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BASEL CONVENTION

Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
Tenth meeting
Cartagena, Colombia, 17–21 October 2011
Item 3 (b) (i) of the provisional agenda*

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

Technical guidelines

Note by the Secretariat

Addendum

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

At its tenth meeting, the Conference of the Parties adopted, as amended, the technical guidelines for the environmentally sound management of wastes consisting of elemental mercury and wastes containing or contaminated with mercury on the basis of the draft contained in document UNEP/CHW.10/6/Add.2, which was prepared by a small intersessional working group led by the Government of Japan. The text of the final version of the technical guidelines is set out in the annex to the present document.

* UNEP/CHW.10/1.

Annex

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

Revised final version (31 October 2011)

Contents

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
CFLs	Compact Fluorescent Lamps
CH_3Hg^+ or $MeHg^+$	Monomethylmercury, commonly called methylmercury
Cl	Chlorine
EMS	Environmental Management System
EN	European Standard
EPR	Extended Producer Responsibility
EU	European Union
ESM	Environmentally Sound Management
FAO	Food and Agriculture Organization of the United Nations
GMP	Global Mercury Project
HCl	Hydrochloric acid
HF	Hydrofluoric acid
Hg	Mercury
$HgCl_2$	Mercury dichloride
HgO	Mercury (II) oxide
HgS	Mercury sulphide or cinnabar
$HgSO_4$	Mercury sulphate
HNO_3	Nitric acid
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILO	International Labour Organization
IMERC	Interstate Mercury Education and Reduction Clearinghouse
IMO	International Maritime Organization
ISO	International Organization for Standardization
J-Moss	Marking of presence of the specific chemical substances for electrical and electronic equipment
JIS	Japanese Industrial Standards
JLT	Japanese Standardized Leaching Test
LCD	Liquid Crystal Displays
LED	Light Emitting Diode
MMSD	Mining, Minerals and Sustainable Development
MSW	Municipal Solid Waste
NEWMOA	Northeast Waste Management Officials' Association
NGO	Non-Governmental Organization
NIP	National Implementation Plan
NIMD	National Institute for Minamata Disease
NOx	Nitrogen oxide
OEWG	Open-ended Working Group
OECD	Organization for Economic Cooperation 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
PVC	Polyvinyl chloride
RoHS	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
SAICM	Strategic Approach to International Chemicals Management
SBC	Secretariat of the Basel Convention
SETAC	Society of Environmental Toxicology and Chemistry
SO_2	Sulphur dioxide
SOP	Standard Operational Procedure
SPC	Sulphur Polymer Cement
S/S	Solidification/Stabilization
TCLP	Toxicity Characteristic Leaching Procedure
TOC	Total Organic Carbon
TS	Technical Specification
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USEPA	United States Environmental Protection Agency
VCM	Vinyl chloride monomer
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization

I. Introduction

A. Scope

1. The present guidelines provide guidance for the environmentally sound management (ESM) of wastes consisting of elemental mercury and wastes containing or contaminated with mercury, pursuant to decisions VIII/33, IX/15 and X/[ ] of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal and decision VII/7 of the Open-ended Working Group of the Basel Convention.

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 wastes are covered by the guidelines (see Table -2 for more examples):

A. Wastes consisting of elemental mercury (e.g., elemental mercury recovered from waste containing mercury and waste contaminated with mercury and surplus stock of elemental mercury designated as waste);

B. Wastes containing mercury (e.g., waste of mercury-added products):

B-1. Wastes of mercury-added products that easily release mercury into the environment when they are broken (e.g., waste mercury thermometers, fluorescent lamps);

B-2. Wastes of mercury-added products other than B-1 (e.g., batteries);

B-3. Stabilized or solidified wastes containing mercury that result from the stabilization or solidification of wastes consisting of elemental mercury;

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

3. The present guidelines focus on wastes consisting of elemental mercury and wastes containing or contaminated with mercury categorized as hazardous waste.

B. About mercury[1]

4. Mercury is or has been widely used in products such as medical devices (thermometers, blood pressure gauges), switches and relays, barometers, fluorescent light bulbs, batteries and dental fillings, and in industrial production such as chlor-alkali plants, vinyl chloride monomer (VCM) production, acetaldehyde production and mercury-added product manufacturing. Mercury may also be a by-product of raw materials refining or production processes such as non-ferrous mining and oil and gas operations. Mercury is recognized as a global hazardous pollutant. Mercury emissions and releases can be human-caused (anthropogenic) and may also come from natural sources. Once mercury is released into the environment, it persists in the atmosphere (mercury vapour), soil (ionic mercury) and aquatic phase (methylmercury (MeHg, or CH_3Hg^+)). Some mercury in the environment ends up in the food chain because of bioaccumulation and biomagnification and is eventually ingested by humans.

1 Further information on mercury and its chemical properties, sources, behaviour in the environment, human health risks and pollution is available from several sources (see Bibliography below)

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

5. Improper handling, collection, transportation or disposal of wastes consisting of elemental mercury and wastes containing or contaminated with mercury can lead to releases of mercury, as can some disposal technologies.

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

7. Although the provisions of the future global legally binding instrument on mercury 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 low-carbon-society strategy, and in those used to back-light for liquid crystal displays (LCD). Ensuring ESM, particularly of wastes consisting of elemental mercury and wastes containing mercury, will be a critical issue for most countries.

II. Relevant provisions of the Basel Convention and international linkages

A. Basel Convention

1. General provisions

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

9. In paragraph 4 of Article 2, the Convention defines disposal as "any operation specified in Annex IV" to the Convention, which includes operations 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).

10. Paragraph 1 of Article 4 ("General obligations") 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)."

11. Paragraphs 2 (a)–(e) and 2 (g) of Article 4 set out key provisions pertaining to ESM, waste minimization, reduction of transboundary movement, and waste disposal practices that mitigate 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

12. Article 1 ("Scope of the Convention") defines the waste types covered by the Convention. Subparagraph (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").

13. 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)” and 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.

14. List A of Annex VIII to the Convention describes wastes that are “characterized as hazardous under Article 1 paragraph 1 (a) of this Convention” although “designation of a waste on Annex VIII does not preclude the use of Annex III (hazardous characteristics) to demonstrate that a waste is not hazardous” (Annex I, paragraph (b)). List B of Annex IX lists 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”.

15. As stated in paragraph 1 (b) of Article 1, “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 Convention.

16. Wastes consisting of elemental mercury and wastes containing or contaminated with mercury listed in Annexes I and VIII to the Basel Convention are shown in Table -1.

Table -1 Wastes consisting of elemental mercury and wastes containing or contaminated with mercury listed in Annexes I and VIII to the Basel Convention

Entries with direct reference to mercury	
Y29	Wastes having as constituents: ***Mercury***; ***mercury compounds***
A1010	Metal wastes and waste consisting of alloys of any of the following: … - ***Mercury*** … but excluding such wastes specifically listed on list B.
A1030	Wastes having as constituents or contaminants any of the following: … - ***Mercury; mercury compounds*** …
A1180	Waste electrical and electronic assemblies or scrap[2] containing components such as accumulators and other batteries included on list A, ***mercury-switches***, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g. cadmium, ***mercury***, 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)[3]
Other entries related to wastes which may contain or be contaminated with mercury	
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)
A4160	Spent activated carbon not included on list B (note the related entry on list B B2060)

2 This entry does not include scrap assemblies from electric power generation.

3 PCBs are at a concentration level of 50 mg/kg or more.

B. International linkages

1. United Nations Environment Programme Governing Council

17. In its decision 25/5 III, the United Nations Environment Programme (UNEP) Governing Council set up an international negotiating committee to prepare a global legally binding instrument on mercury. The committee's work began in June 2010 and is to be completed by early 2013. The instrument's mandate is, among other things:

(a) To reduce the supply of mercury and enhance the capacity for its environmentally sound storage;

(b) To reduce the demand for mercury in products and processes;

(c) To reduce international trade in mercury;

(d) To reduce atmospheric emissions of mercury;

(e) To address mercury-containing waste and remediation of contaminated sites; and

(f) To specify arrangements for capacity-building and technical assistance.

18. In the same decision, the Executive Director of UNEP was requested, coordinating as appropriate with Governments, intergovernmental organizations, stakeholders and the Global Mercury Partnership, to continue and enhance existing work in several areas. The Chemicals Branch of the UNEP Division of Technology, Industry and Economics provides the secretariat services for the mercury negotiations and the Global Mercury Partnership has currently identified seven priority actions (or partnership areas)[4].

2. Rotterdam Convention

19. 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 sets out a list of chemicals subject to the prior informed consent procedure, along with the associated decision guidance documents and any additional information. Annex III includes chemicals that have been banned or severely restricted for health or environmental reasons.

3. Heavy Metals Protocol

20. The objective of the Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Heavy Metals 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 are required to reduce emissions of target heavy metals below their 1990 levels (or an alternative year between 1985 and 1995) by applying best available techniques for new stationary sources, imposing emissions limit values for certain new stationary sources, and applying best available techniques and limit values for certain existing sources. Parties are also required to develop and maintain emission inventories for covered heavy metals. Annex VII to the Protocol specifically lists mercury-containing electrical components and mercury-containing batteries for recommended product management measures, which include substitution, minimization, labelling, economic incentives, voluntary agreements and recycling programmes.

4. SAICM

21. The Strategic Approach to International Chemicals Management (SAICM) comprises three core texts: the Dubai Declaration; an overarching policy strategy; and a global plan of action. Mercury is specifically addressed in the Global Plan of Action under work area 14: "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", with specific activities addressing the reduction of risks, the need for further action and the review of scientific information. A quick start programme for the implementation of SAICM objectives was established 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).

4 For further information, http://www.unep.org/hazardoussubstances/Mercury/GlobalMercuryPartnership/tabid/1253/Default.aspx

III. Guidance on ESM

A. General concept

22. ESM is a broad policy concept. Provisions pertaining to ESM as it applies to wastes consisting of elemental mercury and wastes containing or contaminated with mercury (and, more broadly, to hazardous wastes) covered by the Basel Convention and the Organization for Economic Cooperation and Development (OECD) core performance elements provide international guidance that support ESM efforts underway in various countries and in some industrial sectors. It should be noted that international efforts under the auspices of, among others, the UNEP Global Mercury Partnership and the intergovernmental negotiating committee process are continuing. In the meantime, it is important to use these guidelines to promote and implement ESM for these wastes.

1. Basel Convention

23. In paragraph 8 of its Article 2, 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.

24. In paragraph 2 (b) of Article 4, 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”.

25. In paragraph 8 of Article 4, the Convention requires that “hazardous wastes or other wastes, to be exported, are 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 in the context of wastes consisting of elemental mercury and wastes containing or contaminated with mercury, including appropriate treatment and disposal methods for these waste streams.

26. Several key principles for ESM of waste were articulated in the 1994 guidance document on the preparation of technical guidelines for the environmentally sound management of wastes subject to the Basel Convention (SBC 1994). It recommends legal, institutional and technical conditions (ESM criteria) such as:

(a) A regulatory and enforcement infrastructure to ensure compliance with applicable regulations;

(b) Sites or facilities must be authorized and of an adequate standard of technology and pollution control to deal with hazardous wastes in the way proposed, in particular taking into account the level of technology and pollution control in the exporting country;

(c) Operators of sites or facilities at which hazardous wastes are managed must be required, as appropriate, to monitor the effects of those activities;

(d) Appropriate action must be taken in cases where monitoring gives indications that the management of hazardous wastes has resulted in unacceptable releases; and

(e) People involved in the management of hazardous wastes must be capable and adequately trained in their capacity.

27. ESM is also the subject of the 1999 Basel Declaration on Environmentally Sound Management, which states that numerous activities should be carried out in this context, such as:

(a) Prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention, taking into account social, technological and economic concerns;

(b) Active promotion and use of cleaner technologies with the aim of the prevention and minimization of hazardous and other wastes subject to the Basel Convention;

(c) Further reduction of the transboundary movements of hazardous and other wastes subject to the Basel Convention, taking into account the need for efficient management, the principles of self-sufficiency and proximity and the priority requirements for recovery and recycling;

(d) Prevention and monitoring of illegal traffic;

(e) Improvement and promotion of institutional and technical capacity-building, and development, and of the transfer of environmentally sound technologies, especially for developing countries and countries with economies in transition;

(f) Further development of regional and subregional centres for training and technology transfer;

(g) Enhancement of information exchange, education and awareness-raising in all sectors of society

(h) Cooperation and partnership at all levels between countries, public authorities, international organizations, the industry sector, non-governmental organizations and academic institutions; and

(i) Development of mechanisms for compliance with and for the monitoring and effective implementation of the Convention and its amendments.

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

2. Organization for Economic Cooperation and Development

29. 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). The core performance elements are:

(a) That the facility should have an applicable environmental management system (EMS) in place;

(b) That the facility should take sufficient measures to safeguard occupational and environmental health and safety;

(c) That the facility should have an adequate monitoring, recording and reporting programme;

(d) That the facility should have an appropriate and adequate training programme for its personnel;

(e) That the facility should have an adequate emergency plan; and

(f) That the facility should have an adequate plan for closure and after-care.

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

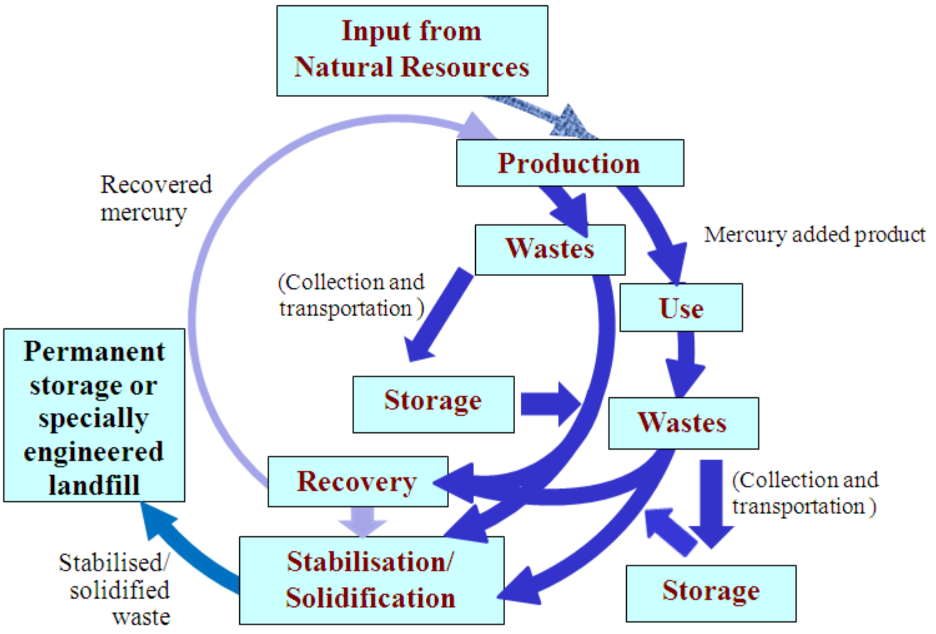
3. Life-cycle management of mercury

31. The concept of life-cycle management provides an important perspective for ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. Life-cycle management provides a framework for analysing and managing the performance of goods and services in terms of their sustainability. Global businesses are using it to reduce, for instance, their products' carbon, material and water footprints, and to improve the social and economic performance of their offerings so as to ensure a more sustainable value chain (UNEP and SETAC 2009). When life-cycle management is applied to mercury, performance should be analysed at the following stages: production of mercury-added products or production of other products using mercury; use of the products; collection and transportation of wastes; and disposal of wastes.

32. In life-cycle management of mercury, it is important to prioritize the reduction of mercury used in products and processes to reduce the mercury content in the wastes to be disposed of and in wastes generated in industrial processes. When using mercury-added products, special care should be taken not to release mercury into the environment. Wastes consisting of elemental mercury or wastes containing or contaminated with mercury should be treated to recover the mercury or to immobilize it in an environmentally sound manner. The recovered mercury should be disposed of after

stabilization/solidification (S/S) at a permanent storage site or a specially engineered landfill site; alternatively, it may be used as an input for products for which mercury-free alternatives do not exist or are unavailable, or where it would take a long time to replace mercury-added products; this could help to reduce the amount of mercury released from the earth. Wastes consisting of elemental mercury or wastes containing or contaminated with mercury may be stored, for example for further treatment until facilities are available or for export to other countries for disposal (see Figure -1).

"Minimize mercury release to the environment at each stage"



*This figure does not cover the flow of waste contaminated with mercury.

Figure -1 Basic concept of mercury management

33. Waste management covers source separation, collection, transportation, storage and disposal (e.g., recovery, solidification, stabilization and permanent storage). When a Government plans to collect wastes consisting of elemental mercury or wastes containing or contaminated with mercury, it also needs to plan the subsequent waste management step, such as storage and disposal.

B. Legislative and regulatory framework

34. Parties to the Basel Convention should examine their national controls, standards and procedures to ensure that they fully implement their Convention obligations, including those pertaining to the transboundary movement and ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury.

35. Implementing legislation should give Governments the power to enact specific rules and regulations, inspect and enforce and establish penalties for violations. Such legislation on hazardous wastes should also define hazardous wastes. Wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be included in the definition. The legislation could define ESM and require adherence to ESM principles, thus ensuring that countries comply with the provisions on ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. 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[5].

5 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), Basel Convention: Manual for Implementation of the Basel Convention (SBC 1995a) and Basel Convention: Guide to the Control System (SBC 1998).

1. Registration of waste generators

36. One approach required to provide full control over wastes consisting of elemental mercury and wastes containing or contaminated with mercury involves establishing a regulatory framework to register generators of this type of waste. The register should include large-scale 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), hospitals, medical clinics, dentists and dental clinics, research institutes, collectors of mercury waste, etc. A register of these waste generators would make it possible to clarify the origins of the waste, and their type and volume (or quantity of used mercury-added products).

37. The information required of generators of this type of waste would be the name, address, responsible person, type of business, amount of waste generated, kind of waste, collection scheme and how such wastes are finally handed over to collectors or are disposed of. Waste generators should transmit and update this information to the public sector (central or local government) regularly. In addition, waste inventory programmes based on the amounts and kinds of waste reported should be developed.

38. Such waste generators should have a duty to avoid any mercury leakage into the environment until the wastes are handed over to collectors or sent to a disposal facility. They should comply strictly with national or local legal frameworks for managing such wastes and be liable for remediating or compensating any environmental or health damage that might occur.

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

39. The reduction and phase-out of mercury in products and industrial processes is one of the most effective ways to reduce releases of mercury to the environment.

40. Parties should develop and enforce a legislative or regulatory framework for a phase-out programme. An effective regulatory framework supports the proper organization of extended producer responsibility (EPR) obligations (as discussed in chapter III, E, 3), which depend on shared responsibilities among stakeholders. One approach to securing a legislative or regulatory framework for a phase-out programme involves establishing a cut-off date for banning the use of mercury in products and processes (except for those for which there are no technically or practically viable alternatives or exemptions.). After this date, mercury use should be banned and EPR collection and treatment schemes on ESM, in cooperation with all stakeholders, should be established. This approach encourages large-scale users and producers of mercury and mercury-containing products to comply with the requirement to embark on a mercury phase-out programme. In certain cases it may be useful to complement the phase-out programme with a ban on the export of wastes.

41. One example of a framework for phase-out production is 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, also known as the “RoHS Directive”, which restricts the use of, among others, mercury in electrical and electronic equipment. Temporary exemptions for the use of these substances are allowed for several products for which there are currently no viable alternatives (e.g., some types of mercury-containing lamps). Most mercury-containing electrical and electronic equipment has thus been phased out in the European Union market since the Directive entered into force on 1 July 2006.

42. Another example from the European Union is Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, 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, subject to exemptions (this ban is not applicable to button cells, which may still have a mercury content of no more than 2 per cent by weight).

43. Norway has imposed a general ban on the use of mercury in products to ensure that mercury is not used in products where alternatives exist[6]. It is prohibited to manufacture, import, export, sell or use substances or preparations that contain mercury or mercury compounds, and to manufacture, import, export or sell solid processed mercury-added products or mercury compounds. This will 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.

3. Transboundary movement requirements

44. Under the Basel Convention, wastes consisting of elemental mercury and wastes containing or contaminated with mercury are hazardous wastes.

45. If a party to the Convention has national legislation banning the import of wastes consisting of elemental mercury and wastes containing or contaminated with mercury, and has reported the information in accordance with paragraph 1 (a) of Article 4, other Parties cannot export such waste to that party.

46. Transboundary movements of hazardous wastes and other wastes must be kept to a minimum consistent with their ESM 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 conducted under conditions that do not endanger human health and the environment;

(b) If exports are managed in an environmentally sound manner in the country of import or elsewhere;

(c) If the country of export does not have the technical capacity and the necessary facilities to dispose of the wastes in question in an environmentally sound and efficient manner;

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

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

47. 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. The Basel Ban Amendment (decision III/1 of the Conference of the Parties to the Convention) would, if it enters into force, prohibit the export of hazardous wastes either for disposal or recycling from Annex VII countries (OECD member countries, the European Union, Liechtenstein), to non-Annex VII countries (i.e., developing countries). Some countries have similar domestic prohibitions.

48. Hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards (United Nations Economic Commission for Europe (UNECE) 2007).

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6 Special exemptions are however made:

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

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.

49. When required by the State of import or any State of transit that is a party, transboundary movement of hazardous or other wastes is to be covered by insurance, a bond or other guarantee.

50. Where it is not possible to complete a transboundary movement of hazardous or other wastes for which the consent of the countries concerned has been given, the country of export is to ensure that the wastes in question are returned to the country of export for disposal if alternative arrangements cannot be made for their disposal in an ESM manner. This is to be done within 90 days of the importing State's notification to the exporting States or within another period of time on which the States involved agree. In the case of illegal traffic (as defined in paragraph 1 of Article 9), 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.

51. No transboundary movements of hazardous wastes and 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.

52. It is worth noting that the export of metallic mercury and certain mercury compounds and mixtures from the European Union has been banned by the Regulation (EC) No 1102/2008 since 15 March 2011 (European Commission 2010). Similarly, the Mercury Export Ban Act of 2008 will ban United States exports of elemental mercury from 1 January 2013 and require long term storage of mercury.

4. Authorization and inspection of disposal facilities

53. Wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be disposed of in facilities that practise ESM.

54. Most countries have legislation or sector-specific regulation that requires waste disposal facilities to obtain some form of approval or operating permit to commence operations. Approvals or operating permits may include specific conditions (facility design and operating conditions) which must be maintained in order for the approval or permit to remain valid. It may be necessary to add requirements specific to wastes consisting of elemental mercury and to wastes containing or contaminated with mercury 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 (BEP) of the Stockholm Convention and the reference documents on BAT by the EU (BREFs) and guidelines for the chlor-alkali sector from the World Chlorine Council and Eurochlor[7]. Approvals or operating permits should be reviewed periodically and if necessary updated in order to improve occupational and environmental safety by applying improved or new technologies.

55. Disposal facilities should be periodically inspected by an independent authority or technical inspection association in order to verify compliance with the requirements set out in the facility's permit. Legislation should also allow for extraordinary inspections if there is evidence for non-compliance.

C. Identification and inventory

56. It is important to identify sources that generate wastes consisting of elemental mercury and wastes containing or contaminated with mercury and to quantify the amount of wastes and mercury concentrations in inventories in order to be able to take effective action to prevent, minimize and manage such waste.

1. Identification

57. Figure -2 shows global mercury use by application in 2007. The largest use sector is artisanal and small-scale gold mining, followed by vinyl chloride monomer VCM/polyvinyl chloride (PVC) production and chlor-alkali production. Mercury is also used for consumer products such as batteries, dental amalgam, measuring devices, lamps, and electrical and electronic devices, although the amount of mercury in these use categories varies by nation. The range of mercury uses in 2007 was 3,000 tonnes - 4,700 tonnes (Maxson 2010).

7 See compilation at http://www.unep.org/hazardoussubstances/Mercury/PrioritiesforAction/ChloralkaliSector/Reports/tabid/4495/language/en-US/Default.aspx

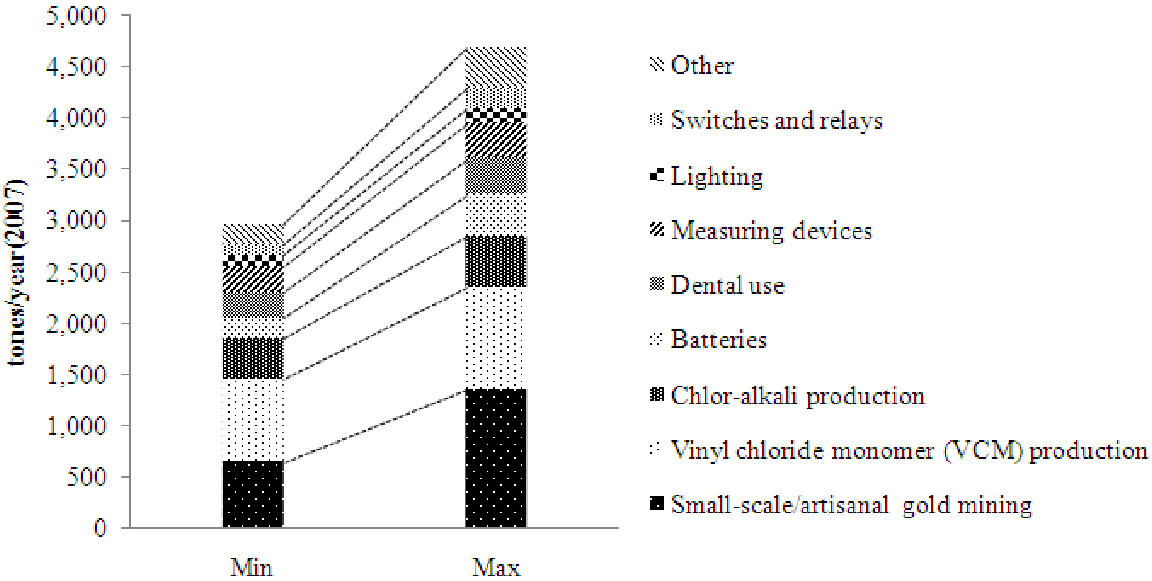

Figure -2 Estimated global mercury use in 2007 (Maxson 2010)

58. The sources, categories and examples of wastes consisting of elemental mercury and wastes containing or contaminated with mercury are summarised in Table -2.

59. It should be noted that in some countries some of the industrial sources presented in Table -2 (Sources 1, 2, 3, 4 and 7, except for the production processes using mercury) neither use mercury, nor generate wastes consisting of elemental mercury and wastes containing or contaminated with mercury at all. Industrial processes depend on a country's technological and social conditions, and these will determine whether mercury-free processes can be introduced.

Table -2 Sources, categories, examples of wastes (UNEP 2002; 2005; 2006b; 2006c).

*** A: Wastes consisting of elemental mercury; B: Wastes containing mercury; C: Wastes contaminated with mercury.**

Source	Cate-gories*	Examples of waste types	Remarks
1. Extraction and use of fuels/energy sources			
1.1. Coal combustion in power plants	C	Flue gas cleaning residues (fly ash, particulate matters, 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		
2. Primary (virgin) metal production			
2.1. Primary extraction and processing of mercury	C	Smelting residue	• Pyrometallurgy of mercury ore
2.2. Metal (aluminium, copper, gold, lead, manganese, mercury, zinc, primary ferrous metal, other non-ferrous metals) extraction and initial processing	C	Tailings, extraction process residues, flue gas cleaning residues, wastewater treatment residues	• Industrial processing; • Thermal treatment of ore; and • Amalgamation.
3. Production processes with mercury impurities			

Source	Cate-gories*	Examples of waste types	Remarks
3.1. Cement production	C	Process residues, flue gas cleaning residues, sludge	• Pyroprocessing of raw materials and fuels with naturally occurring mercury impurities
3.2. Pulp and paper production			• Combustion of raw materials with naturally occurring mercury impurities
3.3. Lime production and lightweight aggregate kilns			• Calcination of raw materials and fuels with naturally occurring mercury impurities
4. Intentional use of mercury in industrial production			
4.1. Chlor-alkali production with mercury-technology	A/C	Solid waste contaminated with mercury, elemental mercury, process residues, soil	• Mercury cell; • Mercury recovery units (retort).
4.2. Production of alcoholates, dithionite and ultrapure potassium hydroxide solution	A/C	Solid waste contaminated with mercury, elemental mercury, process residues, soil	• Mercury cell; • Mercury recovery units (retort).
4.3. VCM production with mercuric chloride $HgCl_2$ catalyst	A/B/C	Process residues	• Mercury catalyst process
4.4. Acetaldehyde production with mercury-sulphate ($HgSO_4$) catalyst	C	Wastewater	• Mercury-sulphate process
4.5. Other production of chemicals and pharmaceuticals with mercury compounds and/or catalysts	C	Process residues, wastewater	• Mercury catalyst process
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	B	Used, obsolete or broken products	• Elemental mercury
5.2. Electrical and electronic switches, contacts and relays with mercury			
5.3. Light sources with mercury	B		• Vapour-phase elemental mercury; • Divalent mercury adsorbed on phosphor powder.
5.4. Batteries containing mercury	B		• Elemental mercury, mercury oxide
5.5. Biocides and pesticides	B	Stockpiles (obsolete pesticides), soil and solid waste contaminated with mercury	• Mercury compounds (mainly ethylmercury chloride)
5.6. Paints	B	Stockpiles (obsolete paints), solid waste contaminated with mercury, wastewater treatment residues	• Phenylmercuric acetate and similar mercury compounds
5.7. Pharmaceuticals for human and veterinary uses	B	Stockpiles (obsolete pharmaceuticals), medical waste	• Thimerosal; • Mercuric chloride; • Phenyl mercuric nitrate; • Mercurochrome, etc.

Source	Cate-gories*	Examples of waste types	Remarks
5.8. Cosmetics and related products	B	Stockpiles	• Mercury iodide; • Ammoniated mercury, etc.
5.9. Dental amalgam fillings	B/C	Stockpiles, wastewater treatment residues	• Alloys of mercury, silver, copper and tin
5.10. Manometers and gauges	B	Used, obsolete or broken products	• Elemental mercury
5.11. Laboratory chemicals and equipment	A/B/C	Stockpiles, wastewater treatment residues, laboratory wastes	• Elemental mercury; • Mercury chloride, etc.
5.12. Polyurethane elastomers	B/C	Defective and excess product waste, used or end-of-life product	• Elastomer waste containing mercury compounds
5.13. Sponge gold/gold production from ASGM sources	C	Flue gas residues, wastewater treatment residues	• Thermal treatment of gold; • Industrial processing.
5.14. Mercury metal use in religious rituals and folklore medicine	C	Solid waste, wastewater treatment residues	• Elemental mercury
5.15. Miscellaneous product uses, mercury metal uses and other sources	B/C	Stockpiles, wastewater treatment residues, solid wastes	• Infra-red detection semiconductors with mercury; • Bougie and Cantor tubes; • Educational uses, etc.
6. Secondary metal production			
6.1. Recovery of mercury	A/C	Spillage during recycling process, extraction process residues, flue gas cleaning residues, wastewater treatment residues	• Dismantling of chlor-alkali facilities; • Recovery from mercury meters used in natural gas pipelines; • Recovery from manometers, thermometers, and other equipment.
6.2. Recovery of ferrous metals	C		• Shredding; • Smelting of materials containing mercury.
6.3. Recovery of gold from e-waste (printed circuit board)	A/C		• Elemental mercury; • Thermal process.
6.4. Recovery of other metals	C		• Other mercury-containing materials or products /components
7. Waste incineration			
7.1. Incineration of municipal solid waste	C	Flue gas cleaning residues, wastewater treatment residues	• Mercury-added products and process waste; • Natural mercury impurities in high volume materials (plastics, paper, etc.) and minerals.
7.2. Incineration of hazardous waste			
7.3. Incineration of medical waste			
7.4. Sewage sludge incineration			
8. Waste deposition/landfilling and wastewater treatment			
8.1. Controlled landfills/deposits	C	Wastewater, wastewater treatment residues, solid waste contaminated with mercury	• Mercury-added products and process waste; • Natural mercury impurities in bulk materials (plastics, tin cans, etc.) and minerals.
8.2. Diffuse deposition under some control			
8.3. Uncontrolled local disposal of industrial production waste			
8.4. Uncontrolled dumping of general waste			

Source	Cate-gories*	Examples of waste types	Remarks
8.5. Wastewater system/treatment		Wastewater treatment residues, slurry	• Intentionally used mercury in spent products and process waste; • Mercury as an anthropogenic trace pollutant in bulk materials.
9. Crematoria and cemeteries			
9.1. Crematoria	C	Flue gas cleaning residues, wastewater treatment residues	• Dental amalgam fillings
9.2. Cemeteries		Soil contaminated with mercury	

60. More detailed information about mercury-added products (specific name and manufacturer of products) is available from the following sources:

(a) UNEP (2008c): Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury-free products and processes, 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, http://ec.europa.eu/environment/chemicals/mercury/pdf/study_report2008.pdf

(c) UNEP Global Mercury Partnership – Mercury-Containing Products Partnership Area, http://www.chem.unep.ch/mercury/Sector-Specific-Information/Mercury-in-products.htm

(d) Lowell Center for Sustainable Production (2003): An Investigation of Alternatives to Mercury-Containing Products, http://www.chem.unep.ch/mercury/Sector-Specific-Information/Docs/lcspfinal.pdf

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

2. Inventories

61. 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, and commodity mercury and wastes consisting of elemental mercury and wastes containing or contaminated with mercury;

(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.

62. After identifying the sources and types of wastes consisting of elemental mercury and wastes containing or contaminated with mercury, 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).

63. It is very difficult to collect the necessary data to estimate these amounts, particularly in developing countries and countries with economies in transition due to a lack of (or no) 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.

64. The Methodological Guide for the Undertaking of National Inventories of Hazardous Wastes within the Framework of the Basel Convention (SBC 2000) should be used to compile inventories of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. The Methodological Guide has also been tried out in conjunction with the Pilot Project on National

Inventories of Hazardous Waste, produced by the SBC-BCRC-SEA, whose report can be used as a practical reference[8].

65. The Toolkit for Identification and Quantification of Mercury Releases (UNEP 2010a) can also be usefully applied. The toolkit helps countries to build their knowledge base by compiling a mercury inventory that identifies sources of mercury releases in their country and estimates or quantifies the releases. The Toolkit is a simple and standardized methodology for producing consistent national and regional mercury inventories (UNEP 2005). The Toolkit has been applied in a number of countries (UNEP 2008c).

66. In keeping with a lifecycle approach, channels or pathways through which the mercury in the waste is released into the environment should also be identified. In view of the potential risks of mercury release into the environment, waste types should be ranked according to priority for action. Information about possible measures should then be collected, especially with regard to sources and types of mercury waste with a large amount of mercury and involving higher risks of mercury release into the environment. Measures must then be analysed or evaluated in terms of the potential amount of environmental mercury release to be prevented, administrative and social costs, availability of techniques and facilities and ease of reaching the social agreement associated with the implementation of these measures, etc.

67. 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 also publicly available[9].

D. Sampling, analysis and monitoring

68. Sampling, analysis and monitoring are critical components in the management of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. Sampling, analysis and monitoring should be conducted by trained professionals in accordance with a well-designed plan and using internationally accepted or nationally approved methods, carried out using the same method each time over the time span of the programme. 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 ensure that training, protocols and laboratory capability are in place for sampling, monitoring and analytical methods and that these standards are enforced.

69. Because there are numerous reasons for sampling, analysing and monitoring and because there are so many different physical forms of waste, 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 will consider the key points involved in sampling, analysis and monitoring.

70. For information on good laboratory practice, the OECD series (OECD, various years) may be usefully consulted; on general methodological considerations, the WHO/UNEP document Guidance for Identifying Populations at Risk from Mercury Exposure contains helpful information[10].

1. Sampling

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

72. Standard 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:

8 http://www.bcrc-sea.org/?content=publication&cat=2

9 For example, the Czech PRTR, known as the Integrated Pollution Register (available at http://www.irz.cz), collects chemically specific data about mercury and mercury compounds transfered in the wastes, which gives a clear picture of the total amount of mercury transfered in wastes as well as data on how the waste is handled.

10 http://www.unep.org/hazardoussubstances/LinkClick.aspx?fileticket=DUJZp8XnXq8%3d&tabid=3593&language=en-US

(a) The number of samples to be taken, the sampling frequency, the duration of the sampling project and a description of the sampling method (including quality assurance procedures put in place, e.g., appropriate sampling containers[11], field blanks and chain-of-custody);

(b) Selection of location or sites and time 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.

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

(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 (USEPA), the Global Environment Monitoring System (GEMS) or the American Society for Testing and Materials (ASTM); and

(c) Establishment of quality assurance and quality control (QA/QC) procedures.

74. All these steps should be followed if a sampling programme is to be successful. Similarly, documentation should be thorough and rigorous.

75. Types of matrices typically sampled for mercury include solids, liquids and gases:

(a) Liquids:

- (i) Leachate from dumpsites and landfills;
- (ii) Liquid collected from spills;
- (iii) Water (surface water, drinking water and industrial effluents);
- (iv) Biological materials (blood, urine, hair; especially in the case of workers' health monitoring);

(b) Solids:

- (i) Stockpiles, products and formulations consisting of, containing or contaminated with mercury;
- (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).

76. 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).

11 Polyethylene bottles are permeable to mercury and should not be used. Please refer to Parker *et al*. (2005) for details.

2. Analysis

77. 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 interlaboratory comparison studies in external proficiency testing schemes).

78. Accreditation of the laboratory according to ISO 17025 or other standards by an independent body is also important. Essential criteria for obtaining high-quality results include:

(a) Specification of the analytical technique;

(b) Maintenance of analytical equipment;

(c) Validation of all methods used (including in-house methods); and

(d) Training of laboratory staff.

79. Mercury analysis is typically performed in a dedicated laboratory. For specific situations, test kits are available that can be used in the field for screening purposes.

80. 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), or national methods such as those of the United States (USEPA) or Japan. Table -3 lists some examples for analysing mercury in wastes, flue gas and wastewater. Most in-house methods are variations of these. As with all chemical analysis, only validated methods should be used by the laboratory.

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

82. The individual steps in the analytical determination include:

(a) Extraction;

(b) Purification;

(c) Identification by suitable detectors such as ICP, AAS; compact instruments;

(d) Quantification and reporting as required; and

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

3. Monitoring

83. In paragraph 2 (b) of its Article 10 (“International Cooperation”), 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.

84. The information from the monitoring programme should be used to ensure that the proper types of hazardous wastes are being managed by the waste management operation, to discover and repair any damage and to determine whether an alternative management approach might be appropriate. By implementing a monitoring programme, facility managers can identify problems and take appropriate measures to remedy them.

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

Table -3 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 (European Committee for Standardization 2002a)
		EN 12920: Characterization of waste - Methodology for the determination of the leaching behaviour of waste under specified conditions (European Committee for Standardization 2006)
		EN 13656: Characterization of waste - Microwave assisted digestion with hydrofluoric (HF), nitric (HNO_3) and hydrochloric (HCl) acid mixture for subsequent determination of elements in waste (European Committee for Standardization 2002b)
		EN 13657: Characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements in waste (European Committee for Standardization 2002c)
		TS 14405: Characterization of waste - Leaching behaviour test - Up-flow percolation test (European Committee for Standardization 2004)
		US EPA Method 1311: TCLP, Toxicity Characteristic Leaching Procedure (US EPA 1992)
	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- (European Committee for Standardization 2003)
		EN 15309: Characterization of waste and soil - Determination of elemental composition by X-ray fluorescence (European Committee for Standardization 2007)
		US EPA Method 7471B: Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique) (US EPA 2007d)
		US EPA Method 7473: Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry (US EPA 2007e)
		US EPA Method 7470A: Mercury in Liquid Waste (Manual Cold-Vapor Technique) (US EPA 1994)
Flue Gas		EN 13211: Air quality - Stationary source emissions - Manual method of determination of the concentration of total mercury (European Committee for Standardization 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 (European Committee for Standardization 2005)
		JIS K 0222: Analysis Method for Mercury in Flue Gas (Japan Standards Association 1997)
		US EPA Method 0060: Determination of Metals in Stack Emissions (US 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)
		1SO 17852: 2006: Water quality – Determination of mercury - Method using atomic fluorescence spectrometry (ISO 2006)

E. Waste prevention and minimization

86. The prevention and minimization of wastes consisting of elemental mercury and wastes containing or contaminated with mercury are the first and most important steps in the overall ESM of such wastes. In its 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”. This section provides information for important sources of wastes.

1. Waste prevention and minimization for industrial processes

87. There are several industrial processes using mercury; however, because of the quantity of mercury used in these processes this section discusses waste prevention and minimization measures only for artisanal and small-scale gold mining, vinyl-chloride monomer production and chlorine and caustic soda (chlor-alkali) production.

(a) Artisanal and small-scale gold mining

88. Mercury-free techniques are available: Gravimetric methods; Centre for Mineral Technology (CETEM); Combining non-mercury methods. In cases where organized alternatives are unavailable, interim solutions that lead towards mercury-free techniques should be used. These can include mercury capture and recycling technologies such as retorts and fume hoods, and mercury re-activation and the avoidance of mercury intensive processing such as whole-ore amalgamation. The details can be found in the following references:

(a) GMP (2006): Manual for Training Artisanal and Small-Scale Gold Miners, UNIDO, Vienna, Austria, www.cetem.gov.br/gmp/Documentos/total_training_manual.pdf;

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

(c) UNEP (2010b): Global ASGM Forum report, http://www.unep.org/hazardoussubstances/GlobalForumonASGM/tabid/6005/Default.aspx;

(d) UNEP (2011): Global Mercury Partnership Reports and Publications, http://www.unep.org/hazardoussubstances/Mercury/PrioritiesforAction/ArtisanalandSmallScaleGoldMining/Reports/tabid/4489/language/en-US/Default.aspx;

(e) US EPA (2008): Manual for the Construction of a Mercury Collection System for Use in Gold Shops, http://www.epa.gov/oia//toxics/asgm.html.

89. Artisanal miners, their families, and the surrounding communities should be educated about: (a) exposure risks to mercury and related health dangers; and (b) environmental impacts of mercury use in artisanal and small-scale gold mining (ASGM). Once awareness of these issues has increased, training in techniques and systems to prevent waste generation should be provided.

(b) Vinyl chloride monomer (VCM) production

90. VCM production using the acetylene process employs mercuric chloride as a component of the catalyst. Waste prevention and minimization opportunities exist and fall into two primary categories: (a) alternative, mercury-free manufacturing methods; and (b) better management of mercury during the process and environmental control to capture releases.

91. 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). Serious efforts to develop a mercury-free catalyst for the acetylene process are ongoing. A commercial-scale demonstration test of a mercury-free catalyst is scheduled for early 2012. If the commercial-scale test proves successful, the company developing the catalyst intends to produce the mercury-free catalyst, and a transition to mercury-free VCM production can be foreseen over the next few years (Jacobs and Johnson Matthey 2011).

92. Suggested measures to reduce generation of wastes contaminated with mercury include: better management of mercury and environmental control to capture releases; development and application of low-mercury catalyst; technological reform to prevent the 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: adsorption by activated carbon in mercury remover and de-acidification through foaming and washing towers; recycling and reuse of mercury-containing effluent; 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, “Project Report on the Reduction of Mercury Use and Emission in Carbide PVC Production” (Ministry of Environmental Protection, China 2010)should be consulted.

(c) Chlor-alkali production

93. As mercury cell factories are replaced by mercury-free processes, mercury emissions and wastes are eliminated. Mercury-free chlor-alkali production employs either diaphragm or membrane processes. Membrane technology is the more cost effective of the two because of the lower total electricity input required (Maxson 2011). Although the mercury cell process is being phased out, as of 2010 there were still about 100 plants using the mercury cell process in 44 countries (UNEP Global Mercury Partnership – Mercury Reduction in Chlor-alkali Sector 2010). In 2010, mercury cell chlor-alkali installations represented about 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 2010, 31 per cent of

European chlorine production capacity was based on mercury cell technology. European chlorine manufacturers have voluntarily committed to replace or close down all chlor-alkali mercury cell plants by 2020 (Euro Chlor 2010). In the US, use of the mercury cell process declined from 14 facilities in 1996 to five facilities in 2007 (Chlorine Institute 2009). According to information from the World Chlorine Council, solid waste from chlor-alkali plants in Europe amounted to 43,293 tonnes in 2009. If North America, India, Russia, Brazil, Argentina and Uruguay are included, the reported total waste generation from this sector was 69,954 tonnes in 2009[12]. The quantity of waste generated by other plants around the world has not been reported.

94. 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 in tanks/sumps. In addition to monitoring of possible leakages and good housekeeping, reduction of mercury evaporation and better control of mercury emissions and recovery of mercury from wastewater and graphite and carbon from flue gas treatment and caustic treatment could reduce waste generation. For further information, the following documents or website should be consulted:

(a) European Commission (2001): Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in Chlor-Alkali Manufacturing Industry [currently being updated].

(b) Global Mercury Partnership Chloralkali sector: http://www.unep.org/hazardoussubstances/Mercury/InterimActivities/Partnerships/ChloralkaliSector/tabid/3560/language/en-US/Default.aspx (this Website contains more than 20 guidelines for this industry).

2. Waste prevention and minimization for mercury-added products

95. Introducing mercury-free alternatives and banning mercury-added products are important ways to prevent generation of wastes containing mercury. As a transitional measure, setting maximum limits of mercury content in products would also help to reduce the generation of wastes containing mercury if mercury-free alternatives are not available or phase-out takes a long time. Replacement of mercury-added products with mercury-free or reduced-mercury alternatives can be facilitated through green purchasing.

96. Where mercury-added products are still in use, the establishment of a safe closed system for utilization of mercury is desirable. Mercury contamination of the waste streams should be prevented by: (a) mercury-free products, (b) setting maximum limits of mercury contents in products, and (c) procurement. Waste containing mercury should be separated and collected, and mercury should then be recovered from the waste and used for production (instead of using primary mercury) or disposed of in an environmentally sound manner (see Figure -3). Extended producer responsibility (EPR) should be used as an instrument to encourage the production of mercury-free or less mercury containing products and collection of end-of-life products.

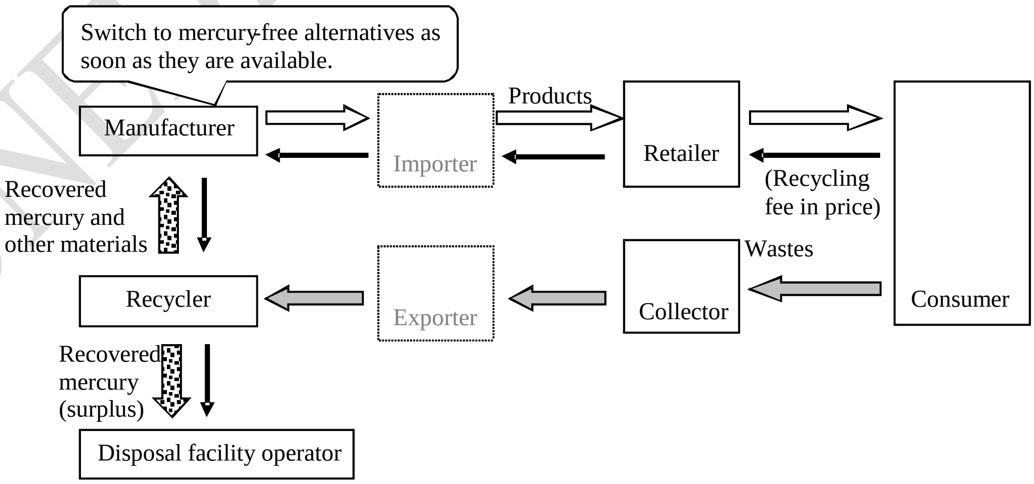

Figure -3 Closed System for Utilization of Mercury

12 http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/chloralkali/WCC_Hg_reporting2009.pdf

(a) Mercury-free products

97. The substitution of mercury in products depends on factors such as product cost, impact on the environment and human health, 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) Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury-free products and processes (UNEP 2008b);

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

(c) An Investigation of Alternatives to Mercury Containing Products, Prepared for the Maine Department of Environmental Protection (Galligan *et al*., 2003) Lowell Center for Sustainable Production, University of Lowell, MA, 2003, http://www.maine.gov/dep/mercury/lcspfinal.pdf.

(b) Setting maximum limits of mercury content in products

98. Mercury content limits should be established for mercury-added products until such time as they can be banned or phased out because they result in less mercury used in the production stage, which, in turn, results in less mercury being emitted throughout the entire product lifecycle. Setting maximum limits of mercury content in products can be achieved through legal requirements (see examples in section III, B, 2 below) or voluntary actions under a publicly announced environmental/mercury management plan by the industry sector. As stated previously, legal requirements for the maximum amount of mercury in each unit have been established for batteries and fluorescent lamps in the EU for both products, and in several States of the USA for the former. In Japan, maximum limits of mercury in fluorescent lamps are set by the corresponding industry association, and such limits have been adopted as a criterion in selecting fluorescent lamps for green purchasing by the national government.

99. In order to reduce the use of mercury in fluorescent lamps, manufacturers have developed their own technologies for ensuring a fixed amount of mercury is included in each lamp, so that the minimum and necessary amount of mercury is present to suit the required performance of each type of lamp. 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 elemental mercury (Ministry of the Environment, Japan 2010).

100. The use of mercury amalgam dosing may have environmental and performance advantages over the use of elemental mercury throughout the life-cycle of compact fluorescent lamps (CFLs) and other types of mercury-added lamps. Its strength is to minimize worker and consumer exposure – as well as environmental releases – to mercury vapour during manufacturing, transportation, installation, storage and recycling and disposal, particularly when lamps break. In addition, this accurate dosing method enables manufacturers to produce CFLs that contain very low mercury levels (two milligrams or less) while meeting important performance requirements including high efficiency and long lamp life.

(c) Procurement

101. Procurement programmes for mercury-free products should be encouraged in order to pursue waste prevention and promote uses of mercury-free products and products containing less mercury. Purchasing practices should aim "to purchase mercury-free products," except in the few cases where alternatives to mercury-added products are practically or technologically unavailable, or "to purchase products whose mercury content is minimized".

102. Larger users of mercury-added products, such as government institutions and healthcare facilities, can play an important role in stimulating the 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

103. 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[13]” is considered to be 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, the manufacturer (and importer) would be considered as the producer (OECD, 2001a). EPR programmes shift the responsibility for end-of-life management of products to the producer, who puts the product for the first time on the market, and away from municipalities, and provide incentives for producers to incorporate environmental considerations in the design of their products so that the environmental costs of treatment and disposal are incorporated into the cost of the product. EPR can be implemented through mandatory, negotiated or voluntary approaches. Take-back collection programmes may be part of EPR programmes (see section F, 3, (b), d).

104. EPR programmes, depending upon their design, can achieve a number of objectives: (1) relieve the local government of the financial and in some cases, the operational burden of the disposal of the waste/products/material, (2) encourage companies to design products for reuse, recyclability, and materials reduction (in terms of quantity and hazardousness); (3) incorporate waste management costs into the product price; (4) promote innovation in recycling technology. This promotes a market that reflects the environmental impact of products (OECD 2001a). Detailed descriptions of EPR schemes are available in several OECD publications[14].

105. Environmental authorities should develop regulatory frameworks providing responsibilities of relevant stakeholders, standards for mercury contents and management of products, and components of EPR programmes and encourage participation by relevant parties and the public. They should also be responsible for monitoring the performance of EPR programmes (e.g. amount of wastes collected, amount of mercury recovered and costs accrued for collection, recycling and storage) and for recommending changes as necessary. The responsibility should be placed on all producers of the products considered, and free riders (producers who do not share their responsibilities) should not be allowed, otherwise, other producers are forced to bear costs which are disproportionate to their product market share.

106. In the EU for example, fluorescent lamps including CFLs are one of the products subject to the requirements of the Waste Electrical and Electronic Equipment (WEEE) Directive. The WEEE Directive requires producer responsibility for end-of-life management of electrical and electronic equipment that contain, inter alia, mercury. Other examples include the EPR programme for batteries in the EU, fluorescent lamps and batteries in the Republic of Korea[15].

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

107. The procedures for handling, separation, collection, packaging, labelling, transportation and storage pending disposal of wastes consisting of elemental mercury and wastes containing or contaminated with mercury are similar to those for other hazardous wastes. Mercury has some physical and chemical properties that require additional precautions and handling techniques but, in its elemental form, it is widely recognizable. In addition, sophisticated, accurate field and laboratory measurement techniques and equipment can, where available, make detection and monitoring for spills relatively straightforward.

108. Specific guidance on handling wastes consisting of elemental mercury and wastes containing or contaminated with mercury are provided in this section, but it is imperative that generators consult and adhere to their specific national and local authority requirements. For transport and transboundary movement of hazardous wastes, the following documents should be consulted to determine specific requirements:

(a) Basel Convention: Manual for the Implementation of the Basel Convention (SBC 1995a);

(b) International Maritime Organization (IMO): International Maritime Dangerous Goods Code (IMO 2002);

(c) International Civil Aviation Organization (ICAO): Technical Instructions for the Transport of Dangerous Goods by Air (ICAO 2001);

13 EU Directive 2008/98/EC provides that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products has extended producer responsiblity.

14 http://www.oecd.org/document/19/0,3746,en_2649_34281_35158227_1_1_1_1,00.html

15 Information is available at http://eng.me.go.kr/content.do?method=moveContent&menuCode=pol_rec_pol_rec_sys_responsibility

(d) International Air Transport Association (IATA): Dangerous Goods Regulations Manual (IATA 2007); and

(e) UNECE: United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations (UNECE 2007).

1. Handling

109. Those who handle wastes consisting of elemental mercury should pay particular attention to the prevention of evaporation and spillage of elemental mercury into the environment. Such waste should be placed in a gas- and liquid-tight container that bears a distinctive mark indicating that it contains "toxic" elemental mercury.

110. End users should handle safely and prevent any breakage or damage to waste mercury-added products such as fluorescent lamps, thermometers, electrical and electronic devices, etc. 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. These wastes should not be mixed with any other wastes. If such wastes are accidentally broken or spilled, the clean-up procedure should be followed (see section III, L below).

111. Those who handle wastes contaminated with mercury should not mix them with other wastes. Such waste should be placed in a container to prevent its release into the environment.

(a) Reduction of discharge from dental amalgam waste

112. To reduce mercury discharge from dental waste, the US EPA recommends Environmentally Responsible Practices[16]. Strategies for proper amalgam management include the following:

(a) Discard excess amalgam wastes into a grey bag. Never dispose of dental amalgam wastes in medical red bags or in office trash containers;

(b) Select a responsible dental amalgam recycler - who will manage your waste amalgam safely to limit the amount of mercury which can go back into the environment;

(c) Install an amalgam separator in the office to capture up to 95 per cent of the mercury leaving a dental office through drains[17]; and

(d) Educate and train staff about the proper management of dental amalgam in the office.

2. Separation

113. Separation and collection of wastes consisting of elemental mercury and wastes containing or contaminated with mercury are key factors in ESM because if such waste is simply disposed of as municipal solid waste (MSW) without any separation, the mercury content in the waste may be released into the environment as a result of landfilling or incineration. Wastes containing or contaminated with mercury should be collected separately from other wastes with no physical breakage or contamination. It is recommended to collect such wastes from households and other waste generators such as companies, governments, schools and other organisations separately, because the amount of waste generated by the two sectors differs.

114. The following items should be considered when implementing collection programmes for wastes consisting of elemental mercury and wastes containing or contaminated with mercury, in particular for waste mercury-added products:

(a) Advertise the programme, depot locations and collection time periods to all potential holders of such waste;

(b) Allow enough time for the collection programmes to complete the collection of all such waste;

(c) Include in the programme, to the extent practical, the collection of all such waste;

(d) Make available acceptable containers and safe-transport materials to owners of any such waste that needs to be repackaged or made safe for transport;

(e) Establish simple, low-cost mechanisms for collection;

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16 http://www.epa.gov/hg/pdfs/dental-module.pdf

17 This is also part of the German Ordinance on Requirements for the Discharge of Wastewaters into Waters of 17 June 2004 (AbwV), (see page 106 in http://www.bmu.de/files/pdfs/allgemein/application/pdf/wastewater_ordinance.pdf)

(f) Ensure the safety both of those delivering such waste to depots and of workers at the depots;

(g) Ensure that the operators of depots are using an accepted disposal method;

(h) Ensure that the programme and facilities meet all applicable legislative requirements; and

(i) Ensure separation of such waste from other waste streams.

115. Labelling products which contain mercury can help to secure the proper separation and consequently the environmentally sound disposal of mercury-added products at the end of their useful life. A labelling system should be implemented by the producer during the manufacturing stage to help collection/recycling programmes to identify products that contain mercury and need special handling[18]. Labelling may need to comply with national right-to-know disclosure regulations for the presence, identity and properties of a toxic substance in products. The label may need to specify proper operating conditions and care during use. It may include end-of-life management instructions that encourage recycling and prevent improper disposal.

116. A labelling system for a "mercury-added product" could achieve the following objectives [19]:

(a) Informing consumers at the point of purchase that the product contains mercury and may require special handling at end-of-life;

(b) Identifying the products at the point of disposal so that they can be kept out of the waste stream destined for landfill or incineration and thus be recycled;

(c) Informing consumers that a product contains mercury, so that they will have information that will lead them to seek safer alternatives; and

(d) Providing right-to-know disclosure for a toxic substance.

117. Manufacturers can indicate mercury-added products by printing the international chemical symbol for mercury, "Hg" on them. For example, mercury-added products sold in the USA are required to carry this symbol: (Hg). In the EU, for example, the chemical symbol "Hg" is required to be printed on mercury-containing batteries by Directive 2006/66/EC. Use of a similar emblem on the packaging labels of lamps traded internationally could promote global recognition that the lamp contains mercury. Additional information in appropriate local languages could further explain the (Hg) symbol.

118. In the US, the National Electrical Manufacturers Association (NEMA) lamp ("light bulb") section maintains that a harmonized national or international approach to labelling mercury-containing lamps is an essential component of the efficient and economic distribution of energy efficient lighting[20]. On 18 June 2010, the US Federal Trade Commission promulgated a rule requiring that, starting in January 2012, packaging for CFLs, light emitting diode (LED) lamps and traditional incandescent lamps must include new labels to help consumers choose the most efficient lamps for their lighting needs. For mercury-added lamps, both the labels and the lamps themselves will include this label disclosure[21]:

18 By way of example, guidelines are available at http://www.newmoa.org/prevention/mercury/imerc/labelinginfo.cfm

19 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://210.254.215.73/jeita_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 (PBB) and/or polybrominated diphenyl ethers (PBDE).

20 http://www.nema.org/gov/env_conscious_design/lamps/upload/Labeling%20White%20Paper%20Final%2010%2004-2.pdf and http://www.nef.org.uk/energysaving/lowenergylighting.htm

21 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

Contains Mercury

For more on clean up and safe disposal, visit
epa.gov/cfl.

Figure -4 Example of Product Labelling (Fluorescent Lamp)

119. When mercury-added products are exported to other countries where those products become waste, local consumers, users and other stakeholders may be unable to read foreign language labelling on those products. In this case, importers, exporters, manufacturers or national agencies in charge of product labelling should use appropriate and/or local language.

3. Collection

(a) Collection of wastes consisting of elemental mercury

120. Wastes consisting of elemental mercury (e.g. from a closing chlor-alkali facility) are typically different from other mercury wastes in volume and in the hazards they may pose if mishandled. Elemental mercury in bulk form must be carefully packaged in appropriate containers before shipping to designated storage or disposal facilities[22].

(b) Collection of wastes containing mercury

121. There are three options for collecting wastes containing mercury such as fluorescent lamps, batteries, thermometers and electronic devices containing mercury from households (mercury batteries may be collected together with other types of batteries); these are discussed in the following three sections.

a. Waste collection stations or drop-off depots

122. Only waste containing mercury should be discarded in a specially designed container at a waste collection station or depot in order to avoid mixing waste containing mercury with other wastes. Waste containing mercury should be collected exclusively by collectors authorised by local governments or appropriate authorities.

123. Boxes or containers for waste containing mercury should be made available for public use at existing waste collection stations. Coloured, marked waste containers should be used exclusively for waste containing mercury such as fluorescent lamps and mercury-containing thermometers and batteries. Designated containers should all be the same colour and/or bear the same logo to facilitate public education and increased participation. Breakage of fluorescent lamps and thermometers should be avoided, *inter alia*, through appropriate box design and by providing 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 the lamp by installing soft, cascading baffles or flaps. Alternatively, a small open box could “invite” users to carefully place their spent bulbs there without breaking them. Another option to minimize breakage is that the consumer hands fluorescent lamps over to competent staff of a collection station who then places the lamps in a box. In the event that lamp breakage does occur, the area should immediately be ventilated and staff should be informed in advance and follow clean up procedures[23].

b. Collection at public places or shops

124. Waste containing mercury, particularly used fluorescent lamps, thermostats, mercury batteries and thermometers may be collected via specially designed collection vehicles or at public places or shops such as town halls, libraries, other public buildings, electronics stores, shopping malls and other retail outlets, provided that appropriate collection containers are available. Separate collection boxes or containers for these wastes should be designed to accommodate their characteristics and to

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22 The US Department of Energy provides detailed guidance on the safe handling and storage of elemental mercury in the following: http://mercurystorageeis.com/Elementalmercurystorage%20Interim%20Guidance%20(dated%202009-11-13).pdf and: http://mercurystorageeis.com/Volume%201-Final%20Mercury%20Storage%20EIS.pdf

23 Cleaning up a broken CFL, US EPA, see: http://www.epa.gov/cfl/cflcleanup.html; *Shedding Light on Mercury Risks from CFL Breakage,* Mercury Policy Project, February 2008, see: http://mpp.cclearn.org/wp-content/uploads/2008/08/final_shedding_light_all.pdf, German Environment Protection Agency, see: http://umweltbundesamt.de/energie/licht/hgf.htm (in German)

minimize breakage. Only containers specifically designed for this purpose and shown to be capable of containing mercury vapour from broken lamps should be used in public collection locations[24]. Consumers should be able to take used fluorescent lamps, mercury batteries, thermostats, and mercury thermometers to those places free of charge. Authorised collectors, such as municipal collectors or private sector collectors (e.g. collectors trusted by producers of those products), should collect the wastes in the waste collection boxes or containers.

125. Boxes or containers for waste containing mercury should be monitored to avoid any other waste being deposited in them. The boxes or containers should also be labelled and placed inside buildings such as public buildings, schools and shops, where they can be monitored in a well ventilated area, or, for example, outside the building in a covered and protected area.

c. Collection at households by collectors

126. Collection at households by authorised collectors may be applied for certain wastes such as e-waste. In order to ensure efficient collection of waste containing mercury by local collectors, an initiative or legal mechanism will be required; for example, governments, producers of mercury-added products or other agencies will need to provide arrangements for the collection of waste containing mercury by local collectors.

d. Take-back collection programme

127. Take-back programmes can refer to a variety of programmes established to divert products from the waste stream for purposes of recycling, reusing, refurbishing or in some cases recovery. Take-back programmes are often voluntary initiatives delivered by the private sector (e.g. manufacturers and in some cases retailers) which provide the opportunity to consumers to return used products at the point of purchase or some other specified facility. Some take-back programmes offer financial incentives to consumers, others can be mandated or operated by governments (e.g., bottle deposits), and others can also partly finance disposal or recycling activities. Generally, take-back collection programmes focus on consumer products which are widely used (Honda 2005), such as batteries, switches, thermostats, fluorescent lamps and other mercury-added products.

128. In a different manner, the producer collects and recycles used fluorescent lamps through leasing systems for business establishments in Japan such as the Akari Anshin Service (Panasonic 2009) and the Hitachi Lighting Service Pack (Hitachi 2006).

(c) Collection of wastes contaminated with mercury

129. Sewage treatment plants and waste incinerators are generally designed to include equipment for collecting sewage sludge, ash and residues which might contain trace amounts of mercury as well as other heavy metals. If mercury concentrations in these wastes exceed the criteria for hazardous waste, the wastes should be collected separately.

4. Packaging and labelling

130. For transporting wastes consisting of elemental mercury and wastes containing or contaminated with mercury from generators' premises or public collection points to waste treatment facilities, the wastes 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 there is no or insufficient instruction, reference materials published by national governments, IATA, IMO and UNCE should be consulted. International standards have been developed for the proper labelling and identification of wastes. The following reference materials are helpful.

(a) UNECE (2003): Globally Harmonized System of Classification and Labelling of Chemicals.

(b) OECD (2001b): Harmonized Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures.

5. Transportation

131. Wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be transported in an environmentally sound manner in order to avoid accidental spills and to track their transportation and ultimate destination appropriately. Prior to transportation, contingency plans should be prepared in order to minimize environmental impacts associated with spills, fires and

24 See: Glenz, T. G., Brosseau, L.M., Hoffbeck, R.W. (2009)

other emergencies that might occur. During transportation, such wastes should be identified, packaged and transported in accordance with the “United Nations Recommendations on the Transport of Dangerous Goods: Model Regulations (Orange Book)”. Persons transporting such wastes should be qualified and certified as carriers of hazardous materials and wastes.

132. Companies transporting wastes within their own countries should be certified as carriers of hazardous materials and wastes, and their personnel should be qualified. Transporters should manage wastes consisting of elemental mercury and wastes containing or contaminated with mercury in a way that prevents breakage, release of their components into the environment and exposure to moisture.

133. Guidance on the safe transportation of hazardous materials can be obtained from IATA, IMO, UNECE and ICAO.

6. Storage

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

134. Storage by waste generators pending collection means that wastes containing mercury are stored temporarily at the waste generator’s premises before the waste is 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. Waste should be stored by generators for a limited time, as allowed by national standards, and in any case sent off-site for appropriate disposal as soon as is practical.

135. Household wastes containing mercury, mainly fluorescent lamps, other lamps, mercury-containing batteries and mercury-containing thermometers, should be stored temporarily after appropriately packaging them, for example by using new product packaging or boxes that fit the shape of the wastes. Any mercury devices that are broken in the course of handling should be cleaned-up and all clean-up materials stored outdoors until collection for further management[25]. Liquid wastes containing mercury such as paints and pesticides should be kept in the original containers and their lids should be tightly closed. Containers and packages enclosing waste containing mercury should not be placed together with other wastes; they should be marked and stored in a dry place such as a warehouse or other space that is not usually frequented by people.

136. In addition to the guidance contained in the two above paragraphs, large-scale users such as governments, businesses and schools will also need a plan to store large amounts of wastes containing mercury. Where original boxes or packages are not available, containers which are specially designed to store wastes containing mercury (e.g. fluorescent lamp containers) should be purchased. Containers or boxes for storing wastes containing mercury should be marked and dated and stored in a dry place. It is recommended to use a separate area or room only for storing such wastes. Guidance developed by the GEF for mercury wastes generated by health care facilities[26] provides detailed advice in this regard, which may be applicable to many commercial facilities that generate waste mercury devices.

(b) Storage of wastes consisting of elemental mercury and wastes containing or contaminated with mercury pending disposal operations

137. This section covers storage of wastes consisting of elemental mercury and wastes containing or contaminated with mercury after collection before disposal as specified in paragraph 147. The technical requirements regarding storage of hazardous waste should be complied with, including national standards and regulations as well as international regulations. The risk of contamination to other materials should be avoided.

a. Technical and operational considerations for storage facilities

138. In terms of siting and design, storage facilities should not be built in sensitive locations such as floodplains, wetlands, groundwater, earthquake zones, Karst terrain, unstable terrain or those with unfavourable weather conditions and incompatible land use, in order to avoid any significant risks of mercury release and possible exposure to humans and the environment. The storage area should be designed to ensure that there is no unnecessary chemical or physical reaction to mercury. The floors of storage facilities should be covered with mercury-resistant materials. Storage facilities should have fire alarm systems and fire suppression systems and have negative pressure environments to avoid mercury

25 Materials should be stored outdoors because many commonly available containers such as plastic bags are permeable to mercury vapour. See, Maine DEP (2008)

26 Guidance on the Clean Up, Temporary or Intermediate Storage, and Transport of Mercury Waste from Healthcare Facilities. http://www.gefmedwaste.org/downloads/Guidance%20on%20Cleanup%20Storage%20and%20Transport%20of%20Mercury%20from%20Health%20Care%20July%202010.pdf

emissions to the outside of the building. The temperature in storage areas should be maintained as low as feasibly possible, preferably at a constant temperature of 21 °C. The storage area for wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be clearly marked with warning signs (FAO 1985; US EPA 1997b; SBC 2006; U.S. Department of Energy 2009).

139. In terms of operation, storage facilities should be kept locked to avoid theft or unauthorized access. Access to wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be restricted to those with adequate training for the purpose including in recognition, mercury-specific hazards and handling. It is recommended that storage buildings for all types of wastes consisting of elemental mercury and wastes containing or contaminated with mercury should not be used to store other liquid wastes and materials. A full inventory of the wastes kept in the storage site should be created and updated as waste is added or disposed of. Regular inspection of storage areas should be undertaken, focusing particularly on damage, spills and deterioration. Clean-up and decontamination should be carried out speedily, but not without alerting the authorities concerned. (FAO 1985; US EPA 1997b).

140. In terms of safety for facilities, site-specific procedures should be developed to implement the safety requirements identified for storage of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. A workable emergency plan, preferably with multiple procedures, should be in place and implemented immediately in case of accidental spillage and other emergencies. The protection of human life and the environment is paramount. In the event of an emergency, there should be a responsible person who can authorize modifications to the 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; SBC 2006; U.S. Department of Energy 2009).

b. Special considerations for wastes consisting of elemental mercury

141. All containers should be designed exclusively for wastes consisting of elemental mercury. The containers should meet the following requirements: (1) no damage from any previously contained materials and those materials should not adversely react with mercury; (2) no damage to the structural integrity of the container; (3) no excessive corrosion; and (4) should have a protective coating (paint) to prevent against corrosion. Appropriate material for mercury containers is carbon or stainless steel which does not react with mercury at ambient temperatures. No protective coating is required for the inner surface as long as mercury meets purity requirements and no water is present inside the container. Protective coating (e.g. epoxy paint and electroplating) should be applied to all exterior carbon steel surfaces in a manner that will not leave the steel exposed. The coating must be applied in a manner that minimizes blistering, peeling, or cracking of the paint. Labelling, including name of suppliers, origin, container number, gross weight, date when mercury was injected and a corrosives label, should be affixed to each container (US Department of Energy 2009). In addition, the container's compliance with specific technical requirements (tightness, pressure stability, shock resistance, behaviour when exposed to heat) should be shown on the label.

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

143. When storing wastes consisting of elemental mercury, it should be as pure as possible in order to avoid any chemical reaction and degradation of containers. A mercury content greater than 99.9 weight per cent is recommended. For purification techniques, see section III, G, 1, f below.

c. Special considerations for wastes contaminated with mercury

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

145. 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

146. The following disposal operations, as provided for in Annexes IV A and IV B of the Basel Convention, should be permitted for the environmentally sound management of wastes consisting of elemental mercury and wastes containing or contaminated with mercury[27]:

(a) R4 Recycling/reclamation of metals and metal compounds;

(b) R5 Recycling/reclamation of other inorganic materials;

(c) R8 Recovery of components from catalysts;

(d) R12 Exchange of wastes[28] for submission to operations R4, R5, R8 or R13;

(e) R13 Accumulation of material intended for operations R4, R5, R8 or R12;

(f) D5 Specially-engineered landfill;

(g) D9 Physico-chemical treatment;

(h) D12 Permanent storage;

(i) D13 Blending or mixing[29] prior to submission to D5, D9, D12, D14 or D15;

(j) D14 Repackaging prior to submission to D5, D9, D12, D13 or D15; and

(k) D15 Storage pending any of the operations D5, D9, D12, D13 or D14.

147. In addition, a form of backfilling in underground facilities may also be permitted whereby waste is utilised in underground facilities for mining safety purposes taking advantage of the respective structural properties of the waste[30]. In Germany for example, such a process is regulated by the Ordinance on Underground Waste Stowage (see http://www.bmu.de/3239) that contains requirements that are equivalent to the European Landfill Directive and is subject to special licensing procedures and supervision.

148. In case a process as described in section III, G, 1 is carried out and the mercury is subsequently sent to a D5 or D12 operation, the operations described in section III, G, 1 would fall under operations D13 and D9. On the other hand, in case a process described under section III, G, 2 (e.g. stabilization) is carried out and the waste is subsequently sent to an R operation, such a process would also fall under an R operation. This may not be the case in all countries.

1. Recovery operations

149. Mercury recovery from solid waste generally comprises four processes: 1) pre-treatment, 2) thermal treatment, 3) thermal desorption and 4) purification, as shown in Figure -5. In order to minimize mercury emissions from the mercury recovery process, a facility should employ a closed-system. The entire process should take place under reduced pressure in order to prevent leakage of mercury vapour into the processing area (Tanel 1998). The small amount of exhausted air that is used in the process passes through a series of particulate filters and a carbon bed which absorbs the mercury prior to exhausting to the environment.

150. Examples for mercury recovery are: waste mercury-added equipment that easily releases mercury into the environment when broken; and wastes contaminated with a high concentration of mercury. The former include lamps containing mercury, measuring devices containing mercury (thermometers, sphygmomanometers, and manometers) and mercury switches and relays. The latter include wastewater treatment sludge from wet scrubbers of non-ferrous metal smelters. In the USA, a specific standard for wastes subject to mercury recovery has been set; the waste having a total mercury content greater than or equal to 260 mg/kg is subject to mercury recovery based on the Land Disposal Restrictions (see: U.S. Code of Federal Regulations: 40 CFR 268.40).

27 For information on storage pending disposal operations (operations R13 and D15), see section III, F, 6.

28 Exchange of wastes is interpreted to cover pre-treatment operations unless another R code is appropriate.

29 Examples include pre-processing such as sorting, crushing, drying, shredding, conditioning or separating.

30 Such backfilling of mercury sulphide resulting from the stabilisation of waste consisting of elemental mercury is currently possible only in Germany.

151. The Technical Guidelines on the Environmentally Sound Recycling/Reclamation of Metals and Metal Compounds (R4) of the Basel Convention focus mainly on the environmentally sound recycling and reclamation of metals and metal compounds including mercury that are listed in Annex I to the Basel Convention as categories of wastes to be controlled. It is possible to recycle wastes consisting of elemental mercury and wastes containing or contaminated with mercury, particularly elemental mercury, in special facilities which have advanced mercury-specific recycling technology. 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 recovery of metal will usually be determined by the degree of allowable use and a commercial evaluation as to whether it can be profitably recovered.

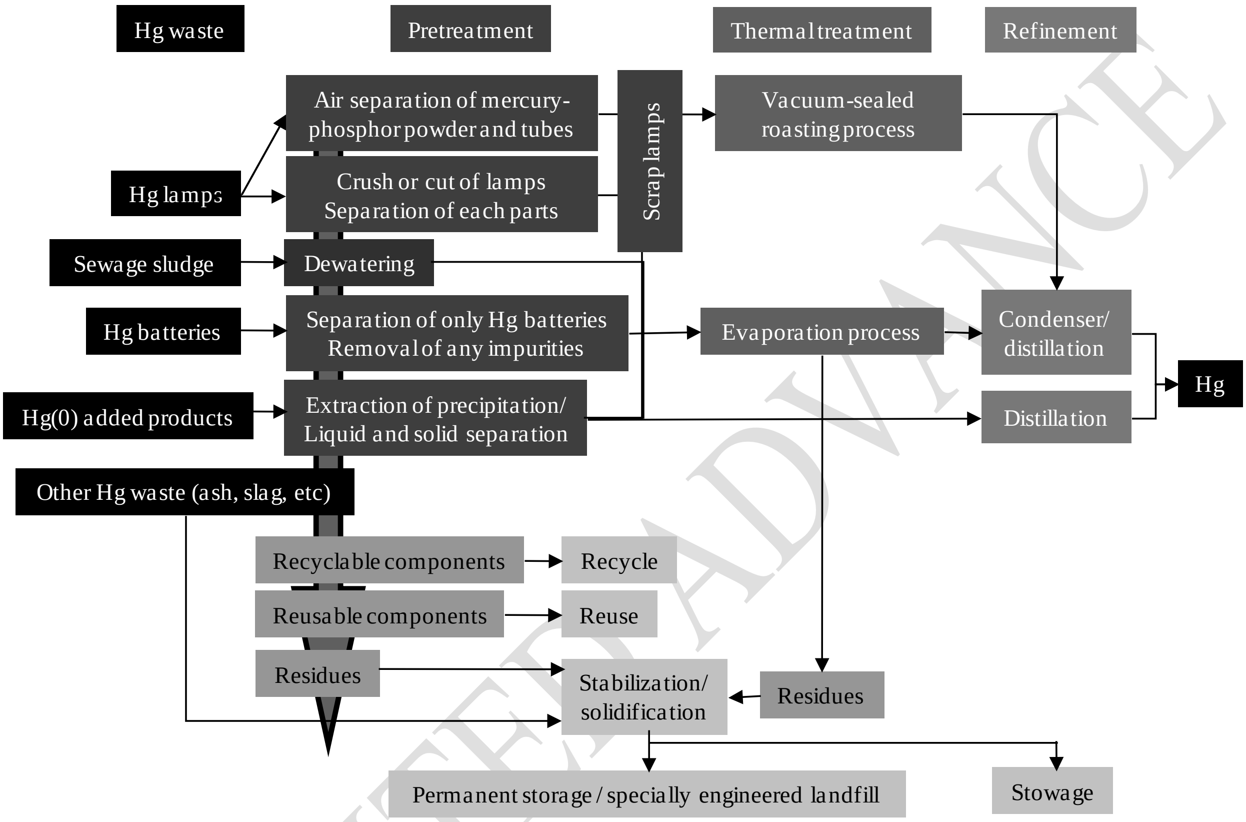

Figure -5 Flow of mercury recovery from solid waste (Nomura Kohsan Co. Ltd. 2007)

152. Mercury recovery from wastewater is generally achieved by chemical oxidation, chemical precipitation, or adsorption and subsequent treatment processes. Mercury exists in wastewater due to accidental or intentional discharging of elemental mercury from thermometers, dental amalgams, or other industrial processes using mercury or mercury compounds. Mercury may be found in wastewater from wet-type air pollution control devices and leachate from landfills/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 into methylmercury which is bioaccumulated and biomagnified in the food chain.

153. Pre-treatment prior to operation R4 (recovery of mercury) falls under operation R12 and roasting, purification, chemical oxidation/precipitation and adsorption fall under operation R4.

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

154. Before undergoing thermal treatment, wastes containing mercury or contaminated with mercury are treated in order to increase the efficiency of the thermal treatment; the pre-treatment processes include removal of materials other than those containing mercury by crushing and air separation, dewatering of sludge and removal of impurities. Examples of waste-specific pre-treatment operations are summarized in Table -4.

Table -4 Examples of Pre-Treatment Operations by Waste Type

Waste Type	Pre-treatment
Fluorescent Lamps	***Mechanical Crushing*** Waste mercury-containing lamps should be processed in a machine which crushes and separates the lamps into three categories: glass, end-caps and a mercury-phosphor powder mixture. This is accomplished by injecting the lamps into a sealed crushing and sieving chamber. Upon completion, the chamber automatically removes the end products to eliminate the possibility of 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 is further processed to separate the mercury from the phosphor (Nomura Kohsan Co. Ltd. 2007,). Lamp glass from crushed mercury-containing lamps can retain significant amounts of mercury, and should be treated thermally or in other ways to remove mercury before sending it for recovery (Jang 2005) or disposal. If this glass is sent for re-melting as part of its recovery process, the melting unit should have air pollution controls specifically directed at capturing released mercury (such as activated carbon injection). A high-performance exhaust air system should prevent the emission of any mercury vapours or dust during the entire process. The fluorescent powder and any mercury should be removed from the chopped lamps in vibro wells by means of vibration and water. The washed-out fluorescent powder, including the mercury and fine particles of glass, sediment in two stages and the process water is returned to the washing process circulation (www.dela-recycling.com)
	Air Separation Aluminium end caps of fluorescent lamps (straight, circular and compact tubes) are cut by hydrogen burners. Air blowing flows into the cut fluorescent lamps from the bottom to remove mercury-phosphor powder adsorbed on glass (Jang 2005). Mercury-phosphor powder is collected at a precipitator and glass parts are crushed and washed with acid, through which mercury-phosphor powder adsorbed on glass is completely removed. In addition, end-caps are crushed and magnetically separated to aluminium, iron and plastics for recycling (Kobelco Eco-Solutions Co. Ltd. 2001; Ogaki 2004).
Mercury-containing Batteries	***Removal of Impurities*** In order to recycle mercury, mercury-containing batteries should be collected separately and stored in suitable containers before treatment and recycling. If mercury-containing batteries are collected together with other types of batteries or with waste electrical and electronic equipment, mercury-containing batteries should be separated from other types of batteries. Before roasting treatment, impurities mixed with and adsorbed onto mercury-containing batteries should be removed, preferably by mechanical process. In addition, mechanical screening of the size of mercury-containing batteries is necessary for an effective roasting process. (Nomura Kohsan Co. Ltd. 2007).
Sewage Sludge	***Dewatering*** Sewage sludge has high water content (more than 95 per cent). Therefore 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 in a roasting process (Nomura Kohsan Co. Ltd. 2007; US EPA 1997a)
Elemental Mercury-containing wastes	***Extraction*** Elemental mercury-containing wastes such as thermometers and barometers should be collected without any breakage. After collection of elemental mercury-containing wastes, elemental mercury in the products should be extracted, and the extracted elemental mercury is distilled for purification under reduced pressure.
Wastes containing mercury attached to devices	***Dismantling*** Wastes containing mercury, such as electric switches and relays, are usually attached to electric devices. Therefore, such wastes should be removed from the devices without breakage of the outer glass. Computer monitors and televisions that use flat screen liquid crystal display (LCD) technology contain one or more small lamps for illumination, usually located along the outside edge of the screen. While new technology sometimes uses light emitting diodes

Waste Type	Pre-treatment
	(LED) for these lamps, most LCD screens contain fluorescent mercury vapour lamps. These mercury lamps may often break during handling and mechanized processing and will then release their mercury vapour. Therefore, they should be carefully removed, by hand, and not be put in mechanized processing such as shredding, unless the shredding equipment has the necessary pollution control equipment to manage such operations and is licensed and permitted to do so, such as at mercury treatment facilities. For further information see section 7.3 of the Basel Convention Partnership for Action on Computing Equipment: Guideline on environmentally sound material recovery and recycling of end-of-life computing equipment (document UNEP/CHW.10/INF/23). Further information on the presence of mercury in LCD backlights is available. (see Waste Resources Action Programme research report at: http://www.wrap.org.uk/recycling_industry/publications/flat_panel_display.html).

(b) Recycling/reclamation of mercury and mercury compounds

a. Thermal treatment

155. Wastes containing or contaminated with mercury such as sewage sludge, contaminated soils or other wastes from contaminated sites that are thermally treated should be equipped with mercury vapour collection technology to recover mercury (ITRC 1998; Chang and Yen 2006).

156. Thermal desorption is a process that uses either indirect or direct heat exchange to heat organic contaminants to a high enough temperature to volatilize and separate them from a contaminated solid matrix and then either collect or destroy them. In the case of mercury and its compounds, indirect thermal desorption with collection of mercury is the recommended option. Air, combustion gas or an inert gas is used as the transfer medium for the vaporized components. Thermal desorption systems are physical separation processes that transfer contaminants from one phase to another. A thermal desorption system has two major components; the desorber itself and the offgas treatment system[31].

157. There are several evaporation processes, namely the rotary kiln distillation, vacuum thermal processing and vacuum dry mixing.

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

159. The waste is fed evenly from a feed hopper via a dosage system to the rotary kiln. Waste that needs to be treated in the rotary kiln distillation should be free-flowing and conveyable. The waste is treated in the rotary kiln distillation at temperatures of up to 800°C. The materials used are moved evenly through the rotary kiln. The mercury in the waste is evaporated by heating the waste up to temperatures over 356°C. The required residence time of the waste in the rotary kiln depends on the input material but is usually between 0.5-1.5 h. 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 higher safety. The stream of exhaust air flows to two gas scrubbers via 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[32].

160. Pre-treated waste, such as mercury-phosphor powder in fluorescent lamps, crushed lamp glass, cleaned mercury-containing batteries, dewatered sewage sludge, and screened soil, may be treated by roasting/retorting facilities, equipped with a mercury vapour collection technology to recover mercury. However, it should be noted that volatile metals, including mercury and organic substances (including POPs), are emitted during roasting and other thermal treatments. These substances are transferred from the input waste to both the flue gas and the fly ash. Therefore, flue gas treatment devices should be equipped (see section III, H, 1 below).

31 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 optimising 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).

32 www.dela-recycling.com

161. In a vacuum dry mixer, pre-treatment and further treatment of sludge containing mercury can be carried out. Operation in vacuum atmosphere lowers the boiling temperature which provides for an energy-efficient process and safe operation. Depending on the vacuum level and temperature reached at the operation of the plant, the mixer can be used for pre-treatment or further treatment of sludge. A two-stage treatment in a vacuum mixer has proven expedient when treating sludge containing mercury with high levels of water and hydrocarbons. In the first process stage, water and most of the existing hydrocarbons evaporate. The quantitative evaporation of the mercury takes place in the second process stage at the maximum treatment temperature. The mercury is condensed separately from the water and hydrocarbons and can be removed from the process. A vacuum unit is designed with a double jacket, indirectly heated with thermal oil, which gives an even distribution of heat into the treated input material. An even more efficient distribution of heat can be achieved with a heated shaft. The flue gas from the vacuum mixer is cleaned in a condensing unit and an activated carbon filter. The vacuum mixer is operated batch-wise (www.dela-recycling.com).

162. Vacuum thermal processing enables the treatment inter alia of thermometers, batteries, especially button cells, dental amalgam, electrical switches and rectifiers, fluorescent powder, exhaust tubes, crushed glass, soil, sludge, mining residues and catalyst material. The process includes in general the following stages:

(a) Heating up the input material in a special kiln or in charging operation to evaporate the mercury contained in the waste. The conditions are temperatures between 340°C and 650°C and pressures of a few millibar;

(b) Thermal post-treatment of vapour containing mercury under temperatures ranging from 800°C to 1000°C, where for example organic components can be destroyed;

(c) Collecting and cooling of mercury containing vapour; and

(d) Distillation to generate pure liquid mercury.

163. The residue which remains at the end of the vacuum thermal processing is essentially mercury-free and is either recycled or otherwise disposed of depending on its composition[33] .

b. Chemical oxidation

164. Chemical oxidation of elemental mercury and organomercury compounds is carried out to destroy the organics and to convert mercury so that it forms mercury salts. It is effective for treating liquid waste containing or contaminated with mercury. Chemical oxidation processes are useful for aqueous waste containing or contaminated with mercury such as slurry and tailings. Oxidizing reagents used in these processes include sodium hypochlorite, ozone, hydrogen peroxide, chlorine dioxide, and free chlorine (gas). Chemical oxidation may be conducted as a continuous or a 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 (US EPA 2007a).

c. Chemical precipitation

165. Precipitation uses chemicals to transform dissolved contaminants into an insoluble solid. In coprecipitation, the target contaminant may be in a dissolved, colloidal, or suspended form. Dissolved contaminants do not precipitate, but are adsorbed onto another species that are 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 water can include a combination of precipitation and coprecipitation. The precipitated/coprecipitated solid is then removed from the liquid phase by clarification or filtration. More detailed information can be found in "Treatment Technologies for Mercury in Soil, Waste, and Water" (US EPA 2007d).

d. Adsorption treatment

166. Adsorption materials hold mercury on the surface 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. Mercury or mercury compounds are adsorbed as liquid wastes pass through the column. The column should be regenerated or replaced with new media when adsorption sites become filled (US EPA 2007b).

33 www.gmr-leipzig.de/gbverfahren.htm

167. Examples of adsorption materials include activated carbon and zeolite. Activated carbon is a carbonic material having that has many fine interconnected openings. It can typically have a wooden base (coconut shells and sawdust), oil base or coal base. It can be classified, based on its shape, into powdery activated carbon and granular activated carbon. Many products are commercially available, offering the specific features 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 and clinoptilolite in particular, have a strong affinity for heavy metal ions where the adsorption mechanism is ion-exchange (Chojnacki *et al.* 2004).

168. Ion exchange resins have proven useful in removing mercury from aqueous streams, particularly at concentrations in the order of 1 to 10 µg/L. Ion exchange applications usually treat mercuric salts, such as mercuric chlorides, that are found in wastewaters. This process involves suspending a medium, 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).

169. Chelating resin is an ion-exchange resin that has been developed as a functional polymer and which selectively catches ions from solutions, including various metal ions, and separates them. It is made of a polymer base of three-dimensional mesh construction, with a functional group that chelate combines metal ions. As the material of the polymer base, polystyrene is most common, 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 mercury adsorption type can effectively remove mercury in wastewater (Chiarle 2000).

e. Distillation of mercury – purification

170. After treatment, collected mercury is subsequently purified by successive distillation (US EPA 2000). High purity mercury is produced by distillation in many steps, permitting a high purity grade to be achieved in each distillation step[32].

2. Operations not leading to recovery of elemental mercury

171. Before disposing of wastes consisting of elemental mercury and wastes containing or contaminated with mercury, they should be treated so as to meet the acceptance criteria of the disposal facilities (see section III, G, 2, (b) below). Wastes consisting of elemental mercury should be solidified or stabilized before being disposed of. The disposal of the wastes should be carried out according to national and local laws and regulations. Treatment operations prior to D5 and D12 operations fall under operation D9.

(a) Physico-chemical treatment

a. Stabilization and solidification

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

173. Solidification and stabilization (S/S) is applied, for example, to waste consisting of elemental mercury and waste contaminated with mercury such as soil, sludge, ash, and liquid. S/S reduces the mobility of contaminants in the media by physically binding them within stabilized mass or inducing chemical reactions that may reduce solubility or volatility, thereby reducing mobility (US EPA 2007b).

174. S/S is usually used for various wastes, such as sewage sludge, incinerator ash, liquid contaminated with mercury, and soils contaminated with mercury. Mercury from these wastes is not easily accessible to leaching agents or thermal desorption but is leachable when the stabilized waste is landfilled and kept at a landfill site for a long time, as is the case with other metals and organic compounds. Mercury in the solidified and stabilized waste in the landfill can leach (i.e. dissolve and move from the stabilized waste through liquids in the landfill), migrate into ground water or nearby surface water and vaporise into the atmosphere under natural environmental conditions.

175. S/S involves physically binding or enclosing contaminants within a stabilized mass (solidification) or inducing chemical reactions between the stabilizing agent and the contaminants to reduce their mobility (stabilization). Solidification is used to encapsulate or absorb the waste, forming a solid material, when free liquids other than elemental 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 the encasing material before solidification occurs. Macroencapsulation refers to the process of pouring the encasing material over and around the waste mass, thus enclosing it in a solid block (US EPA 2007b).

176. Generally speaking, the solidification process involves mixing soil or waste with binders such as Portland cement, sulphur polymer cement (SPC), sulphide and phosphate binders, cement kiln dust, polyester resins, or polysiloxane compounds to create a slurry, paste, or other semi-liquid state, which is allowed time to cure into a solid form (US EPA 2007b).

177. There are two main chemical approaches that can be applied to wastes consisting of elemental mercury and wastes containing or contaminated with mercury (Hagemann 2009):

(a) Chemical conversion to mercury sulphide; and

(b) Amalgamation (formation of a solid alloy with suitable metals).

178. A sufficient risk reduction is achieved if the conversion rate to mercury sulphide (percentage of reacted mercury) is near or equal to 100 per cent. Otherwise mercury volatility and leachability remains high, as is the case with amalgams (Mattus 1999).

Stabilization as mercury sulphide

179. Since the most common natural occurrence of mercury is as cinnabar (HgS) from which metallic mercury is derived, one of the most important and well investigated approaches is the reconversion of elemental mercury close to its natural state as HgS. Wastes consisting of elemental mercury are mixed with elemental sulphur or with other sulphur-containing substances to form mercury sulphide (HgS). The production of HgS can result in two different types, alpha-HgS (Cinnabar) and beta-HgS (meta-cinnabar). Pure alpha-HgS (intensive red colour) has a slightly lower water solubility compared to pure beta-HgS (black colour). HgS is a powder with a density of 2.5-3 g/cm^3.

180. In general, HgS is produced by blending mercury and sulphur under ambient conditions for a certain time, until mercury(II) sulphide is produced. To start the reaction process, a certain activation energy is required which may be provided by intensive mixing of the blend. Among other factors, higher shear rates and temperatures during the process support the production of the alpha phase, whereas a longer process time favours the creation of beta cinnabar. Excessively long milling in the presence of oxygen can lead to the production of mercury(II) oxide. As HgO has higher water solubility than HgS, its creation should be avoided by 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 a safe operation. The process is robust and relatively simple to carry out. The HgS is insoluble in water and non-volatile, chemically stable and nonreactive, being attacked only by concentrated acids. As a fine powdery material, its handling is subject to specific requirements (to avoid, for example, the risk of dust releases). This stabilisation process leads to an increase in volume by ~300 per cent and in weight by ~16 per cent based on molecular weights compared to elemental mercury.

181. A large scale stabilisation process for waste consisting of elemental mercury with sulphur, forming mercury sulphide (HgS), has been available since 2010. 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, with 800 kg of metallic mercury in each batch. A dust filter and an activated carbon filter prevent releases from the plant. The reaction between mercury and sulphur takes place at a stoichiometric ratio. The end product consists of red mercury sulphide with leaching values below 0.002 mg Hg/kg (tests according to EN12457/1-4). The end product is thermodynamically stable up to 350°C. The vacuum mixing process ensures a safe operation i.e. there is no leakage during the operation and energy demand is reduced through a lowering of the boiling point[32]. The waste acceptance criteria including a leaching test according to European 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 for the mercury sulphide have been met. The mercury sulphide should preferably be disposed of in an underground facility.

Sulphur polymer stabilization/solidification (SPSS)

182. The Sulphur Polymer Stabilization Process (SPSS) is a modification of sulphur stabilization with the advantage of a lower chance of mercury vapour and leaching because the final product is monolithic with a low surface area. Within this process elemental mercury reacts with sulphur to mercury(II) sulphide. Simultaneously, the HgS is encapsulated and thus the final product is a monolith. The process relies on the use of ~95 per cent by weight of elemental sulphur and 5 per cent of organic polymer modifiers, also called sulphur polymer cement (SPC). The SPC can be dicyclopentadiene or oligomers of cyclopentadiene. The process has to be carried out at a relatively high temperature of about 135°C, which may lead to some volatilization and thus emission of the mercury during the process. In any event, the process requires the provision of an inert atmosphere in order to prevent the formation of water soluble mercury(II) oxide. In the case of SPC, beta-HgS is obtained. The addition of sodium sulphide nonahydrate results in alpha-HgS as a product.

183. A relatively high Hg load of the monolith (~70 per cent) can be achieved with this process as there is no chemical reaction of the matrix required to set and cure. The process is robust and relatively simple to implement and the 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. During the process, volatile losses are liable to occur and therefore appropriate engineering controls are needed. Engineering controls to avoid possible ignition and explosions are also necessary. Additionally, the volume of the resulting waste material is considerably increased[34].

184. Product stability is reported as the lowest leaching behaviour achieved at a pH value of 2 with 0.001 mg/l. In a more or less linear trend the leaching value reaches a maximum of ~0.1 mg/l at pH value of 12 and another example between 0.005 and 45 mg/l for different pH values. The reason for this wide range of leaching behaviour of the latter was not the pH dependency but a small amount of elemental mercury which still existed in the final product. The investor explained that product quality increased as the process became better controlled. No mercury emission from the product was reported (BiPRO 2010).

Amalgamation

185. 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 elemental 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 elemental mercury, forming a solidified amalgam. The aqueous replacement process is applicable to both mercury salts and elemental mercury, while the non-aqueous process is applicable only to elemental mercury. However, mercury in the resultant amalgam is susceptible to volatilization or leaching. Therefore, amalgamation is typically used in combination with an encapsulation technology (US EPA 2007b).

b. Soil washing and acid extraction

186. 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. This process is based on the concept that most contaminants tend to bind to the finer soil particles (clay and silt) rather than the larger 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" (US EPA 2007b).

(b) Specially engineered landfill

187. Following stabilization or solidification, waste containing or contaminated with mercury that meets the acceptance criteria for specially engineered landfills defined by national or local regulations,

34 For further information see MERSADE project under http://www.mersade.eu/.

may be disposed of in specially engineered landfills. Some jurisdictions have defined acceptance criteria for landfilling of wastes containing or contaminated with mercury. Under EU 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 in landfills for non-hazardous and hazardous wastes, respectively. Under US mercury waste treatment regulations, only low concentration mercury wastes can be treated and landfilled. 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 in excess of 0.005 mg/L (Leaching Test Method: Japanese Standardized Leaching Test No. 13 (JLT-13) (Ministry of the Environment Notification No. 13)) should be disposed of at a specially engineered landfill in Japan (Ministry of the Environment, Japan 2007b). In addition, disposal of certain wastes containing or contaminated with mercury in landfills is banned in some countries.

188. 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 secure (SBC 1995b).

189. In principle, and for a defined time period, a landfill site can be engineered to be environmentally safe subject to the site being appropriate and with proper precautions and efficient management. Specific requirements should be met pertaining to site selection, design and construction, landfill operations and monitoring for specially engineered landfills, in order to prevent leakages and contamination of the environment. Control and oversight procedures should apply equally to the process of site selection, design and construction, operation and monitoring, as well as closure and post-closure care (SBC 1995b). Permits should include specifications regarding types and concentrations of wastes to be accepted, leachate and gas control systems, monitoring, on-site security, and closure and post-closure.

190. Particular attention should be paid to the measures required to protect groundwater resources from leachate infiltration into the soil. Protection of soil, groundwater and surface water should be achieved by the combination of a geological barrier and a bottom liner system during the operational phase and by the combination of a geological barrier and a top liner during the closure and post-closure phase. A drainage and collection system for leachate should be installed within the landfill that will allow 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 a landfill so that any possible adverse environmental effects of the landfill can be identified and the appropriate corrective measures 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 the specially-engineered landfill such as the construction of the dykes, cut slopes, landfill cells, roadways and drainage structures (Canadian Council of Ministers for the Environment CCME) 2006). For example, the landfill site could be enclosed in watertight and reinforced concrete, and covered with the sort of equipment which prevents rainwater inflow such as a roof and a rainwater drainage system (Figure -6) (Ministry of the Environment, Japan 2007a). A number of liner and leachate control systems have been documented for their effectiveness under varying conditions. The Basel Convention Technical Guidelines on Specially Engineered Landfills explain in detail a few other approaches to engineered containment systems that may be considered if the conditions are appropriate (SBC, 1995b).

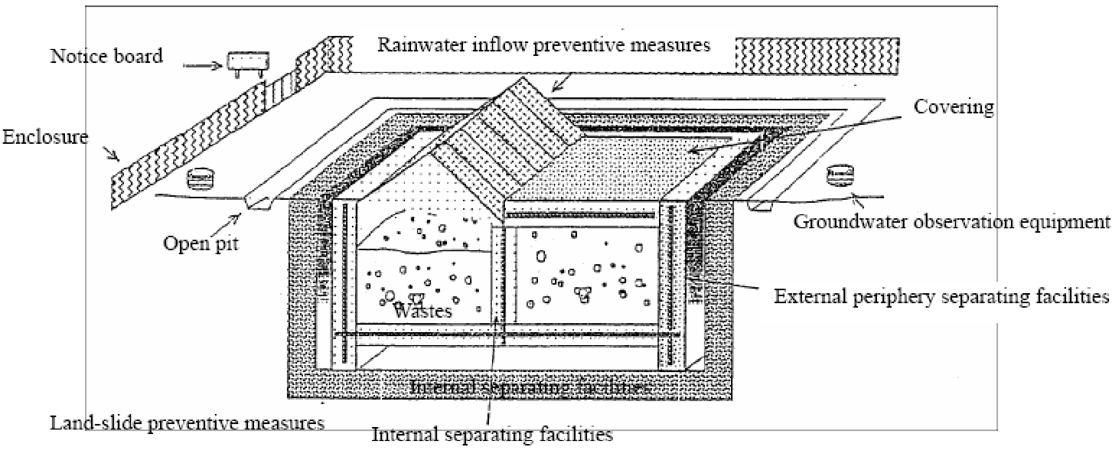

Figure -6 Specially engineered landfill (Ministry of the Environment, Japan 2007a)

191. For further information about specially engineered landfills, see the Basel Convention Technical Guidelines on Specially Engineered Landfill (D5) (SBC 1995b).

(c) Permanent storage (underground facility)

192. Following solidification or stabilization, if appropriate, wastes containing or contaminated with mercury[35] which meet the acceptance criteria for permanent storage may be permanently stored in special containers in designated areas such as an underground storage facility.

193. The technology for underground storage is based on mining engineering, which includes the technology and the methodology to excavate mining areas and construct mining chambers as tessellated grid of pillars[36]. Disused mines could be used for the permanent storage of solidified and stabilized waste once they have been specifically adapted for the purpose.

194. In addition, the principles and experience in the underground disposal of radioactive waste can be applied to the underground storage of wastes containing or contaminated with mercury. While excavation of a deep underground repository using standard mining or civil engineering technology is a possibility, it is limited to accessible locations (e.g. below surface or nearshore), to rock units that are reasonably stable and without major groundwater flow, and to depths of 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).

195. The following publications contain further detailed information on permanent storage for wastes containing or contaminated with mercury:

(a) European Community (2003): Safety Assessment for Acceptance of Waste in Underground Storage -Appendix A to Council Decision 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 : http://eur-lex.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, http://ec.europa.eu/environment/chemicals/mercury/pdf/bipro_study20100416.pdf;

(c) International Atomic Energy Agency (IAEA) (2009): Geological Disposal of Radioactive Waste: Technological Implications for Retrievability http://www-pub.iaea.org/MTCD/publications/PDF/Pub1378_web.pdf;

(d) World Nuclear Association (2010): Storage and Disposal Options, 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, http://www.unep.org/hazardoussubstances/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, http://www.unep.org/hazardoussubstances/Mercury/InterimActivities/Partnerships/SupplyandStorage/AsiaPacificMercuryStorageProject/tabid/3552/language/en-US/Default.aspx.

196. Permanent storage in facilities located underground in geohydrologically isolated salt mines and hard rock formations is an option to separate hazardous wastes from the biosphere for geological periods of time. A site-specific risk assessment according to pertinent national legislation such as the provisions contained in Appendix A to the Annex to European 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 should be performed for every planned underground storage facility.

197. Wastes should be disposed of in a manner that excludes (a) any undesirable reaction between different wastes or between wastes and the storage lining and (b) the release and transport of hazardous substances. Operational permits should define the waste types that should be generally excluded. Isolation is provided by a combination of engineered and natural barriers (rock, salt, clay) and no obligation to actively maintain the facility is passed on to future generations. This is often termed a multi-barrier concept, with the waste packaging, the engineered repository and the geology

35 This includes wastes consisting of elemental mercury after stabilization or solidification.

36 In Germany for example, significant experience on underground storage of hazardous waste is available.

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

198. Specific factors such as layout, containments, storage place and conditions, monitoring, access conditions, closure strategy, sealing and backfilling and depth of the storage place, which affect the behaviour of mercury in the host rock and the geological environment, need to be considered separately from the waste properties and the storage system. Potential host rocks of permanent storage for wastes containing or contaminated with mercury are salt rock and hard rock formations (igneous rocks, e.g. granite or gneiss including sedimentary rocks e.g. limestone or sandstone) (BiPRO 2010; European Community 2003; IAEA 2009; World Nuclear Association 2010).

199. The following considerations should be borne in mind when selecting a permanent storage site for the disposal of wastes containing or contaminated with mercury:

(a) Caverns or tunnels used for storage should be completely separated from active mining areas and areas that maybe reopened for mining;

(b) Caverns or tunnels should be located in geological formations that are well below zones of available groundwater or in formations that are completely isolated by impermeable rock or clay layers from water-bearing zones; and

(c) Caverns and tunnels should be located in geological formations that are extremely stable and not in areas subject to earthquakes.

200. In order to guarantee complete inclusion, the disposal mine and any area around it which might be affected by the disposal operations (e.g. geomechanically or geochemically) should be surrounded by a host rock (called Isolating Rock Zone) of sufficient thickness and homogeneity, with suitable properties and at suitable depth (see Figure -7). As a basic principle, a long-term risk assessment should be able to prove that the construction, the operation and the post-operational phase of an underground disposal facility would not lead to any degradation of the biosphere. Consequently, appropriate models must be used to analyse and assess all technical barriers (e.g. waste-form, backfilling, sealing measures), the behaviour of the host and surrounding rock, overburden rock formations and the sequence of possible events in the overall system.

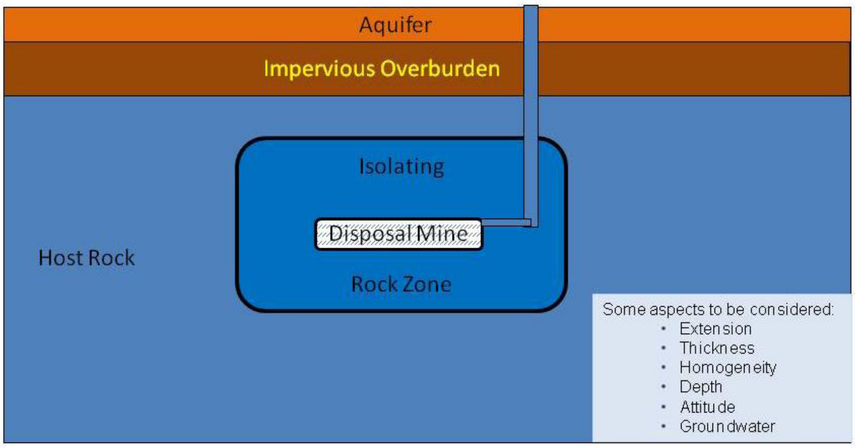

Figure -7 Concept of complete inclusion (schematic) (courtesy: GRS)

201. If the rock formation under consideration shows any deficiencies (e.g. of homogeneity or thickness), a multi-barrier system can compensate for the missing or inadequate barrier properties of the host rock. In general, a multi-barrier system of this kind may be composed of one or several additional barrier components (see Table -5 and Figure -8) that can help to achieve the ultimate goal, viz. to durably isolate the wastes from the biosphere.

202. A long-term safety assessment (see above) should be conducted to ascertain the need for and the mode of action of the multi-barrier system within the disposal system. By way of example, the geological formation(s) overlaying a disposal mine ('overburden') may be effective in different ways by (a) protecting the underlying host rock from any impairments of its properties and/or (b) the provision of additional retention capacities for contaminants which might be released from the disposal mine under certain circumstances.

Table -5 Possible components of a multi-barrier system and examples for their mode of action

Barrier component	Example for mode of action
Waste content	Reducing 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	Backfill 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 case)
Overburden	Additional natural (geological) barrier, e.g. overlaying clay layer with sufficient thickness and suitable properties

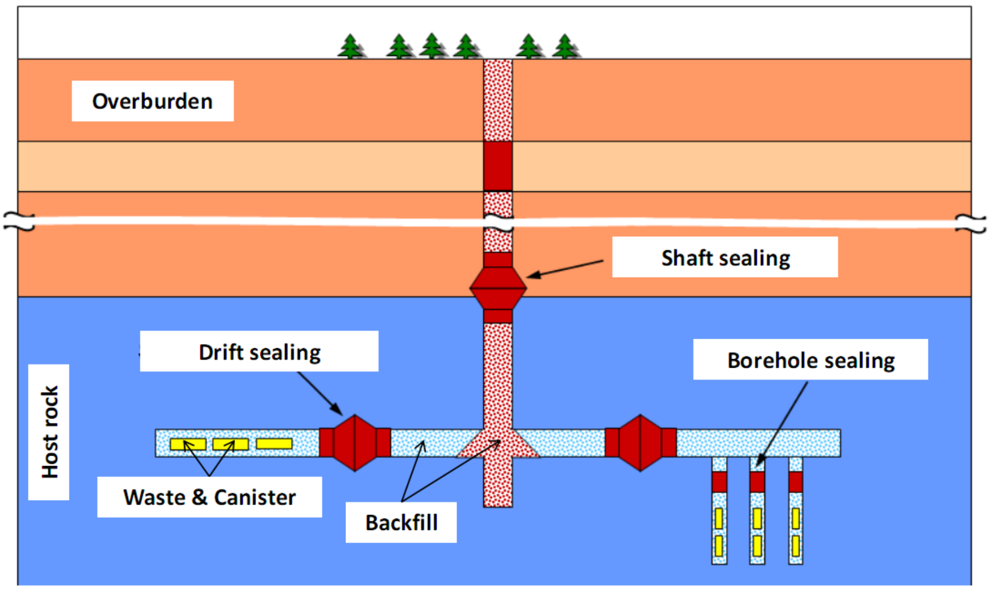

Figure -8 Main components of a multi-barrier system and their layout within the system (schematic) (courtesy: GRS)

203. In general, an underground disposal concept as described above, including all the criteria, requirements and final layout etc., should be designed according to waste-specific and site-specific criteria, taking into consideration all relevant regulations (e.g. European Community 2003). To give a rough idea of the depth and thickness of different types of host rock, the following Table -6 lists typical dimensions, based on current experience and plans.

Table -6 Typical values of vertical thickness of host rock body and potential disposal depth (after 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 disposal of waste

1. Reduction of mercury releases from thermal treatment of waste

204. Mercury may currently still be contained in municipal waste, e.g. in batteries, thermometers, fluorescent lamps or mercury switches. Separate collection of these leads to a reduction of overall loads in mixed MSW but collection rates of 100 per cent are not achieved in practice. Consequently, wastes containing or contaminated with mercury may be combusted whereby, by reason of its low boiling point, almost all the mercury in the waste is transferred to combustion gas and little mercury remains in bottom ash. Most of the mercury in combustion gas within a waste combustion unit is in the form of elemental mercury, but most of the elemental mercury transforms to divalent mercury after passing through the combustion unit, and part of the divalent mercury is transferred to fly ash. The divalent mercury is assumed to be mercuric chloride; consequently, flue gas treatment devices that can effectively remove such mercuric chloride and elemental 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 an incinerator without flue gas treatment devices (Arai *et al*. 1997). Emission and effluent standards for mercury should be set and the mercury level of treated flue gas and wastewater should be monitored to ensure mercury releases into the environment are kept to a minimum. Such practices should also be applied in other thermal treatment of waste such as vacuum-sealed roasting facilities.

205. Primary techniques for preventing mercury releases to air from waste incineration are those which prevent or control, if possible, the inclusion of mercury in the waste stream, such as the following (European Commission 2006):

(a) Efficient removal of mercury-added products from the waste stream, e.g., separate collection of certain types of batteries, dental amalgam (using amalgam separators) before these wastes are co-mingled with other wastes or wastewaters);

(b) Notifying waste producers of the need to segregate mercury;

(c) Identification and/or restriction of receipt of potential wastes containing or contaminated with mercury; and

(d) Where such wastes are known to be received – control of feeding such waste to avoid overload of abatement system capacity.

206. Secondary techniques for preventing mercury releases to air from the waste stream include treatment of flue gas. The EU established standards in the Directive on the Incineration of Waste (2000/76/EC) (European Community 2001), such as emission limit values for discharges of waste water from the cleaning of flue gases 0.03 mg/L for mercury and its compounds, expressed as mercury (Hg), and an air emission limit of 0.05 mg/m^3 for 30 minutes average and 0.1 mg/m^3 as eight hours average limit for mercury and its compounds, expressed as mercury (Hg). The Protocol on Heavy Metals within the framework of the UNECE Convention on long-range transboundary air pollution sets legally binding limit values for the emission of mercury of 0.05 mg/m^3 for hazardous waste incineration and 0.08 mg/m^3 for municipal waste incineration.

207. The selection of a process for mercury abatement depends upon the chlorine content of the burning material. At higher chlorine contents, mercury in the crude flue gas will be increasingly in the oxidized form, which can be deposited in wet scrubbers. In incineration plants for municipal and hazardous wastes, the chlorine content in the average waste is usually high enough, in normal operating states, to ensure that Hg is present mainly in the oxidized form. Volatile Hg compounds, such as $HgCl_2$, will condense when flue-gas is cooled, and dissolve in the scrubber effluent. The addition of reagents for the specific removal of Hg provides a means for removing it from the process. It should be noted that in the incineration of sewage sludge, mercury emissions are mostly in the elemental form, due to the lower chlorine content of the waste than in 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 is done by adding oxidants and then depositing it in the scrubber or deposing it directly on sulphur doped activated carbon, hearth furnace coke, or zeolites. Removal of heavy metals from wet scrubber systems can be achieved by flocculation, where metal hydroxides are formed under the influence of flocculation agents (poly-electrolytes) and $FeCl_3$. For the removal of mercury, complex-builders and sulphides (e.g. Na_2S, Tri-Mercaptan, etc.) are added.

208. Mercury in flue gas can be removed by adsorption on activated carbon reagents in an entrained flow system whereby activated carbon is injected into the gas flow. The carbon is filtered from the gas

flow using bag filters. The activated carbon shows a high adsorption efficiency for mercury as well as for PCDD/PCDF. Different types of activated carbon have different adsorption efficiencies. This is believed to be related to the specific nature of the carbon particles, which are, in turn, influenced by the manufacturing process (European Commission 2006). Static bed filters of grained Hearth Furnace Coke (HFC – a fine coke of 1.25 mm to 5 mm) are effective in depositing almost all emission relevant flue-gas components, in particular, residual contents of hydrochloric acid, hydrofluoric acid, sulphur oxides, heavy metals (including mercury), sometimes to below the detection limit. The depositing effect of the HFCs is essentially based on mechanisms of adsorption and filtration. In general, incinerators are equipped with flue gas treatment devices so as not to release NO_x, SO_2 and particulate matter (PM), and these devices can capture mercury vapour and particulate-bound mercury as a co-benefit. Powdered activated carbon (PAC) injection is one of the advanced technologies used for mercury removal in incinerators or coal fired power plant. Mercury adsorbed on activated carbons can be stabilised or solidified for disposal (see section III, G, 2, (a), a above)

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

(a) National legislation, e.g. EU Directive 2000/76/EC on Waste Incineration;

(b) UNEP (2002): Global Mercury Assessment, http://www.unep.org/hazardoussubstances/LinkClick.aspx?fileticket=Kpl4mFj7AJU%3d&tabid=3593&language=en-US;

(c) European Commission (2006): Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration, http://eippcb.jrc.es/reference/wi.html; and

(d) UNEP (2010c): Study on mercury sources and emissions and analysis of cost and effectiveness of control measures “UNEP Paragraph 29 study” (UNEP(DTIE)/Hg/INC.2/4), http://www.unep.org/hazardoussubstances/Mercury/Negotiations/INC2/INC2MeetingDocuments/tabid/3484/language/en-US/Default.aspx;

(e) UNECE Heavy Metals Protocol under LRTAP Convention.

210. When a wet scrubber is used as one of the flue gas treatment methods, it is essential to treat the wastewater from the wet scrubber.

2. Reduction of mercury releases from landfills

211. When landfilling of wastes containing or contaminated with mercury is unavoidable (operation D1), there are three types of mercury release channels from sanitary landfills to the environment: releases from the working face of landfills, the leachate and the landfill gas. The most important sites of mercury emissions are from the working face and the methane vents (Lindberg and Price 1999).

212. It is reported that mercury releases through leachate are fairly minimal compared to those through landfill gas (Yanase *et al*. 2009; Takahashi *et al*. 2004; Lindberg *et al*. 2001). Mercury transferred to leachate can be removed by leachate treatment, which is the same as that for wastewater from a wet scrubber of waste incinerators. Mercury releases from landfills can be reduced through prevention of wastes containing or contaminated with mercury going into landfills and prevention of landfill fires.

213. Daily landfill cover should be applied to reduce the direct release of mercury from wastes that have been newly added to landfills (Lindberg and Price 1999), and the potential for landfill fires. For prompt application of soil cover in case of landfill fire, materials for soil cover should be stocked and machines used for applying soil cover for fire extinguishing purpose (e.g. dump truck, dozer shovel) should be provided for.

214. A landfill gas capture system should be installed to capture mercury vapour and methylmercury, in order to prevent release into the atmosphere.

I. Remediation of contaminated sites

215. Mercury-contaminated sites are widespread around the world and are largely the result of industrial activities, primarily mining, chlorine production, and the manufacture of mercury-added products. The vast majority of contamination in those sites is the result of ASGM using mercury; an activity that has largely ceased or is subject to regulatory and engineering controls in developing countries, but which continues in the developing world at large sites and in the form of ASGM. Sites with mercury-contaminated soils and large mine tailings, or sites with widely dispersed areas of

contamination that has migrated via water courses and other elements, are a result of both historic and current operation. This section summarizes: (a) both the established and newer remediation techniques available for clean-up; and (b) the emergency response actions appropriate when a new site is discovered.

1. Identification of contaminated sites and emergency response

216. A mercury-contaminated site that poses a threat to human health or the environment can be identified through:

(a) Visual observation of the site conditions or attendant contaminant sources;

(b) Visual observation of manufacturing or other operations known to have used or emitted a particularly hazardous contaminant;

(c) Observed adverse effects in humans, flora, or fauna presumably caused by the proximity to the site;

(d) Physical (e.g. pH) or analytical results showing contaminant levels; and

(e) Reports from the community to the authorities of suspected releases.

217. 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 different levels of toxicity depending on form (i.e. elemental mercury vs. methylmercury). Mercury is also readily detectable using a combination of field instruments and laboratory analysis.

218. The first priority is to isolate the contamination from the receptors as far as possible in order to minimize further exposure. In this way, sites contaminated with mercury are similar to a site with another potentially mobile, toxic contaminant.

219. If the site is residential and relatively small, ample guidance for emergency response is available from the US EPA in their Mercury Response Guidebook, which was designed to address small- to medium-sized spills in residences (US EPA 2001a).

220. Alternatively, for larger sites resulting from informal mercury use in developing countries (e.g. ASGM), recommendations for response are outlined in Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small–Scale Gold Miners (GMP 2004).

2. Environmentally sound remediation

221. Remedial actions (clean-ups) for sites contaminated with mercury are dependent on a variety of factors that define the site and the potential environmental and health impact. In selecting an initial group of treatment technologies for screening and then choosing one or a combination of techniques and technologies, the factors involved in selection include:

(a) Environmental factors

(i) The amount of mercury released during operations;

(ii) The origin of the contamination;

(iii) The chemical state of mercury on the contaminated site;

(iv) The number, size, and location of mercury hotspots (requiring remediation);

(v) For mining operations, the properties from which the mercury is mined including, soil characteristics, etc.;

(vi) Methylation potential of the mercury;

(vii) Leaching potential of mercury from the contaminated media (e.g. soils and sediments);

(viii) Background mercury contamination - regional atmospheric mercury deposition not related to localized sources;

(ix) Mercury mobility in aquatic system; and

(x) Local/State/Federal Clean-up Standards: water, soils/sediment, air.

(b) Receptor

(i) Bioavailability to aquatic biota, invertebrates, edible plants; and

(ii) Mercury concentrations in receptors – human, animal and plants to indicate exposure.

222. Once these factors have been assessed, then a more complete analysis of the appropriate remediation techniques can commence. Depending on the severity, size, level and type of mercury contamination, other contaminants present, and the receptors, it is likely that a remedial plan that utilizes several techniques may be developed that most efficiently and effectively reduces the toxicity, availability and amount of mercury contamination at the site. More details of remediation techniques are found in "Mercury Contaminated Sites: A Review of Remedial Solutions" (Hinton 2001) and "Treatment Technologies for Mercury in Soil, Waste, and Water" (US EPA 2007b)[37]. Information about remediation cases is available for Minamata Bay, Japan (Minamata City Hall 2000) and chemical plant area in Marktredwitz, Germany (North Atlantic Treaty Organization Committee on the Challenges of Modern Society 1998).

J. Health and safety

223. Employers should ensure that the health and safety of every employed person is protected while they are working. Every employer should obtain and maintain insurance, under an approved policy from an authorized insurer that provides a sufficient level of insurance coverage in case of liability (compensation) for bodily illness or injury sustained by employees arising out of and in the course of their employment. Health and safety plans should be in place at all facilities that handle wastes consisting of elemental mercury and wastes containing or contaminated with mercury to ensure the protection of everyone in and around the facility. Such a plan should be developed for each facility by a trained health and safety professional with experience in managing health risks associated with mercury.

224. Protecting workers who are engaged in the management of wastes consisting of elemental mercury and waste containing or contaminated with mercury and the general public can be achieved in the following ways:

(a) Keep workers and the public away from all possible source of wastes;

(b) Control wastes so that the possibility of exposure is minimised; and

(c) Protect workers by ensuring that personal protective equipment is used.

225. Guideline values for mercury concentrations in drinking water and ambient air have been established by WHO; they are 0.006mg/L (inorganic mercury) and 1 µg/m^3 (inorganic mercury vapour) respectively (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 management activities of waste consisting of elemental mercury and wastes containing or contaminated with mercury take place. Some countries have established permissible levels of mercury in the working environment (e.g. 0.025mg/m^3 as Hg for inorganic mercury excluding mercury sulphide and 0.01mg/m^3 as Hg for alkylmercury compounds in Japan; waste management operations should be conducted so as to satisfy permissible levels of mercury in the working environment and facilities where these operations are conducted should be designed and operated so as to minimize mercury releases to the environment as far as technically possible.

226. Special attention should be paid to sites where mercury-added products are handled. Within the waste stream, mercury emissions from mercury-added products can create 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 such waste. Waste management employees at the "working face" of a landfill – the active area where waste is dumped, spread, compacted and buried – can be exposed to mercury vapour repeatedly. The informal waste sector involved in scavenging landfills for reclaimable items can be chronically exposed. Venting points for methane gas generated from decayed organic wastes are additional sources of mercury release and exposure.

227. Disposal facilities, especially where recovery operations are conducted, also have a high risk of mercury exposure. Major activities with a high risk include crushing fluorescent lamps, extracting elemental mercury from mercury-added products such as thermometers and barometers, thermally

37 Additional information is available on US EPA websites, e.g. Mercury Treatment Technologies (http://www.clu-in.org/contaminantfocus/default.focus/sec/Mercury/cat/Treatment_Technologies/) and Policies and Guidance (http://www.epa.gov/superfund/policy/guidance.htm).

treating wastes containing mercury or contaminated with mercury, and stabilisation/solidification of elemental mercury.

228. Employee training in effective ESM should be provided, also to ensure employee safety against mercury exposure and accidental injury during waste management.

229. The basic level of knowledge employees need includes:

(a) The definition of wastes consisting of elemental mercury and wastes containing or contaminated with mercury and chemical aspects of mercury with its adverse effects;

(b) How to segregate such waste from other wastes;

(c) Occupational safety and safeguarding health against mercury;

(d) Use of personal protective equipment, such as body covering, eye and face protection, gloves and respiratory protection;

(e) Proper labelling and storage requirements, container compatibility and dating requirements, closed-container requirements;

(f) How to technically deal with wastes consisting of elemental mercury and wastes containing or contaminated with mercury, particularly used products containing elemental mercury such as thermometers, barometers, etc., using the equipment available in the facility;

(g) Uses of engineering controls in minimizing exposure; and

(h) How to respond in an emergency if mercury in waste is accidentally spilled.

230. 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.

231. In addition, the Awareness Raising Package (UNEP 2008d) is recommended for use in employee training. All training materials should be translated into local languages.

K. Emergency response

1. Emergency response plan

232. Emergency response plans should be in place for mercury in production, in use, in storage, in transport, and in disposal sites. While the emergency response plans can vary according to the waste management stage and physical and social conditions of each site, the principle elements of an emergency response plan include identifying potential hazards, legislation governing emergency response plans, actions to be taken in emergency situations including mitigation measures, personnel training plans, communication targets (fire services, police, neighbouring communities, local governments, etc.) and methods in case of emergency, and testing methods and frequencies of emergency response equipment.

233. When an emergency occurs, the first step is to investigate the site. The person in charge should approach cautiously from upwind, secure the scene and identify the hazard. 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 to evacuate, 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, the spill or leak area should be isolated for at least 50 meters in all directions. In case of fire, an extinguishing agent suitable for the type of surrounding fire should be used, whereas water should not. For further information, "Emergency Response Guidebook" (US Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico (SCT) 2008) is helpful.

2. Special consideration for spillage of elemental mercury

234. Spillage of elemental mercury accidentally occurs when waste mercury-added products are broken. Most of these cases seem to involve mercury-containing glass thermometers which are widely used in the world but easily broken. Although the mercury in each glass thermometer is about 0.5-3 g and does not usually lead to serious health problems, mercury spills should be considered hazardous and should be cleaned up with caution. If somebody shows any discomforts following a mercury spill, a medical doctor and/or environmental health authorities should be contacted immediately.

235. If the spill is small and 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 personally. If the spill is large, or on a rug that cannot be discarded, on upholstery or in cracks or crevices, it may be necessary to hire a professional. 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 to be on the safe side. 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).

236. Spills of elemental 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 US EPA 2007c.

237. Critical to determining what type of response is appropriate for any mercury spill is evaluating its size and 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 that necessitate clean-up efforts;

(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.

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

L. Awareness and participation

239. Public awareness and participation play key roles in implementing ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. Public participation is a core principle of the 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.

240. Articles 6, 7, 8 and 9 of the 1998 Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters 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.

241. When initiating activities such as the collection and recycling of waste containing mercury, it is essential to ensure cooperation from the consumers who generate mercury-containing waste. Continuous awareness-raising is a key to the successful collection and recycling of waste containing mercury. Encouraging public involvement in designing a collection and recycling system for waste containing mercury, which provides participating residents with information about the potential problems caused by the environmentally unsound management of such waste, would help to increase consumer awareness.

242. Public awareness and sensitization campaigns for local communities and citizens are important elements in promoting public participation in the ESM of wastes consisting of elemental mercury and wastes containing or contaminated with mercury. 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 enable citizens to take an interest in protection against the adverse effects to human health and the environment. In addition, it is important to involve community-based societies in the campaigns because they have a closer relationship with residents and other stakeholders in the communities (Honda 2005).

243. Programmes for public awareness and public participation should generally be developed around a waste management situation at national/local/community level. Table -7 shows an example of programmes for public awareness and participation. There are four elements: publications, environmental education programmes, public relations (PR) activities and risk communication, which citizens can easily access in public places (Honda 2005).

Table -7 Programmes for public awareness and public participation

	Contents	Expected results
Publications	• Booklet, pamphlets, brochures, magazines, posters, web sites, etc., in various languages and dialects to simply explain mercury issues • Guidebooks on how to dispose of waste	• Knowledge sources • Explanation of how people can handle mercury-added products and dispose of waste
Environmental Education Programmes	• Voluntary seminars • Community gatherings • Linkages with other health workshops • Demonstration of take-back programme • Scientific studies • Tours to facilities, etc. • eLearning	• Raising knowledge • Sharing common issues • Opportunities to discuss environmental issues directly
Activities	• Take-back programmes • Mercury-free product campaigns • Waste minimization campaigns • Community gatherings • House-to-house visit	• Implementation of environmental activities among all partners • Environmental appeal for citizens • Closer communications
Risk Communication	• Mercury exposure in general living environment • Safe level of mercury exposure • Mercury pollution levels • PRTR • Fish consumption advisories (only for populations that consume large amounts of fish) • Rice consumption advisories • Response to mercury spills from mercury-added products	• Proper understanding of safe- and risk levels of mercury exposure, in appropriate circumstances • Avoidance of overreaction

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

245. The components of an environmental education programme on wastes consisting of elemental mercury and wastes containing or contaminated with mercury are as follows (Honda 2005):

(a) Awareness and sensitivity to the environment and environmental challenges;

(b) Knowledge and understanding of the environment and environmental challenges;

(c) Attitudes of concern for the environment and a motivation to improve or maintain environmental quality;

(d) Skills to identify and help resolve environmental challenges; and

(e) Participation in activities that lead to the resolution of environmental challenges.

246. The partners for programmes on public participation can be summarized as follows (Honda 2005):

(a) Officials and staff in governments who work for environmental issues;

(b) People who are interested in environmental problems and have a high potential to understand quickly and disseminate information to others:

(i) Children and students at schools, undergraduate students at universities;

(ii) Teachers of primary and middle schools, sometimes University professors;

(iii) Men and women from local communities and groups; and

(iv) Retired persons with a suitable education.

(c) People who work in the environmental fields at the local or community level:

(i) Non-governmental organizations (NGOs);

(ii) Small and medium-sized enterprises; and

(iii) Local producers, collectors and recyclers; the disposal facility owners that handle mercury waste.

(d) People who used to live at polluted sites:

(i) Local organizations;

(ii) City residents; and

(iii) Enterprises.

247. 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). This can be achieved through: awareness-raising activities such as seminars, which can provide information about new systems and regulations and opportunities for information exchange; preparing and distributing leaflets; and disseminating information via the internet.

Annex

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