing soil or waste with binders such as Portland cement, sulphur polymer cement (SPC), sulphide or phosphate binders, cement kiln dust, polyester resins or polysiloxane compounds to create a slurry, a paste, or another kind of semi-liquid substance, which is then cured into a solid form over a period of time (EPA, 2007b).

194. There are two main chemical approaches to the solidification process that can be applied to mercury wastes (Hagemann, 2009):

- (a) Chemical conversion to mercury sulphide; and
- (b) Amalgamation (formation of a solid alloy with suitable metals).

195. In both approaches, the risk of mercury volatility and leachability can be reduced to an acceptable level if the conversion rate to mercury sulphide (percentage of reacted mercury) reaches near 100 per cent. If a sufficiently high rate is not achieved, the probability of mercury volatility and leachability remains high, as is the case with amalgams (Mattus, 1999).

196. While appropriate technologies for stabilization and solidification of wastes consisting of mercury can reduce releases of mercury to the environment, the long-term effectiveness of these technologies has not been sufficiently studied. Therefore, the collection and analysis of information and data on such effectiveness are necessary.

#### **Stabilization as mercury sulphide**

197. One of the most important and well investigated approaches to stabilization is the conversion of mercury into mercury sulphide (HgS), which is much less soluble and has lower volatility than most mercury compounds and is therefore less mobile in the environment. Mercury is mixed with elemental sulphur or other sulphur-containing substances to form HgS. The production of HgS can result in two different types of HgS, alpha-HgS (cinnabar) and beta-HgS (meta-cinnabar). Pure alpha-HgS is intensively red and has a slightly lower water solubility compared to pure beta-HgS, which is black in colour. HgS is a powder with a density of 2.5-3 g/cm<sup>3</sup>.

198. HgS can be produced by blending mercury and sulphur under ambient conditions for a certain period of time, until HgS is produced. To start the reaction process, a certain activation energy is required and may be provided by forcefully mixing the blend. Among other factors, high shear rates and temperatures during the process support the production of alpha-HgS, while a longer process time favours the creation of beta-HgS. Excessively long milling in the presence of oxygen can lead to the production of mercury (II) oxide (HgO). Because HgO has higher water solubility than HgS, its creation should be avoided through milling under inert atmospheric conditions or through the addition of an antioxidant (e.g., sodium sulphide). Since the reaction between mercury and sulphur is exothermic, an inert atmosphere also contributes to making the operation safe. The conversion process is robust and relatively simple to carry out, but strict controls are needed to prevent volatile losses of mercury during conversion. In addition, treatment residue should be tested to ensure the completeness of the conversion to mercury sulphide.

199. Mercury sulphide can also be formed by creating a reaction between mercury and sulphur in the vapour phase. Reaction of mercury with sulphur in a sealed vessel at elevated temperature and pressure can also form the alpha cinnabar form of mercury sulphide (United States Patent: US 7691361 B1, April 10, 2010). This process is being developed in the U.S., but is not yet commercially available.

200. HgS is very insoluble in water and has very low volatility. Although HgS is chemically very stable and non-reactive, exposure to ambient environmental conditions will result in its conversion to other mercury compounds over time. The isolation of HgS from the environment through encapsulation and disposal in a specially engineered landfill or permanent underground storage may therefore be necessary to ensure that it does not convert into other mercury compounds. In addition, the fact that dissolved organic matter and high chloride concentrations in leachate increase mercury releases from HgS (Waples et al., 2005; Science Applications International Corporation, 2002) suggest that mercury converted into HgS should be disposed of in ways that ensure the waste has no contact with water or other types of waste, especially those containing organic matter and chloride. Moreover, since micro-organisms inhabiting acid mine drainage systems, which are dominated by Fe-oxidizing and S-oxidizing bacteria, in the microcosm with metacinnabar (beta-HgS) increase

dissolved Hg concentrations (Jew et al, 2014), exclusion or at least inhibition of the influence of such microorganisms in specially engineered landfills and permanent underground storage may be required for disposal of mercury treated as HgS.

201. As a fine powdery material, the handling of HgS subject to specific requirements, including stabilization, in order to avoid, for example, the risk of dust releases. The stabilization process leads to an increase in volume by approximately 300 per cent and in weight by approximately 16 per cent, based on molecular weight compared to mercury. For solidification of mercury sulphide, materials with low alkali content should be used as a recent study indicates that mercury release from mercury sulphide increases when pH value of eluate exceeds 10 (Mizutani et al., 2010).

202. A large-scale stabilization process for waste consisting of mercury that uses sulphur to form HgS is also available.<sup>45</sup> The process takes place in a vacuum mixer operated in inert vacuum atmosphere which ensures good process control and safe operation. The mixer is operated batch-wise. A dust filter and an activated carbon filter prevented releases from the plant. The reaction between mercury and sulphur takes place at a stoichiometric ratio. The end product consists of red mercury sulphide. The end product is thermodynamically stable up to 350°C.

#### **Sulphur polymer stabilization and solidification (SPSS)<sup>46, 47</sup>**

203. The sulphur polymer stabilization and solidification (SPSS)<sup>48</sup> process involves sulphur stabilization followed by solidification, with the advantage of a lower chance of mercury vaporization and leaching because the final product is monolithic with a low surface area. The process involves two steps: in the first step, mercury is stabilized with sulphur to form beta-HgS (meta-cinnabar dust) (López et al, 2010; López-Delgado et al, 2012); in the second step, the beta-HgS is incorporated and microencapsulated in a polymeric sulphur matrix at 135°C to obtain a fluid that is cooled to room temperature, in moulds, to obtain solid blocks (monoliths). The second step is the creation of a barrier to prevent mercury releases to the environment, thereby minimizing the possibility of HgS converting into other forms of mercury by reducing its contact with the environment. The SPSS process has low energy consumption, entails low mercury emissions, requires no water, has no effluents and generates no wastes other than HgS. Controls should be in place to prevent and emissions of mercury and to ensure safe conditions for workers and for the environment, including engineering controls to prevent possible fires and explosions.

204. A relatively high Hg load of the monolith (about 70 per cent) can be achieved with this process. The process is robust and relatively simple to implement and its final product is very insoluble in water, has a high resistance to corrosive environment, is resistant to freeze-thaw cycles and has a high mechanical strength. The SPSS technology can be directly applied to waste consisting of mercury with different degrees of purity, without the need for previous distillation, and to a wide range of mercury-containing wastes without previous treatment of such wastes (López et al., 2010, López-Delgado et al., 2012, López et al., 2015). All the final stabilized-microencapsulated products (from metallic mercury, zinc waste, aluminum waste and fluorescent lamp dust) are compact solids that have a stability and resistance similar to that of concrete. The SPSS process therefore ensures the complete immobilization of mercury, rendering it impermeable and giving it extremely low porosity, thereby minimizing the risk of mercury releases to the environment. The final products are hard monolithic blocks, the shape of which can be adapted to facilitate transport.

205. Monolith samples (of 40 x 40 x 160 mm) have been tested for leaching in accordance with European standards TS 14405 (CEN, 2004) and EN-12457-4 (CEN, 2002a), with tests involving a dynamic flow percolation assay on encapsulate monoliths and a leaching by agitation assay on granular material obtained through monolith crushing. All mercury concentrations found in the leachates, for a liquid/solid ratio of 10 l/kg, were <0.01 mg/kg, so the monoliths met the European Union criterion for the acceptance of waste into landfills for inert waste (<0.01 mg/kg, as per Council Decision 2003/33/EC, establishing criteria and procedures for the acceptance of waste at landfills (European Union, 2003).

206. Another example of a similar technology is solidification of beta-HgS with modified sulphur. The first step is to form beta-HgS by mixing mercury with a purity of 99.9 per cent or higher with sulphur powder, and the second step involves solidifying the beta-HgS with modified sulphur by

<sup>45</sup> See <http://www.nqr-online.de/index.php?id=17348&L=1>.

<sup>46</sup> This section contains information provided by the National Technological Centre for Mercury Decontamination (CTNDM) (Spain). For further information, please contact: [info@ctndm.es](mailto:info@ctndm.es) or visit: <http://www.ctndm.es>.

<sup>47</sup> There is a standard definition for sulphur polymer cement in ASTM C1159-98.

<sup>48</sup> The project of an industrial plant in Spain to develop this process is already made and the budget for its construction is approved; the commercial availability of this plant is expected at the end of 2015.

mixing the two substances for one hour and subsequently heating the mix to 130°C for one hour. Results of a Japanese leaching test (JLT-13) of solidified mercury sulphide show that the product's leaching rate ranges from 0.0009 to 0.0018 mg/L, which is below the elution test standard (0.005 mg/L) (Committee on consideration of environmentally sound management of mercury waste, 2014).

#### **Stabilization and solidification with sulphur microcements<sup>49</sup>**

207. The treatment of mercury wastes with sulphur microcements is another stabilization and solidification technology. Application of the technology results in a solid matrix that ensures the confinement of mercury because of its precipitation in the form of very insoluble oxides, hydroxides and sulfides. The technology is commercially available and has been tested in wastes with low levels of mercury contamination ( $\text{Hg} \leq 2$  per cent by weight).

208. Once the contaminated material to be treated has been characterized, the amount and type of microcement suitable for the application is determined. Microcements must have the following characteristics so that an adequate level of stabilization and microencapsulation of the mercury contained in contaminated materials can be achieved:

- (a) They must be inorganic and all particles are less than a certain size (a few microns);
- (b) They must contain mercury stabilising components, such as alkali sulphides;
- (c) They must have very high mechanical properties, so that volatilization and leaching of mercury can be avoided;
- (d) They should have a blast furnace slag percentage of over 60 per cent, a portland clinker component C3A content lower than 3 per cent and an alkali content below 0.6 per cent.

209. The process involves mixing of mercury-contaminated waste with the selected sulphur microcement and with water; the mixture is then discharged into the desired mould and matured over a 24–48 hour period in watertight and leak-protected areas. The final product can take different forms; the ones with fewer exposed surfaces, such as large cubic blocks, are recommended for the most contaminated waste.

210. The sulphur microcement treatment technology has been tested on, among others, mercury-containing waste obtained from the dredging of contaminated sludge from the Flix dam in the province of Tarragona in Spain. The final products ensure a high level of strength and durability and enable a safe handling and transport. The leaching values following tests according to standard EN 12457-4 (European Committee for Standardization (2002a) with a water/solid ratio of 10/1 are below 0,003 mg/kg, well below the EU acceptance criteria for landfills for inert solid wastes (<0.01 mg/kg, as per Decision 2003/33/EC). It is an inert product, and has high strength and durability enabling a safe mechanical handling and transport.

#### **Amalgamation**

211. Amalgamation is the dissolution and solidification of mercury in other metals such as copper, nickel, zinc and tin, resulting in a solid, non-volatile product. It is a subset of solidification technologies. 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 a wastewater that contains dissolved mercury salts; the base metal reduces mercuric and mercurous salts to mercury, which dissolves in the metal to form a solid mercury-based metal alloy called amalgam. The non-aqueous process involves mixing finely divided metal powders into waste mercury, forming a solidified amalgam. The aqueous replacement process is applicable to both mercury salts and mercury, while the non-aqueous process is applicable only to mercury. However, mercury in the resultant amalgam is susceptible to volatilization and leaching. Therefore, amalgamation is typically used in combination with an encapsulation technology, although based on concerns regarding possible volatilization and leaching, it should not be considered as a first option for treating wastes consisting of mercury (EPA 2007b).

#### **(ii) Soil washing and acid extraction**

212. Soil washing is an *ex situ* treatment of soil and sediment contaminated with mercury. It is a water-based process that uses a combination of physical particle size separation and aqueous-based chemical separation to reduce contaminant concentrations in soil. The process is based on the concept that most contaminants tend to bind to the finer soil particles (clay and silt) rather than the larger

<sup>49</sup> This section contains information provided by Cement International Technologies S.L. For further information, please contact: [info@cementinternationaltechnologies.com](mailto:info@cementinternationaltechnologies.com), or consult their website at: <http://www.cemintech.com>.



particles (sand and gravel). Physical methods can be used to separate the relatively clean larger particles from the finer particles because the finer particles are attached to larger particles through physical processes (compaction and adhesion). This process thus concentrates the contamination bound to the finer particles for further treatment. Acid extraction is also an *ex situ* technology that uses an extracting chemical such as hydrochloric acid or sulphuric acid to extract contaminants from a solid matrix by dissolving them in the acid. The metal contaminants are recovered from the acid leaching solution using techniques such as aqueous-phase electrolysis. More detailed information can be found in “Treatment technologies for mercury in soil, waste, and water” (EPA 2007b).

**(b) Disposal in specially engineered landfills**

213. Wastes contaminated with mercury or mercury compounds that meet the acceptance criteria for specially engineered landfills, as defined by national or local regulations, may be disposed of in specially engineered landfills.

214. Wastes containing mercury or mercury compounds<sup>50</sup> that result from the stabilization and solidification of wastes consisting of mercury or mercury compounds that meet the acceptance criteria for specially engineered landfills defined by national or local regulations may be disposed of in such landfills. Additional measures should be taken at such landfills to minimize releases and the methylation of mercury, for instance through the prevention of rainwater and groundwater inflows, the prohibition of mixing of different kinds of waste at the landfill site, the maintenance of records of waste amounts and areas landfilled, the collection of leachate and the long-term monitoring of releases of mercury and methylmercury from landfill sites into, e.g., air and groundwater.

215. Some jurisdictions have defined landfill acceptance criteria for wastes contaminated with mercury or mercury compounds. Under European Union legislation, only wastes with leaching limit values of 0.2 and 2 mg Hg/kg dry substance at a liquid-solid ratio of 10 l/kg can be accepted into landfills for non-hazardous and hazardous wastes, respectively. Under United States mercury waste treatment regulations, only low concentration mercury wastes can be treated and landfilled (high concentration waste must be retorted for mercury recovery). Treated mercury waste must leach less than 0.025 mg/l mercury (by TCLP testing) to be accepted for landfill disposal. Under Japanese legislation, treated wastes with mercury concentration equal to or less than 0.005 mg/l (Leaching Test Method: Japanese Standardized Leaching Test No. 13 (JLT-13) (Ministry of the Environment Notification No. 13) can be accepted into landfills for industrial wastes (leachate-controlled type), and those with mercury concentration in excess of 0.005mg/L should be disposed of at landfills for hazardous industrial wastes (isolated type) (see figure 6) (Ministry of the Environment of Japan, 2007b). In addition, disposal of certain mercury wastes in landfills is banned in some countries.

216. When wastes containing mercury or mercury compounds that result from the stabilization and solidification (S/S) of wastes consisting of mercury or mercury compounds are disposed of in a specially engineered landfill, special consideration should be given to the combination of S/S and methods for the final disposal of such wastes. Mercury sulphide is thermally decomposed at fire temperatures and can be oxidised by atmospheric oxygen at approximately 250-300°C to gaseous mercury and sulphur dioxide. The surface sealing of a landfill may be permeable to air in the long term. Mercury sulphide can then come into contact with atmospheric oxygen and become oxidised to mercury and sulphate. The formation of methylmercury may occur under certain geochemical conditions. Both gaseous mercury and methylmercury can leave the landfill via the gas circuit (landfill gas) (German Federal Environment Agency, 2014).

217. In addition to fire prevention, methods to stabilize and solidify wastes consisting of mercury or mercury compounds as well as the structure and sealing of the landfill accepting them should respond to mechanism referred to in the preceding paragraph to ensure mercury releases from the disposed wastes are minimized.

218. As an option for the disposal of wastes consisting of mercury, Japan has identified specific treatments and types of landfills that can be combined to dispose of such wastes, namely: 1) stabilization of mercury as mercury sulphide (HgS), followed by solidification (e.g., through the use of modified sulphur as described in paragraph 206) and disposal in a leachate-controlled type of landfill for industrial wastes, with additional measures taken to minimize releases and methylation of mercury, for instance through the prevention of rainwater and groundwater inflow, the prohibition of mixing of different types of waste at the landfill, and the maintenance of records of waste amounts and areas landfilled; and 2) stabilization of mercury as HgS followed by solidification and disposal in an isolated

<sup>50</sup> Waste mercury-added products should be treated to remove or recover mercury. This treatment will produce waste consisting of mercury or mercury compounds and waste contaminated with mercury or mercury compounds.

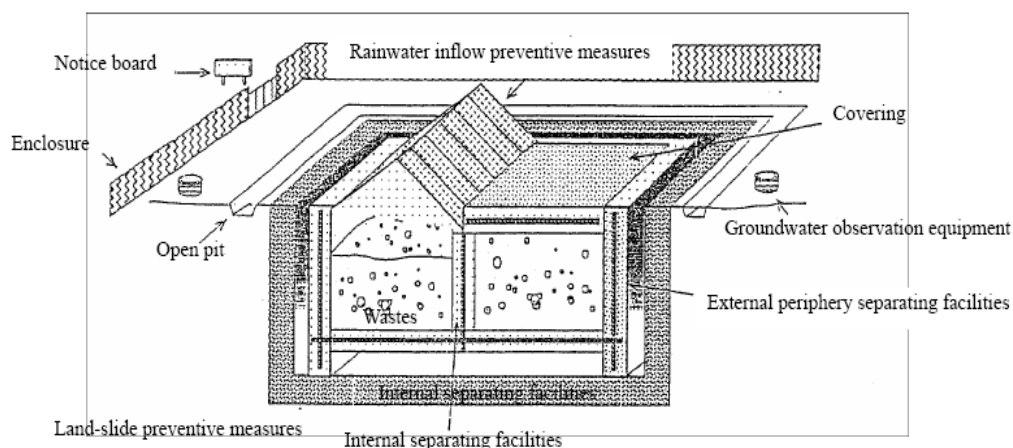
type of landfill for hazardous industrial wastes (see figure 6). Further specifications on these combinations will be determined based on further experiments and studies (Ministry of the Environment of Japan, 2015).

219. A specially engineered landfill is an environmentally sound system for solid waste disposal and is a site where solid wastes are capped and isolated from each other and from the environment. All aspects of landfill operations should be controlled to ensure that the health and safety of everyone living and working around the landfill are protected, and the environment is secured (UNEP, 1995b).

220. In principle, and for a defined period of time, a landfill site can be engineered to be environmentally safe provided that the site is appropriate and proper precautions and efficient management are undertaken. Specific requirements pertaining to site location, design and construction, landfill operations and monitoring should be met at specially engineered landfills in order to prevent leakages and contamination of the environment. In addition, control and oversight should be applied to the processes of site selection and landfill design and construction, operation and monitoring, and closure and post-closure care (UNEP, 1995b). Landfill permits should include specifications regarding the types and concentrations of wastes to be accepted, leachate and gas control and collection systems, groundwater monitoring, on-site security, and closure and post-closure requirements.

221. Particular attention should be paid to measures required to protect groundwater resources from leachate infiltration into soil. The protection of soil, groundwater and surface water should be achieved through a combination of a geological barrier and a bottom liner system during the operational phase of the landfill and a combination of a geological barrier and a top liner during the closure and post-closure phases. A drainage and collection system for leachate should be installed within the landfill to enable leachate to be pumped to the surface for treatment prior to discharge to water systems. Moreover, monitoring procedures should be established for the operation and post-closure phases of the landfill so that any possible adverse environmental effects of the landfill can be identified and appropriate corrective measures can be taken. The choice of landfill development and lining method should be made in light of the site, geology and other project-specific factors. Appropriate geotechnical engineering principles should be applied to different aspects of specially engineered landfills, such as the construction of dykes, cut slopes, landfill cells, roadways and drainage structures (Canadian Council of Ministers for the Environment, 2006). For example, landfill sites can be enclosed in watertight and reinforced concrete and covered with the types of equipment that prevent rainwater inflow such as a roof and a rainwater drainage system (See figure 6) (Ministry of the Environment of Japan, 2007a). A number of liner and leachate control systems have proven to be effective under varying conditions. The Basel Convention *Technical guidelines on specially engineered landfill[s] (D5)* provide details on a few examples of engineered containment systems that may be considered if the conditions are appropriate (UNEP, 1995b).

**Figure 6:** Example of a specially engineered landfill (landfill for hazardous industrial wastes (isolated type)) (Ministry of the Environment of Japan, 2007a)



222. For further information on specially engineered landfills, see Basel Convention *Technical guidelines on specially engineered landfill (D5)* (UNEP, 1995b).

**(c) Disposal in permanent storage (underground facilities)**

223. After having been solidified or stabilized, where appropriate, mercury wastes that meet the acceptance criteria for permanent storage (disposal operation D12) may be permanently stored in special containers in designated areas in underground storage facilities such as salt rocks.

224. The technology for underground storage is based on mining engineering, which uses technologies and methodologies to excavate mining areas and construct mining chambers as tessellated grids of pillars.<sup>51</sup> Decommissioned mines could be used for the permanent storage of solidified and stabilized waste once they have been evaluated and specifically adapted for that purpose.

225. In addition, the principles of and experience obtained with underground disposal of radioactive waste can be applied to the underground storage of mercury wastes. While the excavation of deep underground repositories can be achieved using standard mining or civil engineering technologies, such operations can only be conducted when locations are accessible (e.g., below surface or nearshore locations), rock units are reasonably stable and there is no major groundwater flow, and the excavation depth ranges between 250 m and 1000 m. At a depth greater than 1000 m, excavations become increasingly technically difficult and correspondingly expensive (World Nuclear Association, 2010).

226. The following publications, among others, contain detailed information on permanent underground storage for mercury wastes:

(a) European Union, 2003. "Safety Assessment for Acceptance of Waste in Underground Storage", Appendix A to *Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC*. Available at:

<http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:011:0027:0049:EN:PDF>;

(b) BiPRO, 2010. *Requirements for Facilities and Acceptance Criteria for the Disposal of Metallic Mercury*. Available at:

[http://ec.europa.eu/environment/chemicals/mercury/pdf/bipro\\_study20100416.pdf](http://ec.europa.eu/environment/chemicals/mercury/pdf/bipro_study20100416.pdf);

(c) International Atomic Energy Agency, 2009. *Geological Disposal of Radioactive Waste: Technological Implications for Retrievability*. Available at: [http://www-pub.iaea.org/MTCD/publications/PDF/Pub1378\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/Pub1378_web.pdf);

(d) World Nuclear Association, 2010. *Storage and Disposal Options*. Available at: <http://www.world-nuclear.org/info/inf04ap2.html>;

(e) Latin America and the Caribbean Mercury Storage Project, 2010. *Options analysis and feasibility study for the long-term storage of mercury in Latin America and the Caribbean*. Available at:

<http://www.unep.org/chemicalsandwaste/Mercury/InterimActivities/Partnerships/SupplyandStorage/LACMercuryStorageProject/tabid/3554/language/en-US/Default.aspx>; and

(f) Asia-Pacific Mercury Storage Project, 2010. *Options analysis and feasibility study for the long-term storage of mercury in Asia*. Available at:

<http://www.unep.org/chemicalsandwaste/Mercury/InterimActivities/Partnerships/SupplyandStorage/AsiaPacificMercuryStorageProject/tabid/3552/language/en-US/Default.aspx>.

227. Permanent storage in facilities located underground in geohydrologically isolated salt mines and hard rock formations is an option for separating hazardous wastes from the biosphere for geological periods of time. A site-specific risk assessment in accordance with pertinent national legislation, such as the provisions regarding safety assessment for acceptance of waste in underground storage contained in Appendix A to the Annex to Council Decision 2003/33/EC (European Union, 2003), which establishes criteria and procedures for the acceptance of waste at landfills, should be performed for every planned underground storage facility.

228. Wastes should be disposed of in a manner that (a) excludes any undesirable reaction between different types of waste and between stored wastes and storage linings; and (b) prevents the release and transport of hazardous substances. Operational permits should define the types of wastes that should be generally excluded. Wastes should be isolated through a combination of engineered barriers and natural barriers (rock, salt, clay), also known as a "multi-layer" approach to waste disposal. Facilities should be checked or monitored periodically to assure that the containment remains secure and stable. This is often termed a multi-barrier concept, with the waste packaging, the engineered

<sup>51</sup> Germany, for example, has significant experience with underground storage of hazardous waste.

repository and the geology all providing barriers to prevent any mercury leakage from reaching humans and the environment (BiPRO, 2010; European Union, 2003; IAEA, 2009; World Nuclear Association, 2010).

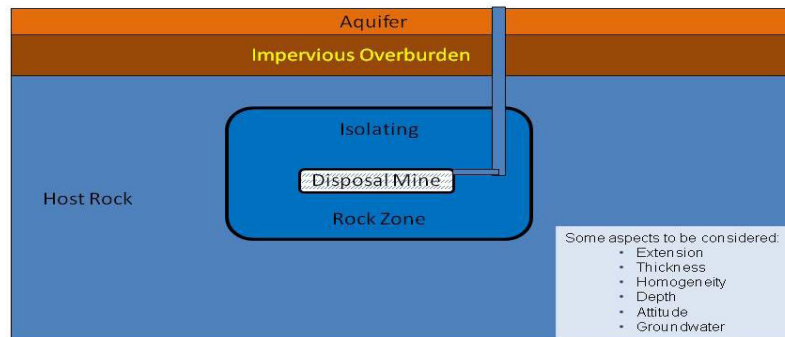
229. Specific factors that can affect the behaviour of mercury in the host rocks and geological formations used for permanent storage, such as the layout of storage facilities, types of containments used, storage location and conditions, monitoring, site access conditions, storage closure strategy, sealing and backfilling and depth of storage facilities, need to be considered separately from the properties of the wastes to be stored and the storage system to be used. Potential host rocks for permanent storage of mercury wastes include salt rock and hard rock formations (igneous rocks such as granite, metamorphic rocks, and gneiss sedimentary rocks such as limestone or sandstone). (BiPRO, 2010; European Union, 2003; IAEA, 2009; World Nuclear Association, 2010).

230. The following issues should be borne in mind when selecting a permanent underground storage site for the disposal of mercury wastes:

- (a) Caverns or tunnels used for storage should be completely separated from active mining areas and areas that may be reopened for mining;
- (b) Caverns or tunnels should be located in geological formations that are well below zones where groundwater is present or in formations that are completely isolated from water-bearing zones by impermeable rock or clay layers; and
- (c) Caverns and tunnels should be located in geological formations that are extremely stable and not in areas subject to earthquakes.

231. In order to guarantee the complete inclusion of wastes in permanent storage facilities, the disposal mine and any area around it that might be affected (geomechanically or geochemically) by disposal operations should be surrounded by a host rock (known as an “isolating rock zone”) of sufficient thickness and homogeneity, with suitable properties and at a suitable depth (see figure 7). As a basic principle, a long-term risk assessment should enable parties to prove that the construction and operational and post-operational phases of underground disposal facilities do not lead to any degradation of the environment. Consequently, appropriate models must be used to analyse and assess all technical barriers (e.g., waste forms, backfilling, sealing measures), the behaviour of the host and surrounding rock, overburden rock formations and the sequence of possible events in the overall system.

**Figure 7:** Concept of complete inclusion (schematic diagram) (courtesy: GRS)



232. If the host rock under consideration shows any deficiencies (e.g., insufficient homogeneity or thickness), a multi-barrier system can compensate for the missing or inadequate barrier properties of the rock. In general, a multi-barrier system of this kind is composed of one or several additional barrier components (see table 6 and figure 8) that can help to achieve the ultimate goal, i.e., to durably isolate stored wastes from the biosphere.

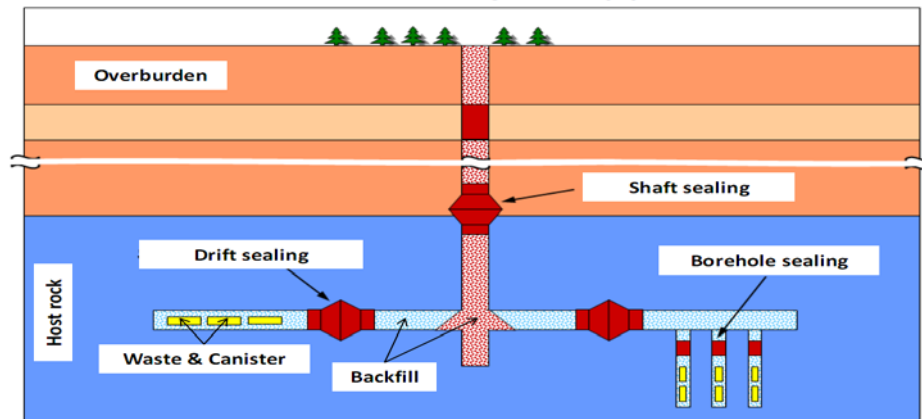
233. A long-term safety assessment (see above) should be conducted to ascertain the need for a multi-barrier system, and the mode of action of barrier components, within the disposal system. By way of example, the geological formation(s) overlaying a disposal mine (“overburden”) may be effective in:

- (a) Protecting the underlying host rock from any impairments of its properties; and/or
- (b) Providing additional retention capacities for contaminants that might be released from the disposal mine under certain circumstances.

**Table 6:** Possible components of a multi-barrier system and examples for their modes of action

Barrier component	Example for mode of action
Waste content	Reduction of the total amount of contaminants to be disposed of
Waste specification	Treatment of waste in order to get a less soluble contaminant
Waste canister	Bridging of a limited time period until natural barriers become effective
Backfill measures	Backfilling of void mine spaces to improve geomechanical stability and/or to provide special geochemical conditions
Sealing measures	Shaft sealing should provide the same properties where the natural barrier(s) is(are) disturbed by mine-access
Host rock	Complete inclusion of contaminants (in ideal cases)
Overburden	Provision of an additional natural (geological) barrier, e.g., through overlaying a clay layer with sufficient thickness and suitable properties

**Figure 8:** Main components of a multi-barrier system and their layout within the system (schematic diagram) (courtesy: GRS)



234. In general, an underground disposal system including all the criteria, requirements and final layout described above should be designed according to waste-specific and site-specific criteria, taking into consideration all relevant regulations (e.g., European Union, 2003). To give readers a rough idea of the depth and thickness of different types of host rocks suitable for underground storage, table 7 lists typical acceptable dimensions, based on past experience and current plans.

**Table 7:** Typical values of vertical thickness of host rock body and potential disposal depth (Grundfelt et al., 2005)

Geosystem		Thickness of host rock body	Potential disposal depth
Host rock	Variant		
Rock salt	Salt dome	up to > 1,000 m	800 m
Rock salt	Layered salt	app. 100 m	650 – 1,100 m
Clay / Claystone		up to 400 m	400 – 500 m
Rocks under clay cover		app. 100 m	500 – 1,000 m

## H. Reduction of mercury releases from thermal treatment and landfilling of waste

### 1. Reduction of mercury releases from thermal treatment of waste

235. Whenever possible, mercury-added products should not be disposed of together with municipal solid waste (MSW). Separate collection of mercury wastes leads to a reduction of overall mercury loads in mixed MSW, but separate collection rates of 100 per cent are not achieved in practice. As a result, wastes containing or contaminated with mercury or mercury compounds may be combusted with MSW and, by reason of its low boiling point, almost all the mercury in the waste may be transferred to combustion gas and, to a lesser extent, bottom ash. Most of the mercury in the combustion gas fed into waste combustion units is elemental mercury and transforms to divalent mercury after passing through the units, and part of the divalent mercury transfers to fly ash. The divalent mercury is assumed to be mercuric chloride; consequently, flue gas treatment devices that can effectively remove mercuric chloride and mercury should be selected. In addition, waste that potentially contains or is contaminated with mercury, such as poorly segregated waste from healthcare facilities, should not be incinerated in incinerators that lack flue gas treatment devices (Arai et al., 1997). Emission and effluent standards for mercury should be set and mercury levels of treated flue gas and wastewater should be monitored to ensure that mercury releases into the environment are kept to a minimum. Such practices should also be applied in other thermal waste treatment processes such as vacuum-sealed roasting facilities.

236. Primary techniques for reducing the inclusion of mercury in the waste stream include the following (European Commission, 2006):

- (a) Efficient removal of mercury-added products from the waste stream (e.g., through separate collection of certain types of batteries dental amalgam (using amalgam separators) before mercury-added wastes are co-mingled with other wastes or wastewaters;
- (b) Notification of waste producers of the need to segregate mercury;
- (c) Identification and/or restriction of receipt of potential mercury wastes; and
- (d) When mercury wastes have been knowingly received, control of feeding of such wastes into abatement systems in order to avoid overloading system capacities.

237. Secondary techniques for preventing mercury releases to the air from the waste stream include treatment of flue gas. The European Union industrial emissions directive (European Union, 2010b), which repealed and replaced Directive 2000/76/EC on the incineration of waste, sets emission limit values for discharges of wastewater from the cleaning of flue (waste) gases and air emission limit values for waste incineration plants. Regarding the former, unfiltered samples must not contain more than 0.03 mg/L mercury and its compounds, expressed as mercury (Hg); as for the latter, air emissions must not exceed 0.05 mg/Nm<sup>3</sup> mercury and its compounds, expressed as mercury (Hg), over a sampling period of a minimum 30 minutes and a maximum eight hours. Under the 1998 Protocol on Heavy Metals to the 1979 UNECE Convention on Long-range Transboundary Air Pollution, as amended by Decision 2012/5 by the parties to the Protocol, mercury emissions from waste incineration must not exceed 0.05 mg/m<sup>3</sup>.

238. The selection of a process to control mercury flue gas emissions depends on the chlorine content of the materials being burned. When the chlorine content of such materials is high, the mercury contained in resultant crude flue gas will tend to be in the oxidized form, in which case it can be deposited and captured in wet scrubbers. In incineration plants for municipal and hazardous wastes, under normal operating conditions, the chlorine content of such wastes usually will be high enough to ensure that mercury is present mainly in the oxidized form. Volatile mercury compounds, such as HgCl<sub>2</sub>, will condense and dissolve in the scrubber effluent when flue gas is cooled. The addition of reagents for the removal of mercury provides a means for removing mercury from the process. It should be noted that, in the incineration of sewage sludge, mercury emissions will consist mostly of elemental mercury, due to the lower chlorine content of such sludge compared to that of municipal or hazardous waste. Consequently, special attention must be paid to capturing these emissions. Elemental mercury can be removed by transforming it into oxidized mercury; this can be done by adding oxidants to the mercury and then depositing the resultant mix in a scrubber or directly on sulphur doped activated carbon, hearth furnace coke, or zeolites. The removal of heavy metals, including mercury, from wet scrubber systems can be achieved through flocculation, a process in which metal hydroxides are formed under the influence of flocculating agents (poly-electrolytes) and FeCl<sub>3</sub>. For the removal of mercury, complex-builders and sulphides (e.g., Na<sub>2</sub>S and Tri-Mercaptan) are added.

239. The removal of mercury from flue gas can be achieved through adsorption on activated carbon reagents in an entrained flow system in which activated carbon is injected into the gas flow and filtered from the gas flow with the use of bag filters. Activated carbon has demonstrated to have a high adsorption efficiency for mercury, as well as for dioxins and furans (PCDD/PCDF). Different types of activated carbon have different adsorption efficiencies, presumably due to the nature of various carbon particles and the influence exerted on the particles by manufacturing processes (European Commission, 2006). Almost all emission relevant flue-gas components, in particular residual contents of hydrochloric acid, hydrofluoric acid, sulphur oxides and heavy metals (including mercury), can effectively be deposited in static bed filters of grained hearth furnace coke (HFC), a fine coke of 1.25 mm to 5 mm. The depositing effect of HFC is essentially based on mechanisms of adsorption and filtration. In general, incinerators should be equipped with flue gas treatment devices to capture NO<sub>x</sub>, SO<sub>2</sub>, particulate matter, mercury vapour and particulate-bound mercury as a co-benefit. Powdered activated carbon injection is one of the advanced technologies used for mercury removal in incinerators and coal-fired power plants. Mercury adsorbed on activated carbon can be stabilized or solidified for disposal (see subsection III.G.2 (a) above).

240. For the reduction of mercury emissions from waste incineration, the following documents provide additional technical information:

(a) UNECE, 1998 *Heavy Metals Protocol to the Long-range Transboundary Air Pollution* and 2013 *Guidance document on best available techniques for controlling emissions of heavy metals and their compounds from the source categories listed in annex II*. Both documents are available from: <http://www.unece.org/env/treaties/welcome.html>;

(b) UNEP, 2010. *Study on mercury sources and emissions and analysis of cost and effectiveness of control measures: "UNEP Paragraph 29 study"* (doc. UNEP(DTIE)/Hg/INC.2/4). Available from: <http://www.unep.org/chemicalsandwaste/Mercury/Negotiations/INC2/INC2MeetingDocuments/tabid/3484/language/en-US/Default.aspx>;

(c) UNEP, 2002. *Global Mercury Assessment*. Available at: <http://www.unep.org/chemicalsandwaste/LinkClick.aspx?fileticket=Kpl4mFj7AJU%3d&tabid=3593&language=en-US>;

(d) European Commission, 2006. *Reference Document on the Best Available Techniques for Waste Incineration*. Available from: <http://eippcb.jrc.ec.europa.eu/reference/wi.html>; and

(e) National legislation, e.g., European Union Directive 2010/75/EU on Industrial Emissions (European Union, 2010a).

241. When a wet scrubber is used as a flue gas treatment method, it is essential that wastewater from the wet scrubber be treated.

## 2. Reduction of mercury releases from landfills

242. For reduction of mercury releases from specially engineered landfills, see subsection III.G.2 (b) above. The following paragraphs provide directions for the reduction of mercury releases from municipal solid waste landfills.

243. When the disposal of wastes containing or contaminated with mercury or mercury compounds in landfills (operation D1) is unavoidable, there are three types of pathways through which mercury can be released into the environment: the working face of the landfill, leachate, and landfill gas. The most important sites of mercury emissions are landfill working faces and methane vents (Lindberg and Price, 1999).

244. Landfill cover should be applied every day to reduce the direct release of mercury from wastes that have been newly added to landfills (Lindberg and Price, 1999). Landfill fires can also result in increased mercury releases. For prompt application of soil cover in case of landfill fires, soil cover materials and machines used for applying soil cover for the purpose of extinguishing fires (e.g., dump truck, dozer shovel) should be readily available.

245. It is reported that mercury releases through leachate are fairly minimal compared to releases through landfill gas (Yanase et al., 2009; Takahashi et al., 2004; Lindberg et al., 2001). Mercury transferred to leachate can be removed through leachate collection and treatment, as is the case for wastewater from wet scrubbers of waste incinerators.

246. A landfill gas capture system should be installed at the site to capture mercury vapour and methylmercury and thereby prevent their release into the atmosphere.

## I. Remediation of contaminated sites

247. Mercury-contaminated sites are widespread around the world and are largely the result of industrial activities, primarily mining, including non-ferrous metals mining and ore processing; chlorine production; and the manufacture or improper disposal of mercury-added products. The vast majority of contamination at mining sites is the result of ASGM in which mercury is used, an activity that has largely ceased or is subject to regulatory and engineering controls in developed countries but that continues in the developing world. The existence of sites with mercury-contaminated soils and large mine tailing piles and of sites with widely dispersed areas of contamination that has migrated via water courses and other elements is the result of both historic and current operations.

248. The Minamata Convention contains provisions that require the development of detailed technical guidance for addressing contaminated sites (see paragraph 26 above).

### 1. Identification of contaminated sites and emergency response

249. The identification of a mercury-contaminated site that poses a threat to human health or the environment can be achieved through:

- (a) Records identifying past industrial or other activities at the site;
- (b) Visual observation of site conditions and attendant contaminant sources;
- (c) Visual observation of manufacturing or other operations known to have used or emitted a particularly hazardous contaminant;
- (d) Observed adverse effects in humans, flora or fauna possibly caused by their proximity to the site;
- (e) Physical or analytical results showing contaminant levels; and
- (f) Community reports to the authorities regarding suspected releases.

250. Sites contaminated with mercury are similar to other contaminated sites in that mercury can reach receptors in a variety of ways. Mercury is particularly problematic because of its hazardous vapour phase, its low level of observable effects on animals, and the different levels of toxicity of its different forms (e.g., mercury vs. methylmercury). Mercury is also readily detectable using a combination of field instruments and laboratory analyses. Sites contaminated with mercury may also be contaminated with other pollutants. During site assessments and remediation activities, all possible on-site pollutants should be considered; consideration of all possible pollutants is likely to be the most cost-effective approach to making the site available for future use.

251. The first priority when dealing with mercury-contaminated sites is to isolate the contamination from contamination receptors in order to minimize their further exposure. In this respect, dealing with sites contaminated with mercury is similar to dealing with any other site contaminated with potentially mobile toxic contaminants.

252. If the mercury-contaminated site is residential and is relatively small, ample guidance on emergency response is available in the *EPA Mercury Response Guidebook*, which was designed to address small- to medium-sized mercury spills in residences (EPA, 2001).

253. For larger sites in developing countries contaminated as the result of informal mercury use (e.g., ASGM), the *Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners* (GMP, 2004) provides recommendations on emergency response.

### 2. Environmentally sound remediation

254. The types of remedial action (i.e., clean-up activities) to be taken at mercury-contaminated sites depend on a variety of factors that define the type of contamination present and its potential environmental and health impacts. The following factors should be considered in the selection of treatment technologies for initial site screening and of techniques and technologies to clean up the site:

- (a) Environmental factors:
  - (i) Amounts of mercury released during site operations;
  - (ii) Origin of the contamination;
  - (iii) Chemical state of the mercury found at the contaminated site;



- (iv) Number, size and location of mercury hotspots requiring remediation;
  - (v) For mining operations, properties of the geological material from which the mercury is mined, including soil characteristics, etc.;
  - (vi) Methylation potential of the mercury found at the site;
  - (vii) Leaching potential of mercury from contaminated media (e.g., soils and sediments);
  - (viii) Background mercury contamination (i.e., regional atmospheric mercury deposition not related to localized sources);
  - (ix) Mercury mobility in aquatic systems;
  - (x) Presence and levels of other pollutants, particularly those that may be treated or partially treated through the same methods used to treat mercury; and
  - (xi) Local/state/federal clean-up standards for water, soils and sediments, and air.
- (b) Receptor:
- (i) Bioavailability to aquatic biota, invertebrates and edible plants; and
  - (ii) Mercury concentrations in receptors (humans, animals and plants indicating exposure to mercury).

255. Once these factors have been assessed, a more complete analysis of the appropriate remediation techniques can be performed. Depending on the severity, extent, level and type of mercury contamination, the presence of other contaminants and receptors, a remedial plan based on the use of several techniques may need to be developed to efficiently and effectively reduce the toxicity, availability and amount of mercury contamination at the site. For information on remediation techniques, see *Mercury Contaminated Sites: A Review of Remedial Solutions* (Hinton, 2001) and *Treatment Technologies for Mercury in Soil, Waste, and Water* (EPA, 2007b).<sup>52</sup> Information about remediation cases is available with regard to mercury contamination in Minamata Bay, Japan (Minamata City Hall, 2000), and near Marktredwitz, Germany (North Atlantic Treaty Organization Committee on the Challenges of Modern Society, 1998).

## J. Health and safety

256. Employers should ensure that the health and safety of every employee are protected while they are at work. Every employer should obtain and maintain insurance, under an approved policy from an authorized insurer, providing a sufficient level of coverage in case of liability (compensation) for bodily illness or injury sustained by employees arising out of and in the course of their employment, in accordance with national law. Health and safety plans should be in place at all facilities that handle mercury wastes to ensure the protection of everyone in and around such facilities. Such plans should be developed for each facility by trained health and safety professionals with experience in managing health risks associated with mercury.

257. The protection of workers who are engaged in the management of mercury wastes and the general public can be achieved through the following ways:

- (a) By allowing access to facilities to authorized personnel only;
- (b) By ensuring that occupational exposure limits for hazardous substances are not exceeded by making sure that all personnel use appropriate protective equipment;
- (c) By ensuring appropriate ventilation of facilities to minimize risk from exposure to volatile substances or substances that can become airborne; and
- (d) By ensuring facility compliance with all national and regional laws on workplace health and safety.

258. Guideline values for mercury concentrations in drinking water and ambient air have established by WHO are 0.006 mg/L for inorganic mercury and 1 µg/m<sup>3</sup> for inorganic mercury vapour (WHO, 2006; WHO Regional Office for Europe, 2000). Governments are encouraged to monitor air and water in order to protect human health, especially near sites where mercury waste management

<sup>52</sup> Additional information is available on the EPA website, e.g., *Mercury Treatment Technologies* (available at: [http://www.clu-in.org/contaminantfocus/default.focus/sec/Mercury/cat/Treatment\\_Technologies/](http://www.clu-in.org/contaminantfocus/default.focus/sec/Mercury/cat/Treatment_Technologies/)) and *Policies and Guidance* (available at: <http://www.epa.gov/superfund/policy/guidance.htm>).

activities take place. Some countries have established permissible levels of mercury in the working environment (e.g., 0.025mg/m<sup>3</sup> Hg for inorganic mercury, excluding mercury sulphide, and 0.01mg/m<sup>3</sup> Hg for alkylmercury compounds in Japan); waste management operations should be conducted so as to satisfy requirements regarding permissible levels of mercury in the working environment, and facilities where such operations are conducted should be designed and operated so as to minimize mercury releases to the environment as far as is technically possible.

259. Special attention should be paid to sites where mercury-added products are handled. Within the waste stream, mercury emissions from mercury-added products can lead to exposures that raise health concerns and contribute to environmental releases at multiple points. Waste collectors, truck drivers and workers at transfer stations can be exposed to brief peaks of mercury vapour when handling waste mercury-added products. Waste management employees at the “working face” of a landfill – the active area where waste is dumped, spread, compacted and buried – can be repeatedly exposed to mercury vapour. Those in the informal waste sector involved in scavenging landfills for reclaimable items can be chronically exposed. Venting points for methane gas generated by decaying organic wastes are additional sources of mercury release and exposure.

260. Disposal facilities, especially where mercury recovery operations are conducted, also present a high risk of mercury exposure. Major activities presenting high risk of exposure include the crushing of fluorescent lamps, the extraction of mercury from mercury-added products such as thermometers and barometers, the thermal treatment of wastes containing or contaminated with mercury, and the stabilization and/or solidification of wastes consisting of mercury or mercury compounds.

261. Employee training in effective ESM and workplace health and safety should be provided to, among other things, ensure employee safety against mercury exposure and accidental injury when managing waste.

262. The basic knowledge that employees need includes:

- (a) The definition of mercury wastes and the chemical properties and adverse effects of mercury;
- (b) How to identify mercury wastes and to segregate such wastes from other types of wastes;
- (c) Occupational safety standards relevant to mercury and how to safeguard their health against mercury exposure;
- (d) How to use of personal protective equipment, such as body coverings, eye and face protectors, gloves and respiratory protectors;
- (e) Proper labelling and storage requirements, container compatibility and dating requirements, and closed-container requirements;
- (f) How to safely handle mercury wastes, particularly used products containing mercury such as thermometers and barometers, using the equipment available at the facility in which they work;
- (g) How to uses engineering controls to minimize exposure; and
- (h) How to respond in an emergency if mercury in waste is accidentally spilled.

263. It is important to have worker insurance and employer liability insurance in order to be better prepared for accidents or injuries sustained by workers in the facility, as appropriate under national law.

264. A mercury awareness-raising package developed by UNEP (UNEP, 2008d) is recommended for use in employee training. All training materials should be translated into local languages and made accessible to employees.

## **K. Emergency response**

### **1. Emergency response plan**

265. Emergency response plans should be in place at each stage of the mercury waste processing chain (e.g., generation, storage, transport, treatment or recovery, and disposal). While emergency response plans can vary depending on the activities carried out at each stage of waste management and the physical and social conditions of each management site, the principal elements of an emergency response plan include the identification of potential hazards; compliance with legislation

governing emergency response plans; specification of actions to be taken in emergency situations, including mitigation measures, personnel training plans, communication targets (e.g., fire services, police, neighbouring communities, local governments, etc.) and methods to be used in case of emergency; and specification of the method and frequency of testing of emergency response equipment.

266. When an emergency occurs, the first step is to examine the site. The person in charge should approach the site cautiously from upwind, secure the scene and identify any hazards. Placards, container labels, shipping documents, material safety data sheets, car identification charts and/or knowledgeable persons on the scene are valuable information sources. The need for site evacuation, the availability of human resources and equipment, and possible immediate actions should then be assessed. In order to ensure public safety, an emergency response agency call should be made and, as an immediate precautionary measure, spill and leak areas should be isolated for at least 50 meters in all directions. In case of fire, a suitable extinguishing agent should be used and the use of water should be avoided. For further information, the *Emergency Response Guidebook* (U.S. Department of Transportation et al, 2012) can be consulted.

## 2. Special consideration for spillage of mercury or mercury compounds

267. Spillage of mercury or mercury compounds occurs primarily when waste mercury-added products are broken. Most cases of spillage seem to involve mercury-added glass thermometers, which are easily broken. Although the mercury in each glass thermometer is about 0.5-3 g and does not usually lead to serious health problems, all mercury spills should be considered hazardous and should be cleaned up with caution. Indoor areas should be adequately ventilated. If a person experiences discomfort following a mercury spill, a medical doctor and/or the environmental health authorities should be contacted immediately.

268. If the spill is small and simple (e.g., it occurs on a non-porous area such as linoleum or hardwood flooring, or on a porous item that can be thrown away, such as a small rug or mat), it can be cleaned up by an individual. If the spill is large or complex (e.g., it occurs on a rug that cannot be discarded, on upholstery, or in cracks or crevices), it may be necessary to hire a trained professional to contain it or clean it up. Large spills involving more than the amount of mercury found in a typical household product should be reported to the local environmental health authorities. If there is any uncertainty as to whether a spill should be classified as “large”, the local environmental health authorities should be contacted as a precautionary measure. Under certain circumstances, it may be advisable to obtain the assistance of qualified personnel for professional clean-up or air monitoring, regardless of spill size (Environment Canada, 2002).

269. Spills of mercury in the course of commercial activities and in households have the potential to expose workers and the general public to hazardous mercury vapours. In addition, the spills are both costly to clean up and disruptive. Clean-up procedures for small mercury spills are found in the USEPA’s website (United States EPA, 2007c).

270. Critical to determining what type of response is appropriate for any mercury spill is evaluating the size of the spill and the extent of mercury dispersal and whether the necessary clean-up resources and expertise are available. Professional help should be sought in the following cases:

- (a) The amount of mercury could be more than 2 tablespoons (30 millilitres). Larger spills should be reported to the authorities for oversight and follow-up;
- (b) The spill area is undetermined: If the spill was not witnessed or the extent of the spill is hard to determine, there could be small amounts of mercury that are hard to detect and must be cleaned up;
- (c) The spill area contains surfaces that are porous or semi-porous: Surfaces such as carpet and acoustic tiles can absorb the spilled mercury and make clean-up practically impossible; and
- (d) The spill occurs near a drain, fan, ventilation system or other conduit: mercury and mercury vapours can quickly move away from the spill site and contaminate other areas without being easily detected.

271. Scattering of spilled mercury (e.g., with the use of water jets) should be avoided as much as possible because it significantly increases the mercury evaporation rate. (World Chlorine Council, 2004)

## L. Awareness and participation

272. Public awareness and participation play key roles in implementing ESM of mercury wastes. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. It is essential that the public and all stakeholders have a chance to participate in the development of legislation, policy, programmes and other decision-making processes related to mercury.

273. Articles 6, 7, 8 and 9 of the 1998 United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) require specific action pertaining to public participation in specific government activities, the development of plans, policies and programmes, and the development of legislation, and call for access to justice for the public with regard to the environment.

274. When initiating activities such as the collection and recycling of mercury waste, it is advisable that participation and cooperation from the consumers who generate mercury-containing waste be obtained. Continuous awareness-raising is key to the successful collection and recycling of mercury waste. Encouraging public involvement in the design of a collection and recycling system for mercury waste by providing the public with information about potential problems caused by the environmentally unsound management of such waste would help to increase consumer awareness about the risks of mercury and mercury waste.

275. Public awareness and sensitization campaigns for local communities and citizens are important elements in promoting public participation in the ESM of mercury wastes. In order to raise the awareness of citizens, the authorities concerned, e.g., local governments, need to initiate various awareness-raising and sensitization campaigns to prompt citizens to take an interest in protecting themselves and others against the adverse effects of mercury on human health and the environment. It is important to involve community-based organizations in such campaigns because they have a close relationship with residents and other stakeholders in their communities (Honda, 2005).

276. Programmes for public awareness and public participation should generally be developed around a waste management situation at the national, local or community level. Table 8 shows examples of programmes for public awareness and participation. Such programmes have four elements: publications, environmental education programmes, public relations activities, and risk communication, to which citizens should have easy access in public places (Honda, 2005).

**Table 8:** Programmes for public awareness and public participation

	Contents	Expected results
<b>Publications</b>	<ul style="list-style-type: none"> <li>• Booklets, pamphlets, brochures, magazines, posters, websites, etc., in various languages and dialects to explain mercury issues in simple terms</li> <li>• Guidebooks on how to dispose of mercury waste</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge sources</li> <li>• Explanation of how people can handle mercury-added products and dispose of mercury waste</li> </ul>
<b>Environmental Education Programmes</b>	<ul style="list-style-type: none"> <li>• Voluntary seminars</li> <li>• Community gatherings</li> <li>• Linkages with other health workshops</li> <li>• Demonstrations of take-back programmes</li> <li>• Scientific studies</li> <li>• Tours to facilities, etc.</li> <li>• eLearning</li> </ul>	<ul style="list-style-type: none"> <li>• Raising knowledge</li> <li>• Sharing common issues</li> <li>• Opportunities to discuss environmental issues directly</li> </ul>
<b>Activities</b>	<ul style="list-style-type: none"> <li>• Take-back programmes</li> <li>• Mercury-free product campaigns</li> <li>• Waste minimization campaigns</li> <li>• Community gatherings</li> <li>• House-to-house visits</li> </ul>	<ul style="list-style-type: none"> <li>• Implementation of environmental activities among all partners</li> <li>• Environmental appeal for citizens</li> <li>• <i>One-on-one</i> communications</li> </ul>
<b>Risk Communication</b>	<ul style="list-style-type: none"> <li>• Mercury exposure in general living environments</li> <li>• Safe level of mercury exposure</li> <li>• Mercury pollution levels</li> </ul>	<ul style="list-style-type: none"> <li>• Proper understanding of safe- and risk levels of mercury exposure, in appropriate circumstances</li> </ul>

	Contents	Expected results
	<ul style="list-style-type: none"> <li>• PRTR</li> <li>• Fish consumption advisories</li> <li>• Rice consumption advisories</li> <li>• Response to mercury spills from mercury-added products</li> </ul>	<ul style="list-style-type: none"> <li>• Avoidance of overreaction</li> </ul>

277. As part of environmental education programmes, publications should provide basic knowledge of mercury properties, mercury toxicology, the adverse effects of mercury on human health and the environment, and mercury waste-related issues, including how to manage and avoid possible exposure to mercury from such waste. Publications should be translated into locally relevant languages and dialects to ensure the information is communicated efficiently to the target population.

278. The components of an environmental education programme on mercury wastes are as follows (Honda, 2005):

- (a) Awareness-raising and sensitization regarding the environment and environmental challenges;
- (b) Building of knowledge and understanding of the environment and environmental challenges;
- (c) Development of attitudes of concern for the environment and a motivation to improve or maintain environmental quality;
- (d) Development of skills to identify and help resolve environmental challenges; and
- (e) Participation in activities that lead to the resolution of environmental challenges.

279. The partners of programmes on public participation can be summarized as follows (Honda, 2005):

- (a) Government officials and staff in governments who work on environmental issues;
- (b) People who are interested in environmental problems and have the ability to quickly understand and disseminate information to others:
  - (i) Children and students;
  - (ii) Teachers and professors;
- (c) Leaders and representatives from local communities and groups and others working in the field of the environment at the local or community level:
  - (i) People who work in non-governmental organizations;
  - (ii) People who work in small and medium-sized enterprises;
  - (iii) Local producers, collectors and recyclers, disposal facility owners, operators, and workers who handle mercury waste;
- (d) People who are, or reside, in proximity to waste management or mercury contaminated sites;
- (e) Local organizations;
- (f) City residents; and
- (g) Enterprises.

280. To ensure that mercury releases from collection, transportation and disposal of waste are kept to a minimum, it is important to raise the awareness of the parties concerned (e.g., transporters, recyclers, and treatment operators) about the risks of mercury. This can be achieved through awareness-raising activities, such as seminars, that can provide information about new systems and regulations and opportunities for information exchange; the preparation and distribution of leaflets; and the dissemination of information via the Internet.

## Annex to the technical guidelines

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