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**Preparation of a global legally binding instrument
on mercury**

**Guidelines on the environmentally sound management of
elemental mercury and waste containing or contaminated with
mercury**

Note by the secretariat

The secretariat has the honour to provide, in the annex to the present note, the sixth draft of technical guidelines on the environmentally sound management of elemental mercury and waste containing or contaminated with mercury as published in October 2010 under the auspices of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The text has been reproduced as received, without formal editing.

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Annex

Technical Guidelines for the Environmentally Sound Management of Waste consisting of Elemental Mercury and Wastes Containing or Contaminated with Mercury – 6th Draft

6th Draft (October 2010)

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Acronyms and Abbreviations

AMDE	Atmosphere mercury depletion event
ASGM	Artisanal and small scale gold mining
AOX	Adsorbable organic halides
BAT	Best available techniques
BMP	Best management practices
BEP	Best environmental practices
CDI	Case development inspection
CEI	Compliance evaluation inspection
CETEM	Centre for Mineral Technology
CFL	Compact fluorescent lamps
CFM	Chemische Fabrik Marktredwitz
CH ₃ Hg ⁺ or MeHg ⁺	Monomethylmercury, commonly called methylmercury
Cl	Chlorine
COP	Conference of the parties
DfE	Design for Environment
DTC	Drum top crushers
EC	European Community (current EU: European Union)
EMS	Environmental management system
ESM	Environmentally sound management
E-waste	Electronic and electrical waste
FAO	Food and Agriculture Organization of the United Nations
GC	Governing Council
GMP	Global Mercury Project
GTG	General technical guidelines
HCl	Hydrochloric acid
HF	Hydrofluoric acid
Hf	High frequency
Hg	Mercury
Hg(0) or Hg ⁰	Elemental mercury
Hg(I)	Monovalent mercury
Hg(II) or Hg ²⁺	Divalent mercury
HgCl ₂	Mercury dichloride
Hg ²⁺	Mercuric compound
Hg ₂ ²⁺	Mercurous compound
Hg ₂ Cl ₂	Mercury (I) chloride
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
IHU	Industrial Health Unit
ILO	International Labour Organization
IMERC	Interstate Mercury Education and Reduction Clearinghouse
IMO	International Maritime Organization
INC	Intergovernmental negotiating committee

J-Moss	Marking of presence of the specific chemical substances for electrical and electronic equipment
JIS	Japanese Industrial Standards
JLT	The Japanese Standardized Leaching Test
LCD	Liquid crystal displays
LED	Light emitting diode
MMSD	Mining, Minerals and Sustainable Development
MSW	Municipal solid waste
N ₂ O	Nitrous oxide
NaClO	Sodium hypochlorite
NEWMOA	The Northeast Waste Management Officials' Association
NGOs	Non-governmental organizations
NH ₃	Ammonia
NIP	National implementation plan
NIMD	National Institute for Minamata Disease
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxide
OEWG	Open-ended Working Group
OECD	Organization for Economic Cooperation and Development
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
QSP	Quick Start Programme
PAC	Powdered activated carbon
PACE	The Partnership for Action on Computing Equipment
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PM	Particulate matter
POPs	Persistent organic pollutants
PVC	Polyvinyl chloride
PR	Public relation
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
SO ₂	Sulphur dioxide
SPC	Sulphur polymer cement
S/S	Solidification and stabilization
TCLP	Toxicity characteristic leaching procedure
TOC	Total organic carbon
TWA	Time weighted average
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UNITAR	United Nations Institute for Training and Research
USA	United State of America
USEPA	United States Environmental Protection Agency
VCM	Vinyl chloride monomer
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization

Introduction

Scope

1. The guidelines provide basic knowledge and expertise on the environmentally sound management (ESM) of mercury waste and give comprehensive information about mercury waste, including the chemistry and toxicology of mercury. The practical examples of ESM of mercury waste are described in the Good Practices for Management of Mercury Releases from Waste being developed under the Waste Management Partnership Area in United Nations Environment Programme (UNEP) Global Mercury Partnership.

2. Scope of the Basel Convention includes not only transboundary movement of hazardous wastes and their disposal but also ESM of those wastes. The present technical guidelines focus on mercury waste (Y29 Mercury; mercury compounds in Annex I of the Basel Convention) and follow the decision VIII/33 of the Conference of the Parties (COP) to the Basel Convention, namely the programme to support the implementation of the Strategic Plan focus area: B9 mercury waste. The guidelines categorize mercury waste as follows (see Table 0-1 for more examples):

- A. Waste consisting of elemental mercury:
 - A-1 Waste elemental mercury (e.g. elemental mercury recovered from waste containing mercury and waste contaminated with mercury, spent catalyst, surplus stock of elemental mercury designated as waste);
 - A-2 Stabilized or solidified waste elemental mercury.
- B. Waste containing mercury (e.g. waste of mercury added products):
 - B-1 Waste products containing mercury that easily releases mercury into the environment when they are broken (e.g. waste mercury thermometer, fluorescent lamps);
 - B-2 Waste products containing mercury other than B-1 (e.g. batteries).
- C. Waste contaminated with mercury (e.g. residues generated from mining processes, industrial processes, or waste treatment processes).

3. Many parties to the Basel Convention set the criteria for mercury concentration to define hazardous waste. Although the definitions and mercury concentration for hazardous waste vary among the parties, the guidelines focus on mercury waste categorized as hazardous waste by the parties and others. The instances of the criteria to identify hazardous waste can be found in the Good Practices for Management of Mercury Releases from Waste to be prepared under the UNEP Global Mercury Partnership (Waste Management Partnership Area).

Background

4. Mercury is a chemical element and widely used in products, such as thermometers, barometers, fluorescent lamps, etc., and in industrial processes, such as chlor-alkali production, vinyl-chloride-monomer (VCM) production, acetaldehyde production, etc. Mercury is recognized as one of the global hazardous pollutants due to the anthropogenic mercury emission in addition to natural mercury emission. Once mercury is released into the environment, mercury is never broken down to a harmless form and exists in the atmosphere (mercury vapour, etc), soil (ionic mercury, etc) and aquatic phase (methylmercury (MeHg, or CH_3Hg^+), etc). Some mercury in the environment ends at the food chain because of the bioaccumulation and can be finally taken by human.

5. Only a limited number of countries have a capacity to treat mercury waste in an environmentally sound manner because of availability of a facility with appropriate technologies to treat the wastes. Unfortunately, most mercury wastes, especially waste containing mercury is treated in an environmentally unsound manner such as by mixing with other wastes (e.g. municipal solid waste), open dumping or burning. These likely occur in developing countries

and countries with economies in transition which lack the capacity to collect and treat mercury wastes.

6. There is a growing global trend to phase out mercury-containing products and industrial mercury uses. For example, the use of some mercury-containing products are expected to rise in the coming years, such as fluorescent lamps because of a replacement of incandescent lamps as a strategy for low carbon society, back-light for liquid crystal displays (LCD) because of high demand of information technology and the like. As efforts to phase out mercury-containing products and industrial mercury uses continue, ensuing ESM of mercury waste including excess mercury arising from these phase-outs is a critical issue for a majority of nations.

About Mercury

Chemical Properties

7. Mercury is a metal with atomic number 80. Mercury generally exists as elemental mercury ($\text{Hg}(0)$ or Hg^0), monovalent mercury ($\text{Hg}(I)$), divalent mercury ($\text{Hg}(II)$ or Hg^{2+}) and monomethylmercury ($\text{CH}_3\text{-Hg}^+$, commonly called methylmercury (MeHg^+)). Mercury also forms organometallic compounds by covalent bonding directly with carbon. These organometallic compounds are stable, though some are readily broken down by living organisms (Japan Public Health Association 2001). In addition, mercury, particularly in gaseous form, can be transported over a long distance in the atmosphere and accumulated in Polar Regions which is known as atmospheric mercury depletion events (AMDE) (Steffen 2007).

8. Elemental (Metallic) mercury is a dense, silvery-white, shiny metal and normally liquid at ambient temperature and pressure. It has a relative molecular mass of 200.59, a melting point of $-38.87\text{ }^\circ\text{C}$, a boiling point of $356.72\text{ }^\circ\text{C}$, and a density of 13.534 g/cm^3 at $25\text{ }^\circ\text{C}$ (WHO 2003). Elemental mercury is the most volatile form of mercury. It has a vapour pressure of 0.3 Pa at $25\text{ }^\circ\text{C}$ and transforms into the vapour phase at ambient temperatures (WHO 2003). In particular, if elemental mercury is not enclosed, elemental mercury evaporates and forms mercury vapours which dissolve only slightly in water ($56\text{ }\mu\text{g/L}$ at $25\text{ }^\circ\text{C}$) (WHO 2003). Mercury vapours are colourless and odourless (WHO 2003). The higher the temperature, the more vapours are released from liquid elemental mercury (UNEP 2002).

9. Monovalent mercury ($\text{Hg}(I)$) can form mercury (I) oxide (mercurous oxide or dimercury monoxide) and mercury (I) chloride (mercurous chloride). The chemical formula of mercury (I) oxide is Hg_2O and being unstable, it easily decomposes into metallic mercury and divalent mercury (Japan Public Health Association 2001). The chemical formula of mercury (I) chloride is Hg_2Cl_2 . Mercury (I) chloride is an odourless solid, which is the principal example of mercury (I) compound, and it is known as calomel or mercurous chloride (ILO 2000).

10. Divalent mercury ($\text{Hg}(II)$ or Hg^{2+}) includes mercury (II) chloride (mercuric chloride), mercury (II) oxide (mercuric oxide, mercuric oxide red and mercuric oxide yellow) (Japan Public Health Association 2001). The chemical formula of mercury (II) chloride is HgCl_2 (well known as corrosive sublimate) and a poisonous white soluble crystalline salt of mercury (ILO 2000). The chemical formula of mercury (II) oxide is HgO and it exists as an irregularly shaped, orange-yellow powder (yellow precipitate) and/or orange-red powder (red precipitate) with high lustre.

11. The chemical formula of methylmercury (MeHg) is CH_3Hg^+ and it is an organometallic form. It can bioaccumulate up the food chain and is recognised as a bioaccumulative environment toxicant. Due to this property, methylmercury is accumulated at high concentration in predatory fish which is a very important source of protein and other nutrients for human, particularly for Japanese and other Asians, as well as for people in the Arctic region and other self-sustaining people living along rivers, lakes and coasts. Methylmercury has very high affinity

for sulphur-containing anions, particularly the sulfhydryl (-SH) groups on the amino acid cysteine and hence in proteins containing cysteine, forming a covalent bond (Oliveira 1998).

12. Native mercury is found in small amounts associated with cinnabar (HgS). Cinnabar, the red sulphide of mercury (HgS), is the chief source of the metal. Because of the high atomic weight of Hg, cinnabar when pure contains 86.2% mercury. However, ores are usually poor concentration of mercury and contains only about 0.5 to 7% of mercury. Mercury in soil can be converted to cinnabar as a result of sulphate reduction after the deposition and burial of mercury-contaminated soil (Wiberg 2001, Brandy 2002).

Sources of the Anthropogenic Mercury Emissions

13. The major sources of the anthropogenic mercury emissions estimated for 2005 are fossil fuels combustion for power and heating (878 tonnes), artisanal and small-scale gold production (350 tonnes), metal production (ferrous and non-ferrous, excluding gold) (200 tonnes), cement production (189 tonnes), and waste incineration, waste and other (125 tonnes). The category of “waste incineration, waste and other” includes waste incineration, landfilling, steel scrap, release by breaking and waste recycling (UNEP 2008a).

14. Burning of mercury-containing products is also one of the sources of the anthropogenic mercury emissions. The recent study calculated that 100 – 200 tonnes of mercury were released into the atmosphere due to burning of waste containing mercury. In most of these cases, waste products are treated in an environmentally unsound manner, such as open burning, landfill fire, incinerators without appropriate exhaust gas cleaning systems, etc (The Zero Mercury Working Group 2009).

15. The geographical mercury emission in 2005 can be seen in Figure 0-1. The mercury emission in the Asia accounted for 66% of the global emission and was more than 4 times higher than North America and Europe combined. The major contributors to the mercury emission in the Asia are the power plants at large scale and coal burning at household level, particularly those in China and India (UNEP 2009a).

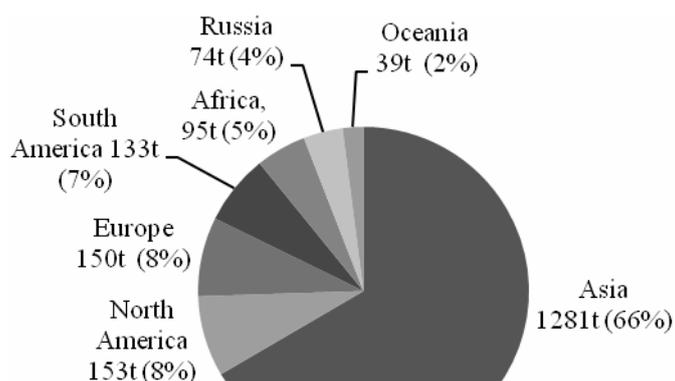


Figure 0-1 Global anthropogenic mercury emissions to air from different regions in 2005 (UNEP 2009a)

Behaviour in the Environment

16. Once mercury enters into the environment, mercury permanently exists in the environment by changing its chemical forms depending on the environment. Figure 1-2 shows the mercury species and transformations in the environment. Mercury in the atmosphere is broadly divided into gas form and particulate form. Most of mercury in the general atmosphere is in gas form (95% or more). Gaseous mercury includes mercury vapour, inorganic compounds (chlorides and oxides), and alkyl mercury (primarily methylmercury) (Japan Public Health Association 2001). In the aquatic environment under suitable conditions, mercury is bioconverted to methylmercury, by a chemical process called methylation (Wood 1974).

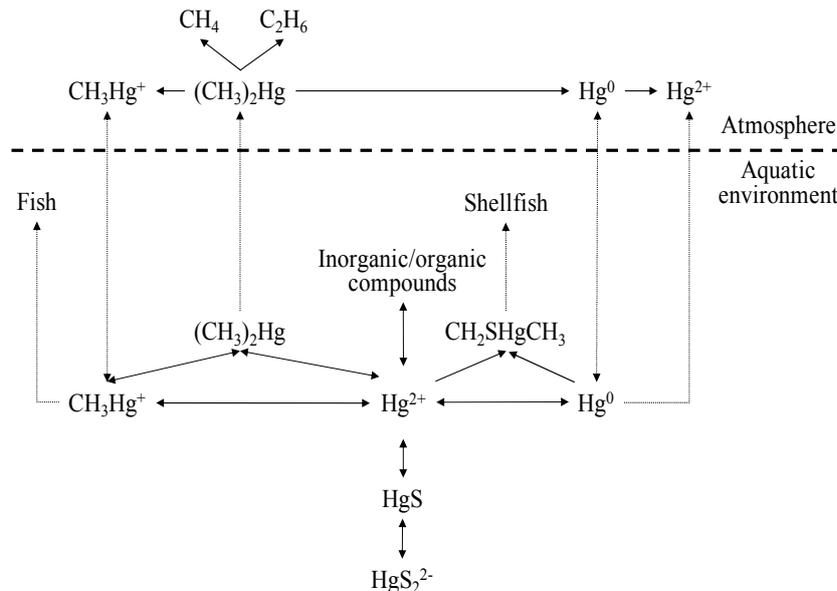


Figure 0-2 Dynamics of mercury in the environment (Beijer 1979)

Human Health Risk

Methylmercury

17. In the aquatic environment, elemental mercury is bioconverted into methylmercury which is the environmental neurotoxicant with well-defined neuropathological and developmental effects (WHO 1990). Methylmercury bioaccumulates, is biomagnified in the food web and enters the human body mainly through the consumption of fish and seafood, particularly large predatory marine species such as tuna, swordfish, shark, whale, etc (Sanborn 2006). Most humans, particularly high-fish-consuming populations, are exposed to methylmercury through fish and seafood consumption (Sakamoto 2005).

18. Ingested methylmercury in the human body is readily and completely absorbed by the gastrointestinal tract, almost completely absorbed into the bloodstream and distributed to all tissues within about 4 days (WHO 1990). Methylmercury is accumulated in the liver and kidney. In addition, methylmercury transported into tissues combines with cysteine which is an amino acid found in most proteins and appears to be mediated by the formation of a methylmercury-cysteine conjugate, which is transported into cells via a neutral amino acid carrier protein (Kanai 2003). A methylmercury-cysteine conjugate can pass through not only the blood-brain barrier but also the placenta via an amino acid transporter (Kerper 1992). Methylmercury can cross to the brain where methylmercury is oxidized and accumulated and eventually causes the chronic exposure to human health (Mottet 1985; Sakamoto 2004).

Elemental Mercury

19. Most cases of the adverse effects to human health caused by elemental mercury are due to inhalation of mercury vapour via the lungs (Oikawa 1983). Elemental mercury becomes mercury vapour at normal room temperature (Bull 2006). Elemental mercury exposure in the general population is primarily the result of the use of dental amalgam (50% Hg⁰ by weight) as a dental restorative material (Richardson 2003; Richardson and Allan 1996; Gay 1979). Exposure also result from the spillage of mercury-containing products, such as breakage of fluorescent lamps and thermometers, or caused by the environmentally unsound uses and disposal of elemental mercury, such as the disposal of dental clinic wastes to sewers and landfills (Boom 2003), mercury vapour released from artisanal and small scale gold mining (ASGM) (Hylander 2005) as well as spills resulting from the industrial use of mercury manometers. Dental waste in sewage sludge applied as a soil amendment to agricultural land is also released into the atmosphere as the vapour (Boom 2003).

20. Approximately 80% of mercury vapour crosses the alveolar membrane and is rapidly absorbed into the blood (WHO 2003). Absorbed elemental mercury is rapidly distributed to all tissues, although it accumulates to the greatest extent in the kidney (WHO 1991; 2003). Due to the high lipophilicity, elemental mercury vapour passes the blood-brain barrier and the placenta (WHO 1991; 2003). When mercury is accidentally swallowed, the gastrointestinal absorption of elemental mercury is very low (less than 0.01%) (Japan Public Health Association 2001).

21. An acute exposure (>0.1 mg-mercury/m³) to mercury vapour causes respiratory effects such as cough, dyspnoea and chest tightness as well as bronchitis and bronchiolitis with interstitial pneumonitis, airway obstruction, and decreased pulmonary function. In addition, pulmonary oedema, respiratory distress and fibrosis would occur (WHO 1991; 2003).

Inorganic Mercury Compounds

22. Exposure to inorganic mercury compounds may occur due to accidental ingestion of mercury (II) chloride or ingestion with the intent of suicide (Japan Public Health Association 2001). In human, about 5-10% of inorganic mercury in food is absorbed after ingestion (WHO 1972). Inorganic mercury is distributed to all tissues following absorption, but due to the poor lipid solubility only a small fraction crosses the blood-brain barrier and the placenta (Asano 2000).

23. With ingestion of inorganic mercury at high concentration, the corrosive effects first damage the digestive tract, cause vomiting and stomach pain, and, in severe cases, may result in shock (Japan Public Health Association 2001). Finally, renal tubule degeneration, kidney dysfunction and nephritic syndrome may be seen (Japan Public Health Association 2001).

Mercury Pollution

Minamata Disease

24. Minamata disease, which is a typical example of the pollution-related adverse effects to human health and the environment, was first officially reported in 1956 around Minamata Bay, Kumamoto, Japan, and occurred in 1965 in the Agano river basin, Niigata, Japan. The causal substance was methylmercury which was produced as a by-product of acetaldehyde production and was discharged from Chisso Corporation into Minamata bay and from Showa Denko Company into the Agano river basin. Methylmercury released from both factories had been bioaccumulated and biomagnified heavily in fish and seafood which were the main source of food for local people (Ministry of the Environment, Japan 2002). Minamata disease was caused by consuming those fish and seafood polluted with methylmercury.

25. The signs and symptoms of the Minamata disease patients are sensory disturbance in the distal portions of four extremities, ataxia, concentric contraction of the visual field, etc. At the end of March 2006, 2,955 Minamata disease patients have been certified, of which 2,265 patients have been located on Yatsushiro sea coast (Ministry of the Environment, Japan 2006). Because of the clinical and protective measures taken after the discovery of Minamata disease, Minamata disease no longer seems to occur in Japan. However, many patients with Minamata disease still are present in Japan.

Iraq Mercury Poisoning

26. Methyl- and ethylmercury poisonings occurred in Iraq following consumption of seed grain that had been treated with fungicides containing these alkylmercury compounds. The first outbreaks were caused by ethylmercury and occurred in 1956 and 1959-1960, and about 1,000 people were adversely affected. The second outbreak was caused by methylmercury and occurred in 1972. Imported mercury-treated seed grains arrived after the planting season and were subsequently used as grain to make into flour that was baked into bread. Unlike the long-term exposures in Japan, the epidemic of methylmercury poisoning in Iraq was short in duration, but the magnitude of the exposure was high. Because many of the people exposed to methylmercury in this way lived in small villages in very rural areas (and some were nomads), these incidents afflicted more than 6,000 people and resulted in 400 deaths (Amin-Zaki 1978; Bakir 1973; Damluji 1972; UNEP 2002)

Mercury Waste Recycling and Disposal – Thor Chemicals

27. In South Africa, Thor Chemicals, Inc. of Great Britain (Thor) was accused of poisoning its workers and putting surrounding communities at risk from mercury exposure. Thor was receiving shipments of mercury wastes from the United States and other countries as part of the company's mercury recycling programme. In 1988 mercury levels in the Umgeni River, 15 km downstream where Thor's facility was located, were reported to be 1,000 times higher than WHO standards for drinking water. Water samples, taken from the Mngeweni River behind Thor and analyzed for mercury, were found to contain 1,500 times higher than the US limit (Lambrecht 1989). In 1990, the samples taken by Greenpeace and local activists found to be still 20 times the US limit as far as 40 miles downstream (Department of Environmental Affairs and Tourism, South African Government 1997; 2007; GroundWork 2005; University of Michigan 2000).

28. Investigations revealed that the workers in Thor's mercury reclaiming plant were uninformed of the potential dangers of and precautions to take against mercury poisoning. A doctor from the Industrial Health Unit (IHU) diagnosed mercury poisoning in 4 workers. Further investigation by IHU into 80 medical records revealed that 87% of workers had mercury levels that were above safe limit (Butler 1997). In 1992, an IHU report stated that 28% of workers were in danger of permanent health damage due to poisoning. A 1992 government report revealed that 29 workers had suffered mercury poisoning (Butler 1997). In 1993, the first death related to mercury poisoning was reported. In 1998 it was shown that workers had been exposed to mercury levels up to 12 times higher than WHO regulations. At least four workers have died and an unknown number are mentally and physically impaired (Butler 1997; Department of Environmental Affairs and Tourism, South African Government 1997).

Illegal Transboundary Movement of Mercury Waste - Paradise Poisoned Sihanouk Ville, Cambodia

29. In November 1998, the infamous dumping of toxic waste, which was mainly composed of by-products of battery production containing mercury, happened in Sihanouk Ville, Cambodia. The toxic mercury wastes were exported from Taiwan from a company called Formosa Plastics. The amount of hazardous waste was about 3,000 tonnes. Unfortunately, at the time of the

incident Taiwan and Cambodia were not parties to the Basel Convention, and the toxic trade was facilitated primarily by Formosa Plastics in collusion with local officials. In the samples taken, the highest total mercury concentration in the waste sample reached to 4,000 µg/g. The toxic waste dumping caused great adverse effects to human health and the environment around Sihanouk Ville, as well as triggering a social scandal in Cambodia. In many incidents around the site where the hazardous wastes were dumped, locals stole the plastic bags encasing the hazardous waste containing mercury, in order to sell the plastic bags to dealers for some income. The persons that had direct contact with the hazardous waste containing mercury, complained about somatise, dizziness, weakness, visual trouble, headache, etc. At least, 10 people were hospitalised. Through the combined efforts by the Cambodian government, local community, and non-governmental organizations the toxic wastes was returned to Taiwan in 1999 (Honda 2006; NIMD 1999).

Environmental Pollution around a Dump Site – Nairobi, Kenya

30. A dumping site located to the East of Nairobi is the main dumping site for most of the solid waste from Nairobi area. Surrounding the dump are informal settlements and the residential estates. Over 2,000 tonnes of waste generated and collected from various locations in Nairobi and its environs are deposited on a daily basis into the dumpsite and what initially was to be refilling of an old quarry has given rise to a big mountain of garbage. Dumping at the site is unrestricted and industrial, agricultural, domestic and medical wastes (including used syringes) are seen strewn all over the dumping site. The Nairobi River also passes beside the dumpsite. Some of the waste from the dump ends up into the River thus extending environmental and health risks to the communities living within the vicinity as well as those living downstream who could be using the water for domestic and agricultural purposes like irrigation. Total mercury concentration in the samples collected from the waste dump exhibited a value of 46.7 mg/L while those collected along the river bank registered a value of 18.6 mg/L. Both of these values greatly exceeded the WHO acceptable exposure level of 2 mg/L. The rest of the samples were inconclusive due to the fact that the analytical method used was only capable of detecting high levels of mercury (15 mg/L and above). From the environmental evaluation conducted, it was determined that the dumpsite exposes the residents around it to unacceptable levels of environmental pollutants with adverse health impacts. A high number of children and adolescents living around the dumping site had illnesses related to the respiratory, gastrointestinal and dermatological systems such as upper respiratory tract infections, chronic bronchitis, asthma, fungal infections, allergic and unspecified dermatitis/pruritis –inflammation and itchiness of the skin (UNEP 2007a).

Relevant Provisions of the Basel Convention and Works under the UNEP

Basel Convention

General Provision

31. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is the most comprehensive global environmental agreement on hazardous and other wastes. The Basel Convention came into force in 1992, and there are 174 parties to the Basel Convention as of July 2010. 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.

32. In its Article 2 (“Definitions”), paragraph 1, 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”. In paragraph 4 of that Article, it defines disposal as “any operation specified in Annex IV” to the Convention. In paragraph 8, it 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 which will protect human health and the environment against the adverse effects which may result from such wastes”.

33. Article 4 (“General obligations”), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall 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).”

34. Article 4, paragraphs 2 (a) - (e) and (g) contains key provisions of the Basel Convention pertaining to ESM, waste minimization, 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; and

- (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.

35. Article 4, paragraph 4 mentions that each Party shall take appropriate legal, administrative and other measures to implement and enforce the provisions of this Convention, including measures to prevent and punish conduct in contravention of the Convention and consider criminal any instance of illegal traffic of hazardous wastes.

36. Article 4, paragraph 8 and 9, mentions requirements of transboundary movement of hazardous wastes. Parties must require that hazardous wastes subject to transboundary movement are managed in an environmentally sound manner, whatever the place of their disposal generated and disposed of domestically or those wastes that are exported. The exporting state may not allow the export of hazardous wastes if it has a reason to believe that they would not be managed in an environmentally sound manner in the state of import. Similarly, parties of import have an obligation to prevent any import if it has reason to believe the import will not occur in an environmentally sound manner.

37. COP3 adapted an amendment, so-called the Ban Amendment, to the Convention which was devised to prohibit the transboundary movement of hazardous wastes from the Annex VII countries, namely, “members of OECD, EC and Liechtenstein”, to other countries. This prohibition is to apply to shipments of hazardous waste for resource recovery and recycling, as well as for final disposal (SBC 2009). However, the Ban Amendment has not yet entered into force as of August 2010.

Mercury Related Provisions

38. Article 1 (“Scope of the Convention”) defines the waste types subject to the Basel Convention. Subparagraph (a) of that Article sets forth a two-step process for determining whether a “waste” is a “hazardous waste” subject to the Convention: first, the waste must belong to any category contained in Annex I to the Convention (“Categories of wastes to be controlled”), and second, the waste must possess at least one of the characteristics listed in Annex III to the Convention (“List of hazardous characteristics”).

39. The present technical guidelines focus on mercury waste listed in Annexes I and VIII to the Basel Convention as categories of wastes to be controlled as shown in Table 0-1.

Table 0-1 Mercury-containing wastes listed in the Basel Convention

Waste entries with direct reference to mercury:	
Y29	Wastes having as constituents: <i>Mercury</i> , mercury compounds
A1010	Metal wastes and waste consisting of alloys of any of the following: - <i>Mercury</i> but excluding such wastes specifically listed on list B.
A1030	Wastes having as constituents or contaminants any of the following: <i>Mercury; mercury compounds</i>
A1180	Waste electrical and electronic assemblies or scrap ¹ containing components such as accumulators and other batteries included on list A, <i>mercury-switches</i> , glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g., cadmium, <i>mercury</i> , lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note

¹ This entry does not include scrap assemblies from electric power generation.

	the related entry on list B B1110)
Wastes entries which may contain 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
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)

40. Taking into consideration mercury poisoning if mercury waste is burned or accidentally spilled (such as mercury in thermometers), the following hazardous characteristics in Annex III of the Basel Convention are considered:

- Poisonous (Acute) (United Nations (UN) Class: 6.1; Code: H6.1): Substances or wastes liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact; and
- Toxic (Delayed or chronic) (UN Class: 9; Code H11): Substances or wastes which, if they are inhaled or ingested or if they penetrate the skin, may involve delayed or chronic effects, including carcinogenicity.

41. Taking into consideration mercury poisoning because of bioaccumulation and biomagnification if mercury in wastes is released into the environment and bioconverted to methylmercury, the following hazardous characteristic is also considered:

- Ecotoxic (UN Class: 9; Code: H12 in Annex III to the Basel Convention): Substances or wastes which if released present or may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon biotic systems.

42. Taking into consideration ESM of mercury waste, the following disposal operations which do not lead to the possibility of resource recovery, recycling, reclamation, direct re-use or alternative uses in Annex IV of the Basel Convention are considered: D5: Specially engineering landfill; D12: Permanent storage; and D15: Storage pending any of the operation in Section A limited to intermediate storage for D5 and D12.

43. In addition, any operation, which may lead to resource recovery, recycling, reclamation, direct re-use or alternative uses, in Section B in Annex IV of the Basel Convention is considered under the guidelines.

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

Works under the UNEP**UNEP Governing Council Decisions**

45. UNEP Governing Council (GC) notes that releases of mercury have harmful effects on human health and may damage ecosystems of environmental and economic importance, and has decided a number of decisions on mercury issues, taking into consideration global adverse effects to human health and the environment caused by mercury. Based on the UNEP GC decisions, UNEP Chemicals have undertaken various remarkable activities to tackle global mercury issues. Table 0-2 shows the main decisions of UNEP GC on mercury issue.

Table 0-2 UNEP GC Decisions on mercury (UNEP 2001; 2003a; 2005a; 2007b; 2009b)

Session	Year	Main decision on mercury
21	2001	<ul style="list-style-type: none"> Development of a global assessment of mercury in order to consider international actions on mercury
22	2003	<ul style="list-style-type: none"> Technical assistance and capacity-building activities to support the efforts of countries to take action regarding mercury pollution
23	2005	<ul style="list-style-type: none"> Initiating national, regional and global actions and partnership, both immediate and long-term, to protect human health and the environment against mercury, in order to eliminate releases of mercury and its compounds into the environment in collaboration with all stakeholders Identification of the five partnership areas: <ol style="list-style-type: none"> Mercury releases from coal combustion; Mercury cell chlor-alkali production; Mercury in products; Mercury air transport and fate research; and Mercury in artisanal and small-scale gold mining.
24	2007	<ul style="list-style-type: none"> Establishment of an ad hoc open-ended working group of governments, regional economic integration organisations and stakeholder representatives to review and assess options for enhanced voluntary measures and new or existing international legal instruments Identification of the additional partnership areas: <ol style="list-style-type: none"> Reduction of global mercury supply; Waste management, including environmentally sound long term storage; Vinyl chloride monomer production; Non-ferrous metals mining; and Cement production.
25	2009	<ul style="list-style-type: none"> Convening an intergovernmental negotiating committee (INC) to prepare a global legally binding instrument on mercury, commencing its work in 2010 with the goal of completing it prior to the 27th regular session of the GC/Global Ministerial Environment Forum in 2013.

46. The 25th session of UNEP Governing Council adopted its decision on chemicals management including mercury in February 2009, which requests the Executive Director of the UNEP to convene INC with the mandate to prepare a global legally binding instrument on mercury. The INC has the mandate to develop a comprehensive and suitable approach to mercury, including provisions on:

- To specify the objectives of the instrument;
- To reduce the supply of mercury and enhance the capacity for its environmentally sound storage;

- (c) To reduce the demand for mercury in products and processes;
- (d) To reduce international trade in mercury;
- (e) To reduce atmospheric emissions of mercury;
- (f) To address mercury-containing waste and remediation of contaminated sites;
- (g) To increase knowledge through awareness-raising and scientific information exchange;
- (h) To specify arrangements for capacity-building and technical and financial assistance, recognizing that the ability of developing countries and countries with economies in transition to implement some legal obligations effectively under a legally binding instrument is dependent on the availability of capacity building and technical and adequate financial assistance; and
- (i) To address compliance.

SAICM

47. In the decision 21/7, the 21st session of the UNEP GC confirmed that there was the need for a strategic approach to international chemicals management, taking into consideration undertaking a comprehensive chemical sound management (UNEP 2001). Mercury including mercury waste is specifically addressed in the Global Plan of Action under Work area 14 with “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. Strategic Approach to International Chemicals Management (SAICM) comprises three core texts: the Dubai Declaration; the Overarching Policy Strategy; A Global Plan of Action.

48. The Quick Start Programme (QSP) 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. The QSP built upon the Bali Strategic Plan for Technology Support and Capacity-building and facilitate environmentally sound chemicals management (UNEP 2004). The QSP takes the strategic priorities mobilize resources for national priority initial enabling activities in keeping with the work areas set out in the strategic objectives, in particularly the followings (UNEP 2006a):

- a) Development or updating of national chemical profiles and the identification of capacity needs for sound chemicals management;
- b) Development and strengthening of national chemicals management institutions, plans, programmes and activities to implement the Strategic Approach, building upon work conducted to implement international chemicals-related agreements and initiatives; and
- c) Undertaking analysis, interagency coordination, and public participation activities directed at enabling the implementation of the Strategic Approach by integrating – i.e., mainstreaming – the sound management of chemicals in national strategies, and thereby informing development assistance cooperation priorities.

Guidance on Environmentally Sound Management (ESM) of Mercury Waste

General Introduction

Introduction

49. While international activities including UNEP Global Mercury Partnership and INC process are ongoing, it is important to promote and implement ESM of mercury waste based on the present international guidance on ESM criteria and practices of mercury waste management. This chapter describes the present international guidance on criteria and practices of ESM of mercury waste.

The Basel Convention

ESM under the Basel Convention

50. In Article 2, paragraph 8, the Basel Convention defines ESM of hazardous wastes or other wastes as taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes (SBC 1992a).

51. Several key principles with respect to ESM of waste were articulated in the 1994 Framework Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention (SBC 1994).

52. ESM is also the subject of the 1999 Basel Declaration on Environmentally Sound Management. The Declaration states that a number of activities should be carried out in this context (SBC 1999):

- 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.

53. The Ad Interim Project Group on ESM Criteria under the Partnership for Action on Computing Equipment (PACE), one of the partnership programmes of the Basel Convention, developed ESM Criteria Recommendations. This document aims to identify recommendations for ESM criteria to assist countries in implementing the principle of ESM for computing equipment. ESM Criteria include: 1) Top management commitment to a systematic approach; 2) Risk assessment; 3) Risk prevention and minimization; 4) Legal requirements; 5) Awareness, competency and training; 6) Record-keeping and performance measurement; 7) Corrective action; 8) Transparency and verification (PACE Working Group 2009).

Mercury Waste and Technical Guidelines on the Environmentally Sound Recycling/Reclamation of Metals and Metal Compounds (R4) of the Basel Convention

54. These guidelines 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 mercury waste, particularly elemental mercury, in special facilities which have the advanced recycling technology especially for mercury waste. It should be noted that appropriate procedures must be employed when recycling mercury to prevent any releases of mercury to the environment. In addition, recycled mercury is sold on the international commodities market, where it is re-used (SBC 2004). The recovery of metal will usually be determined by a commercial evaluation as to whether it can be profitably reused.

OECD – Core Performance Elements for the of ESM of Wastes for Government and Industry

55. OECD adopted a recommendation on ESM of wastes which covers various items, inter alia core performance elements of ESM guidelines applying to waste recovery facilities, including elements of performance that precede collection, transport, treatment and storage and also 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.

56. For further information, please refer to the guidance manual for the implementation of the OECD recommendation on ESM of waste which include the core performance elements (OECD 2007).

Application of Best Available Techniques (BAT) and Best Environmental Practices (BEP)

Best Available Techniques (BAT)

57. The concept of BAT and BEP provides general principles and guidance to prevent or minimize releases from industrial and certain non-industrial sources. Beyond releases to air and water and reduction of resource demand, releases and management of waste is addressed. This concept can be applied also for mercury wastes.

58. BAT means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for release limitations designed to prevent and, where that is not

practicable, generally to reduce releases of chemicals and their impact on the environment as a whole (The Stockholm Convention 2006). In this regard:

- “Best” shall mean most effective in achieving a high general level of protection of the environment as a whole;
- “Available” techniques shall mean those that are accessible to the operator and that are developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages; and
- “Techniques” include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

59. The concept of BAT is not aimed at the prescription of any specific technique or technology, but at taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions (The Stockholm Convention 2006).

Best Environmental Practices (BEP)

60. BEP means the application of the most appropriate combination of environmental control measures and strategies (The Stockholm Convention 2006) and the application of the most appropriate combination of measures to eliminate, minimize or control pollution from a particular source or group of sources (Baltic Marine Environment Protection Commission 1992). BEP takes into consideration the hierarchy of waste management. For example, priority consideration is given to avoiding the generation of mercury waste (such as using mercury-free alternatives) over disposal of mercury waste (The Stockholm Convention 2006).

61. Furthermore, if the reduction of inputs resulting from the use of BEP does not lead to environmentally acceptable results, additional comprehensive strategies should be applied. The intensified exchange of information and knowledge regarding BEP should be promoted to attain the objectives and what constitutes BEP should be revised when appropriate.

62. The application of BEP is guided by the following general environmental management principles and approaches (The Stockholm Convention 2006): 1) Sustainable development; 2) Sustainable consumption; 3) Development and implementation of environmental management systems; 4) Use of science, technology and indigenous knowledge to inform environmental decisions; 5) Precautionary approach; 6) Internalizing environmental costs and polluter pays; 7) Pollution prevention; 8) Integrated pollution prevention and control; 9) Co-benefits of controlling other pollutants; 10) Cleaner production; 11) Life cycle analysis; 12) Life cycle management; 13) Virtual elimination; 14) Community right to know.

Specific Approach for Mercury Waste

63. The framework for a successful mercury reduction programme is geared towards the promotion and implementation of BEP and BAT for the management of mercury-containing products. The key elements of a programme are as follows (Emmanuel 2005): 1) Establishment of a baseline as a basis for evaluating and quantifying programme improvements; 2) Stakeholder participation in the development of plans and strategies for implementing BEP and BAT; 3) Development of model areas to demonstrate the application of BEP and BAT; 4) A systematic approach to mercury waste management and storage; 5) Capacity building; 6) Awareness-raising, training and education; 7) Periodic monitoring and evaluation, and continuous improvement of the programme; 8) Dissemination of information regarding successful models of mercury reduction; 9) Replication of successful models to other areas.

64. Sometimes the management of mercury waste is considered to be tackled at later stage than that of municipal solid waste in general. However, considering effects of mercury on human health and the environment, it is important to tackle ESM of mercury waste in parallel with enhancement of basic capacity of waste management.

65. The overall method is to encourage innovation while establishing principles that allow site-specific approaches that are drawn from basic principles and that are replicable. BEP includes (Emmanuel 2005):

I. Practices for waste minimization and pollution prevention, such as:

- Policies that favour mercury-free equipment, supplies, products and processes when these can be used in a cost-effective manner without compromising quality and safety;
- Site-specific procurement practices aimed at identifying safe and effective supplies, chemicals and instruments that do not contain mercury, and/or that avoid material components or packaging materials mostly likely to contribute to formation and/or release of mercury during their life cycle;
- Promotion of safe reuse and recycling of materials to keep mercury-containing products out of the waste stream;
- Instituting safe practices for use and management of existing mercury-containing equipment to reduce breakage or leaks while the equipment is still in use; and
- Instituting best practices for the cleanup of mercury spills, ensuring safety and minimizing waste.

II. Waste separation and segregation including:

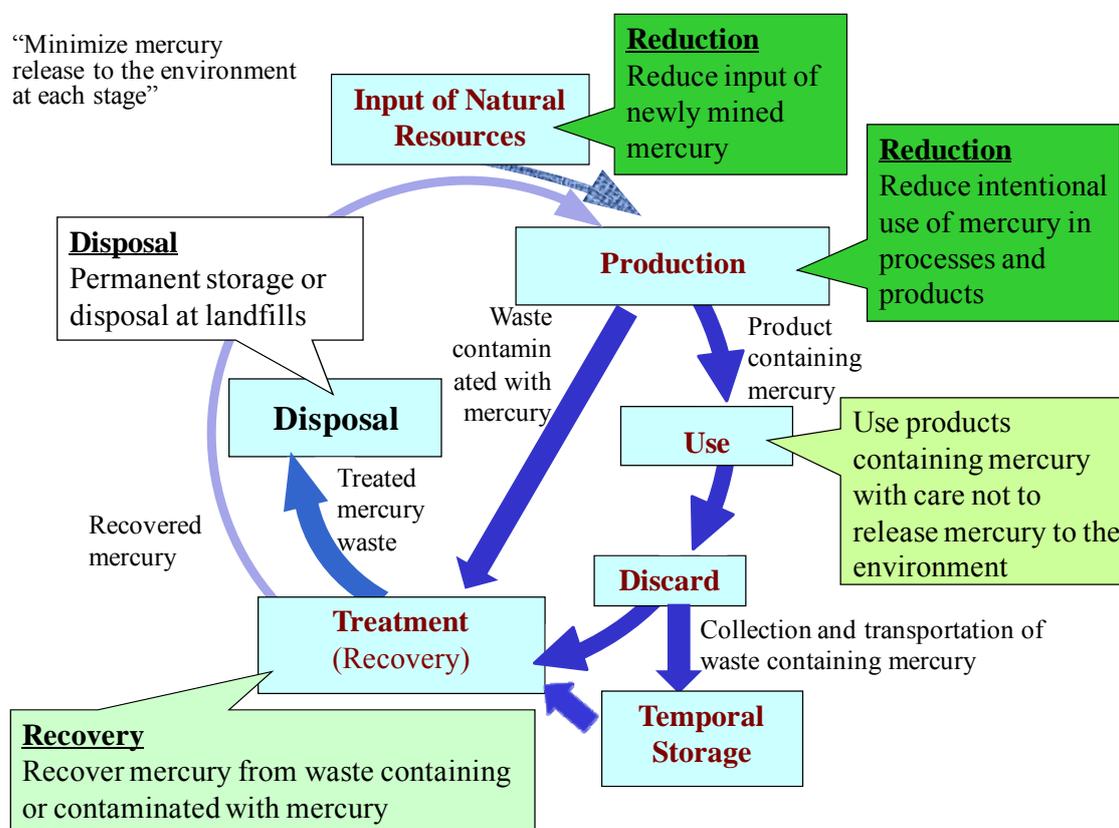
- Rigorous segregation of mercury waste from ordinary wastes;
- Identification of products and packaging containing mercury and segregation of mercury, whenever safely manageable, into waste streams that are recyclable or are disposed of in a manner that ensures no burning; and
- Training and education to ensure that mercury waste does not end up in other waste streams, but are treated as a hazardous chemical waste.

66. In order to practically implement mercury reduction programme, there are complementary activities as follows (Emmanuel 2005):

- I. Documentation of existing mercury waste management practices and policies, the assessment of current mercury products and manufacturing sectors, including purchasing and product utilization policies;
- II. Review and modification, where appropriate, of national policies, laws and regulations regarding mercury waste management, including the import and export of mercury waste and recycled mercury;
- III. Establishment of mercury waste minimization and mercury waste management objectives, and adoption of modifications in current practices and policies aimed at achieving full implementation of ESM;
- IV. Creation of institutional capability to carry out the new policies and practices by implementing capacity-building activities;
- V. Establishment of management structures and management practices to assure that new policies and practices introduced continue to be properly carried out; and
- VI. Selection and development of appropriate mercury waste treatment, storage and disposal methods.

Lifecycle Management of Mercury

67. Management of Mercury Releases from Waste should prioritize reduction of mercury used in products and processes in order to reduce mercury included in products to be disposed and industrial process waste to be generated (see Figure 0-1). During the usage of products containing mercury, special care should be taken not to release mercury to the environment. When waste containing or contaminated with mercury inevitably generated should be treated in order to recover mercury or to immobilize mercury in an environmentally sound manner. The recovered mercury is disposed of at a permanent storage or a specially engineered landfill or used as an input to the products for which mercury-free alternatives do not exist, are not available or take a long time to replace, which could reduce the amount of mercury released from the earth. If mercury recovery facilities and treatment facilities to stabilize or solidify mercury in waste do not exist, waste containing or contaminated with mercury are stored for further treatment until these facilities are available or exported to the countries with these facilities.



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

Figure 0-1 Basic concept of mercury management

68. Lifecycle of waste management covers at source separation, collection, transportation, temporal storage, treatment (e.g. incineration, solidification, stabilization) and disposal of waste. When a government plans to collect a type of waste containing mercury, it is necessary to plan on the following lifecycle of waste management such as temporal storage, treatment and disposal. Without having the other segment of waste management, the lifecycle of waste management cannot be completed.

Legislative and Regulatory Framework

Introduction

69. The parties to the Basel Convention should examine national controls, standards and procedures to ensure that they fully implement their Convention obligations, including those which pertain to the transboundary movement and ESM of mercury waste.

70. 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. Mercury waste should be included in the definition. The legislation could define ESM and require adherence to ESM principles, ensuring that countries satisfy provisions for ESM of mercury waste. Specific components or features of a regulatory framework that would meet the requirements of the Basel and Stockholm conventions and other international agreements are discussed below².

71. A legislative and regulatory framework, such as standard mercury level at each mercury form in the environment (water, soil and air), exists in most of countries. These environmental standards are set based on the drinking water standards and food safety standards for mercury, taking into consideration human exposure pathways to mercury. In order to reduce releases of mercury level in the environment, the principle is not to use mercury in products or production processes or to produce mercury-free products or mercury-containing products that mercury content is as low as possible. As the consequence, uses of mercury and mercury-containing products tend to be phased out.

Phase-out of Production and Use of Mercury in Products and Industrial Processes

72. An enforcement of a legislative or regulatory framework for phase-out programme is recommended. A concept of a legislative or regulatory framework for phase-out programme is to set a certain date that uses of mercury and mercury-containing products, except for mercury-containing products for which there are no-alternatives technically and practically, and is completely phased out at industry and market, respectively, with collection and treatment schemes on ESM in cooperation with all stakeholders. This approach promotes large-scale users and producers of mercury and mercury-containing products to meet the requirements to undertake a mercury phase-out programme. Also, it is highly recommended to undertake this approach with other activities, such as a take-back programme involving manufactures, distributors, and consumers.

73. As an example of a framework on phase-out production, the European Union Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, so-called “RoHS Directive”, is the directive to restrict uses of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) for electrical and electronic equipment, except the several products (e.g. fluorescent lamps) for which there are no alternatives practically. Most of mercury-containing products have been phased out in EU market (European Union 2003).

Identification and Inventories of Mercury Waste

74. Identification of mercury waste and development of mercury waste inventory at a national or local level is the first step to take effective actions to reduce mercury releases to the

² 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 (UNEP, 1995b) and Basel Convention: Guide to the Control System (SBC 1998). Parties to the Stockholm Convention should also consult **G**uidance for developing a **N**ational implementation plan (NIP) for the Stockholm Convention (Secretariat of the Stockholm Convention 2005).

environment efficiently. Sources and types of mercury waste and information about the development of mercury waste inventory is summarized in 0 Inventories.

Purchasing Practices

75. In order to promote uses of mercury-free products, a legal approach of purchasing practices is important. The concept of purchasing practices on mercury waste is “to purchase mercury-free products”, “to change mercury-containing products into mercury-free products” or “to purchase product that mercury contents are minimized”, except mercury-containing products whose alternatives are practically or technologically unavailable.

76. Larger users of mercury-containing products, such as hospitals, or the public sector which is the side to enforce a legal framework can be involved at the beginning of a legal approach of purchasing practices. Under a legal approach of purchasing practices, these targeted organizations have to purchase mercury-free products or mercury-less containing products to reduce amount of mercury waste. In order to effectively enforce a legal approach of purchasing practices, it is recommended that government or other public sectors subsidize the targeted organizations to purchase mercury-free products or mercury-less containing products. This approach is expected to enhance use of mercury-free products and promote the phase out of mercury-containing products as well as to disseminate the concept not to use mercury-containing products.

Control of Mercury in Flue Gas and Wastewater

77. Mercury would be released to air and water during waste treatment activities such as recovery of mercury from mercury waste, incineration of wastes, and cleaning of flue gas from waste incineration. Setting emission and effluent standards for mercury and monitoring mercury level of treated flue gas and wastewater is important to ensure minimizing mercury releases to the environment. EU established such standards by the Directive of the Incineration of Waste (2000/76/EC) (European Commission 2001).

Transboundary Movement Requirements

Introduction

78. Under the Basel Convention, all wastes containing mercury are hazardous wastes. This means that a transboundary movement of mercury waste is allowed only to the countries that permit such movement and where ESM of such waste is ensured, pursuant to Article 4 of the Basel Convention, and conducted in accordance with Article 6 of the Basel Convention. A party to the Basel Convention may prohibit imports of mercury waste under Article 4 of the Basel Convention. Furthermore, transboundary movement of mercury wastes from the Annex VII countries (members of OECD, EC and Liechtenstein) to other parties would be banned if the Ban Amendment is entered into force.

79. If a party to the Basel Convention has established a national legislation to prohibit importing of mercury waste, and reported the information in accordance with para 1 (a) of the Article 4, other parties to the Basel Convention cannot export mercury waste to the party.

Transboundary Movement Requirements

80. Hazardous wastes and other wastes should, as far as is compatible with their ESM, be disposed of in the country where they were generated. Transboundary movements of such 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.

81. Any transboundary movements of hazardous and other wastes are subject to prior written notification from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Parties shall prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes. The Basel Convention also requires that information regarding any proposed transboundary movement is provided using the accepted notification form and that the approved consignment is accompanied by a movement document from the point where the transboundary movement commences to the point of disposal.

82. Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards (UNECE 2007).

83. When transboundary movement of hazardous and other wastes to which consent of the countries concerned has been given cannot be completed, the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal if alternative arrangements cannot be made. In the case of illegal traffic (as defined in Article 9, paragraph 1), the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal or disposed of in accordance with the provisions of the Basel Convention (SBC 1992a).

84. No transboundary movements of hazardous wastes and other wastes are permitted between a Party and a non-Party to the Basel Convention unless a bilateral, multilateral or regional arrangement exists as required under Article 11 of the Basel Convention (SBC 1992a).

Transboundary Movement Control

85. Economic globalization has played a crucial role in the transfer of hazardous wastes from a country to another country, because of the global networks for trade and investments facilitating the relocation of hazards (Jennifer 2001). A factor in the international transfer of hazardous wastes is the potential value of some hazardous wastes as secondary raw materials. Hazardous wastes with an economic value are treated as a tradable commodity and are exported for resource recovery, recycling, reclamation, reuse or alternative use. This accounts for a significant proportion of the movement of hazardous wastes across national borders, and there is a substantial trade in hazardous wastes destined for recycling and recovery (Kummer 1995).

86. Recycling provides certain advantages. For instance, it can slow down the depletion of limited natural resources and reduce the quantity and hazard potential of wastes going to final disposal. Country of destination has more environmentally sound facilities, higher environmental standards, other social liberties such as right to unionize, free press, access to courts, etc., and effective enforcement of laws than the country of origin, export of hazardous wastes for recycling can ultimately lead to an overall reduction of environmental pollution. From an economic viewpoint, recycling of certain wastes leads to the recovery of valuable raw materials. In this case, there usually is an established market for the wastes in question, and the relevant trade has substantive economic significance (Kummer 1995). Recently, with the increase in gold prices, mercury has established itself as a highly-traded commodity in the global market.

87. At COP1, Decision I/22 was passed, where the Parties to the Convention noted that hazardous and other wastes destined for recovery and recycling operations should take place in accordance with the provisions of the Convention, in particular that the wastes be handled in an environmentally sound manner (Kummer 1995; SBC 1992b).

88. Under the Basel Convention, illegal traffic occurs if the transboundary movement of hazardous wastes is taking place under the following conditions:

- Without notification pursuant to the provisions of the Convention to all States concerned;
- Without the consent of a State concerned;
- Through consent obtained by falsification, misrepresentation or fraud;
- When movement does not conform in a material way with the documents; or
- When movement results in deliberate disposal of hazardous wastes in contravention of the Convention and of general principles of international law.

89. Common methods of illegal traffic include making false declarations, the concealment, mixture or double layering of the materials in a shipment and the mislabelling of individual containers. Such methods seek to misrepresent the actual contents of a said shipment and, because of this, the meticulous and thorough scrutiny of national enforcement officers is required to detect cases of illegal traffic (SBC 2007).

90. Raw mercury or mercury in used mercury products, such as thermometers, would be the important mercury source for ASGM in developing countries and countries with economies in transition. It is expected that mercury waste as used mercury products could be on illegal transboundary movement from developed countries, where mercury free products are available and most mercury-containing products are phased out, to developing countries and countries with economies in transition where ASGM activities or other activities relating to mercury are managed in an environmentally unsound manner. In addition, elemental mercury as commodity may currently move from developed countries to developing countries generally for use in ASGM.

91. In order to tackle illegal transboundary movement of mercury waste, it is important for authorities: (1) to implement the Basel Convention strictly, especially inspection at the port of both export and import; (2) to strengthen network among authorities concerned to share information on mercury waste in each country; and (3) to monitor the flow of mercury waste in their jurisdiction.

Registration of Mercury Waste Generators

92. As one of the approaches to fully control mercury waste, it is recommended to register large scale mercury waste generators, such as power plants, industrial establishments, hospitals, medical clinics, dentists, research institutes, collectors of mercury waste, etc. The registration of mercury waste generators is possible to clear origins of mercury waste stream as well as kinds and volume of mercury waste (or a number of used mercury-containing products).

93. The necessary information of mercury waste generators are generator name, address, responsible person, type of business, amount of mercury waste generation, kind of mercury waste, collection scheme of mercury waste, how mercury waste is finally handed out to collectors or dealt with. Mercury waste generators have to inform and update this information to public sectors (central or local government) regularly. In addition, it is recommended that mercury waste generators inform data and kinds of mercury waste so that inventory programmes of mercury waste can be possible to be developed.

94. Mercury waste generators have to take a responsibility to avoid any mercury leakage into the environment until mercury wastes are handed out to collectors or sent to a treatment and

disposal facility. They strictly have to comply with national/local legal frameworks to manage mercury wastes and take a responsibility of remediation or compensating any environmental and health damages if occurred.

Authorization of Treatment and Disposal Facilities

95. Mercury waste should be dealt with on ESM defined as taking all practicable steps to ensure that mercury waste is managed in a manner that will protect human health and the environment against the adverse effects which may result from mercury waste. Otherwise, mercury in waste is leaked out and on the global mercury cycle in which mercury exists not only in the environment but also in the food chain. Therefore, mercury waste should be dealt with by facilities which practice ESM, preferably ESM facilities exclusive for mercury waste.

96. Authorization of treatment and disposal facilities for mercury waste is important to implement ESM of mercury waste. The criteria to authorize treatment and disposal facilities for mercury waste is whether:

- Environmental impacts can be assessed regularly;
- Measures against human health risk can be taken;
- Mercury processing and final treatment schemes are enough to deal with mercury waste on ESM;
- Treatment facilities completely dealt with mercury waste on ESM without emission of mercury during processing;
- Equipments in the facilities are regularly maintained;
- Employees always use protective tools;
- Employees are trained;
- There are manuals including emergency (e.g., spillage of mercury) to deal with mercury waste on ESM;
- An amount of mercury waste is documented;
- Responsibility to take appropriate actions for the adverse effects to human health and the environment can be taken; and
- Social and political acceptability of the facility can be taken, such as stakeholder (NGO and community) participation, transparency of process, access to pollutant release information, etc.

Inspections and Monitoring of Treatment and Disposal Facilities

97. Some example of different types of inspections used to monitor treatment and disposal facilities (US EPA 2006):

1) Compliance evaluation inspection

The compliance evaluation inspection (CEI) is an on-site evaluation of a mercury waste handler's compliance. The purpose of the CEI is to gather information necessary to determine compliance and support enforcement actions. The inspection includes:

- A characterization of the handler's activities;
- Identification of the types of mercury waste managed on-site;
- A record review of reports;
- Documents, and on-site plans; and
- Identification of any units that generate, treat, store, or dispose of mercury waste.

2) Compliance sampling inspection

A compliance sampling inspection is necessary to inspect a facility in order to collect samples for laboratory analysis. These sampling inspections can scientifically clear

mercury exposure level to human health (using human samples) and the environment (using environmental samples) by analyzing total and/or methylmercury concentrations.

3) Case development inspection

The case development inspection (CDI) is an intensive investigation that is conducted to gather sufficient information to support an enforcement action. The CDI can be used to collect supplemental data to support a forthcoming enforcement action.

4) Information gathering

Authorities concerned collect specific information, such as any person who generates, stores, treats, transports, disposes of, or otherwise handles or has handled mercury waste. It is better that this information is transparent so that the public can access information.

Identification and Inventory

Introduction

98. Waste prevention is the first priority to manage mercury waste, but without knowing mercury waste sources and their volumes, effective actions cannot be taken to prevent and minimize mercury waste.

99. Figure 0-2 shows global mercury consumption by application in 2005. The largest consumption sector is artisanal 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. The range of mercury consumption was 3,165 - 4,355 tonnes while the net consumption was 2,500 - 3,500 because of mercury recycled and recovered (650 - 830 tonnes) (UNEP 2008b).

100. Identification of mercury waste is the first step not only to develop an inventory of standardized mercury source but also develop and enforce a legal framework on mercury waste. Identification of mercury waste nationwide is preferably; however, it is recommended to conduct an area wide identification (province, prefecture, city, or community) as the first step for a national inventory preparation, particularly for developing countries and countries with economies in transition where there is no inventory programme of mercury waste. There are 10 categories with sub categories for identification and inventories of waste (see Table 0-1) (UNEP 2005b).

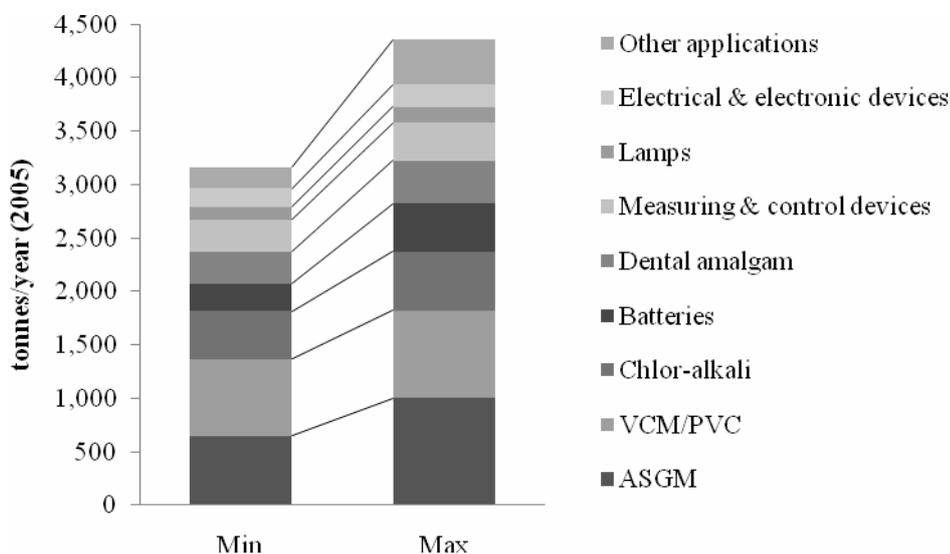


Figure 0-2 Estimated global mercury consumption in 2005 (UNEP 2008b)

101. There are so many kinds of mercury uses, such as mercury-containing products (thermometers, barometers, fluorescent lamps, batteries, switches, dental amalgams, chemical reagents, etc.), and industrial process such as chlor-alkali chlorine or caustic soda manufacturing that intentionally use mercury. As well, there are many kinds of unintentional mercury releases (coal fired power plants, cement production, waste incineration, etc.).

102. Therefore, it is important to collect information what kinds of products and industrial processes that use mercury, would need to continue as there are no practical alternatives, or could be substituted by mercury-free products and industrial processes.

Sources and Types of Mercury Waste

103. UNEP Chemicals published a Global Mercury Assessment (UNEP 2002), and a Toolkit for the Identification and Quantification of Mercury Releases (UNEP 2005b), a Guide for Reducing Major Uses and Releases of Mercury (UNEP 2006b) and a Summary of Supply, Trade and Demand Information on Mercury (UNEP 2006c). These materials clearly provide and describe information about the sources of mercury emissions and types of mercury waste as well as mercury trade statistics and international mercury trade. See these references for further detailed information. According to these references, the sources and types of mercury waste are categorised in Table 0-1.

104. It is noted, in some countries, that some of the industrial sources (Source 1, 2, 3, 4 and 7, except the processes using mercury) of mercury waste in Table 0-1 do not use mercury and discard mercury waste at all. Industrial processes are depended on country’s technological and social issues whether technology of mercury-free processes is introduced for environmental issues.

Table 0-1 Sources, categories, examples and causal factors types of mercury waste (UNEP 2002; 2005b; 2006b; 2006c). * A: Waste consisting of elemental mercury; B: Waste containing mercury; C: Waste contaminated with mercury.

Source	Cate- gories *	Examples	Causal factors
1. Extraction and use of fuels/energy sources			
1.1. Coal combustion in power plants	C	Flue gas cleaning residues (particulate matters, wastewater treatment sludge from flue gas cleaning, etc), fly ash	<ul style="list-style-type: none"> • Combustion of natural mercury impurities in raw materials; • Accumulation in solid incineration residues 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 production	C		
2. Primary (virgin) metal production			

Source	Cate- gories *	Examples	Causal factors
2.1. Primary extraction and processing of mercury	C	Smelting residue	<ul style="list-style-type: none"> 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, exhaust gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> Industrial processing; Thermal treatment of ore; and Amalgamation.
3. Production of other minerals and materials with mercury impurities			
3.1. Cement production	C	Process residues, exhaust gas cleaning residues, sludge	<ul style="list-style-type: none"> Pyroprocessing of natural mercury impurities in raw materials
3.2. Pulp and paper production			<ul style="list-style-type: none"> Combustion of natural mercury impurities in raw materials
3.3. Lime production and light weight aggregate kilns			<ul style="list-style-type: none"> Calcination of natural mercury impurities in raw materials
4. Intentional use of mercury in industrial processes			
4.1. Chlor-alkali production with mercury-technology	A/C	Solid waste contaminated with mercury, elemental mercury, process residues	<ul style="list-style-type: none"> Mercury cell; Mercury recovery units (retort).
4.2. VCM production with HgCl ₂ as catalyst	A	Process residues	<ul style="list-style-type: none"> Mercuric chloride process
4.3. Acetaldehyde production with mercury-sulphate (HgSO ₄) as catalyst	C	Wastewater	<ul style="list-style-type: none"> Mercury-sulphate process
4.4. Other production of chemicals and polymers with mercury compounds as catalysts	C	Process residues, solid waste, wastewater	<ul style="list-style-type: none"> Mercury catalyst process
5. Consumer products with intentional use of mercury³			

³ Information about amount of mercury contained in products can be found in Good Practices for Management of Mercury Releases from Waste to be prepared under the UNEP Global Mercury Partnership – Mercury Waste Management Partnership Area.

Source	Cate- gories *	Examples	Causal factors
5.1. Thermometers and other measuring devices with mercury	B	Used, obsolete or broken products	<ul style="list-style-type: none"> Liquid mercury
5.2. Electrical and electronic switches, contacts and relays with mercury			
5.3. Light sources with mercury	B		<ul style="list-style-type: none"> Vapour-phase elemental mercury Divalent mercury adsorbed on the phosphor powder
5.4. Batteries containing mercury	B		<ul style="list-style-type: none"> Mercury oxide
5.5. Biocides and pesticides	B	Stockpiles (obsolete pesticides), soil and solid waste contaminated with mercury	<ul style="list-style-type: none"> Mercury compounds (mainly ethylmercury chloride)
5.6. Paints	B	Stockpiles (obsolete paints), solid waste contaminated with mercury, wastewater treatment residues	<ul style="list-style-type: none"> Phenylmercuric acetate and similar mercury compounds
5.7. Pharmaceuticals for human and veterinary uses	B	Stockpiles (obsolete pharmaceuticals), medical waste	<ul style="list-style-type: none"> Thimerosal; Mercuric chloride; Phenyl mercuric nitrate; Mercurochrome, etc.
5.8. Cosmetics and related products	B	Stockpiles	<ul style="list-style-type: none"> Mercury iodide; Ammoniated mercury, etc.
6. Other intentional product/process uses			
6.1. Dental mercury-amalgam fillings	B/C	Stockpiles, wastewater treatment residues	<ul style="list-style-type: none"> Alloys of mercury, silver, copper and tin
6.2. Manometers and gauges	B	Used, obsolete or broken products	<ul style="list-style-type: none"> Liquid mercury
6.3. Laboratory chemicals and equipment	A/C	Stockpiles, wastewater treatment residues, laboratory wastes	<ul style="list-style-type: none"> Liquid mercury; Mercury chloride, etc.
6.4. Mercury metal use in religious rituals and folklore medicine	C	Solid waste, wastewater treatment residues	<ul style="list-style-type: none"> Liquid mercury
6.5. Miscellaneous product uses, mercury metal uses, and other	B/C	Stockpiles, wastewater treatment residues, solid wastes	<ul style="list-style-type: none"> Infra red detection semiconductors with mercury; Bougie and Cantor tubes; Educational uses, etc.

Source	Cate- gories *	Examples	Causal factors
sources			
7. Production of recycled metals (secondary metal production)			
7.1. Production of recycled mercury (secondary production)	A/C	Spillage during recycling process, extraction process residues, exhaust gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> • Dismantling of chlor-alkali facilities; • Recovery from mercury meters used in natural gas pipelines; • Recovery from manometers, thermometers, and other equipment
7.2. Production of recycled ferrous metals (iron and steel)	C		<ul style="list-style-type: none"> • Shredding; • Smelting of materials containing mercury.
7.3. Recovery of gold from E-waste (printed circuit board)	A/C		<ul style="list-style-type: none"> • Liquid mercury; • Thermal process
7.4. Production of other recycled metals	C		<ul style="list-style-type: none"> • Other mercury-containing materials or products /components
8. Waste incineration			
8.1. Incineration of municipal/general waste	C	Exhaust gas cleaning residues, wastewater treatment residues	<ul style="list-style-type: none"> • Intentionally used mercury in discarded products and process waste; • Natural mercury impurities in high volume materials (plastics, paper, etc.) and minerals; • Mercury as anthropogenic pollutant in high volume materials.
8.2. Incineration of hazardous waste			
8.3. Incineration of medical waste			
8.4. Sewage sludge incineration			
8.5. Informal waste incineration			
9. Waste deposition/landfilling and wastewater treatment			
9.1. Controlled landfills/deposits	C	Wastewater treatment residues, solid waste contaminated or mixed with mercury	<ul style="list-style-type: none"> • Intentionally used mercury in spent products and process waste; • Natural mercury impurities in bulk materials (plastics, tin cans, etc.) and minerals; • Mercury as an anthropogenic trace pollutant in bulk materials.
9.2. Diffuse deposition under some control			
9.3. Informal local disposal of industrial production waste			
9.4. Informal dumping of general waste			
9.5. Wastewater		Wastewater treatment	<ul style="list-style-type: none"> • Intentionally used mercury in

Source	Cate- gories *	Examples	Causal factors
system/treatment		residues, slurry	spent products and process waste; • Mercury as an anthropogenic trace pollutant in bulk materials.
10. Crematoria and cemeteries			
10.1. Crematoria	C	Exhaust gas cleaning residues, wastewater treatment residues	• Dental amalgam fillings
10.2. Cemeteries		Soil contaminated with mercury	

105. More detailed information about mercury-containing products (specific name and manufactures of products) is available from the following sources:

- UNEP (2008b): 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](http://www.chem.unep.ch/mercury/OEWG2/documents/g7)/English/OEWG_2_7.doc)
- 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
- UNEP Global Mercury Partnership – Mercury-Containing Products Partnership Area, <http://www.chem.unep.ch/mercury/Sector-Specific-Information/Mercury-in-products.htm>

Mercury Notification

106. It is important to identify which products contain mercury and how these products are distributed in the market in order to prepare necessary measures to manage mercury-containing products.

107. The eight Northeast states in the USA (Connecticut, Louisiana, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont) have legislation to require manufactures of mercury-containing products or their designated trade groups to submit mercury notification forms including their contact information as well as information pertaining to the mercury in the product prior to the sale of the products. Some of the states prohibit the sale of the mercury-containing products if such information is not submitted. Required information in the mercury notification form includes description of mercury added components, number of components, amount of mercury, purpose of mercury in the product, total amount of mercury in all units sold in the USA for a particular product.

108. Under the Northeast Waste Management Officials' Association (NEWMOA), the Interstate Mercury Education and Reduction Clearinghouse (IMERC) was formed to assist the eight Northeast States in their implementation of mercury reduction laws and programmes aimed at getting mercury out of consumer products, the waste stream, and the environment. IMERC reviews the mercury notification forms that IMERC member states receive, and once the review of the notification forms has been finished and has been considered complete, the information is entered into an IMERC electronic database (Lowell Center for Sustainable Production 2003).

109. The IMERC Mercury-Added Products Database is a searchable database organized by industry sector and maintained by the NEWMOA and accessible at: <http://www.newmoa.org/prevention/mercury/imerc/notification/>

Common Process and Source on Causal Factors of Mercury Waste

110. The causal factors of mercury waste are categorised into 4 categories of common mechanism as follows:

- I. Industrial process using mercury or mercury used in consumer products;
- II. Wastewater treatment process;
- III. Thermal process of natural mercury impurities in raw materials and mercury waste; and
- IV. Process at Artisanal and Small-Scale Gold Mining.

Industrial Processes using Mercury or Mercury used in Consumer Products

111. Industrial processes using mercury and mercury-containing products tend to be phased out. As a result, a large amount of mercury used in industry and mercury-containing products replaced in the market become mercury waste. Although these mercury wastes should be separately dealt with in an environmentally sound manner, in several cases, they are mixed with municipal solid waste (MSW), as there is neither a special collection mechanism for mercury-containing products nor public awareness on that the product contains mercury. Once mercury waste enters the MSW stream, the probability of mercury being released to the environment becomes greater because the mercury waste in the MSW could very well be subjected to unsound environmental management such as incineration without flue gas treatment systems and landfilling. It is noted that mercury waste as well as other hazardous wastes is collected and treated as MSW in many developing countries. This means that mercury waste is dumped at landfill sites or open dumping sites without any proper treatment.

112. Certain types of mercury compounds are used as preservatives for vaccines. Since there has been outbreak of pandemic diseases such as bird flu, countries are preparing for it by stocking vaccines for their citizens and animals. Once the vaccines containing mercury compounds become outdated, they become mercury waste.

113. In addition, it is expected that liquid mercury used at industrial processes and contained in products, particularly dental amalgam, is intentionally or accidentally discharged into wastewater. In this case, mercury reaches to wastewater treatment plants and ends up as sludge or ash, or directly enters the aquatic environment if there is no wastewater treatment facility.

Wastewater Treatment Process

114. Mercury in thermometers, barometers, dental amalgams, etc., and used in industrial processes is intentionally or accidentally discharged into wastewater and ends up at wastewater treatment plants or flows into river without proper treatment. At wastewater treatment plants, the dynamics of mercury are: 1) during collection and transport of wastewater to the treatment plant, Hg(II) is likely subjected to reducing conditions (caused by anoxia) and various bacteria, resulting in some conversion to elemental mercury. In addition, the methylation of mercury occurs via biotic pathways (Ekstrom 2003; Zhao 2008) or the acetyl coenzyme A pathway (Choi 1993; 1994a; 1994b); 2) in the primary settling tank, mercury adsorbed to and incorporated into settleable solids is removed in the sludge; 3) in the mixed liquor aeration basin or other biological unit, bacteria, protozoa and other microorganisms proliferatively and effectively convert dissolved organic material and colloidal particles with associated mercury to a flocculent biological material which is eventually removed as waste sludge; 4) bacterial action in anaerobic or aerobic digestion to stabilize sludge would produce additional transformations of elemental mercury. Elemental mercury formed may be stripped from solution by gas mixing systems (in the case of anaerobic digesters) or forced aeration. After stabilization, sewage sludge is often thickened or dewatered to reduce volume prior to ultimate disposal by land spreading, landfilling or incineration which are the anthropogenic sources of mercury emission (Huber 1997).

Thermal Process of Natural Mercury Impurities in Raw Materials and Mercury Waste

115. Thermal process includes calcinations, combustion, crematoria, incineration, pyroprocessing, pyrometallurgy, retort, roasting, melting and smelting. Thermal process means to burn raw materials containing trace amount of mercury. For example: 1) coal containing a trace amount of mercury is burned at coal fired power plant for energy production; 2) raw materials such as lime, coal, oil etc., which contain a trace amount of mercury, are thermally processed for cement production; 3) mercury waste, such as mercury-containing thermometers, batteries, etc., is accidentally or intentionally mixed with municipal solid waste destined for incineration.

116. In a thermal and incineration mechanism, only Hg^0 exists in the flue gas leaving the incinerator at about 700 °C, because of the thermo-chemical instability of the mercury compounds. Mercury is highly volatile and is present almost exclusively in the vapour phase in the flue gas. Depending on the other flue gas components, the temperature and the ash composition part of Hg^0 react to several mercurous (Hg_2^{2+}) and mercuric (Hg^{2+}) compounds while the flue gas cools down on its way through the boiler. Elemental mercury reacts in the presence of activated carbon quickly with oxygen to HgO , also quickly with Cl or HCl to HgCl_2 or Hg_2Cl_2 but slowly with NO_2 to HgO . No reaction of the elemental mercury with NH_3 , N_2O , SO_2 or H_2S was observed (Saenger 1999).

117. As these results, mercury is released into environment. On the other cases, mercury vapour can also be generated from leaks in pressurized equipment, maintenance work and dysfunction, absent of any visual appearance of liquid mercury. In addition, mercury accumulates in solid incineration residues, flue gas cleaning residues, ash and slag which are finally landfilled, stabilised as concrete, or recycled as construction materials.

Process at Artisanal and Small-Scale Gold Mining

118. Mercury waste, called as “tailings”, released from ASGM activities has been becoming as one of the hot issues, because almost all ASGM activities are conducted in developing countries and countries with economies in transition. It is very challenging to exact regulatory action on ASGM miners due to the geographic locales where they operate, and most of ASGM miners are driven by poverty to engage in such activity, plight. ASGM becomes an important source of livelihood for rural communities because of increasing price of gold. The impoverished miners are given the untenable choice of poverty or using mercury to do ASGM activities even though it will cause adverse effects to their health and the environment around them.

119. Mercury use at ASGM is to form an amalgam or bind with gold. The wetting of gold by mercury is not alloying, but a phenomenon of moderately deep sorption, involving some interpenetration of the two elements. As the surface tension of mercury is greater than that of water, but less than that of gold, mercury adsorbs onto the surface of gold particles. In addition, mercury acts as a dense medium; gold sinks into the mercury while the lighter gangue material floats on top. When the resulting amalgam is heated, the mercury vaporizes, leaving gold. Gold, in particular, can combine with mercury to form a wide range of compounds from AuHg_2 to Au_8Hg . The three principal gold amalgams are: AuHg_2 , Au_2Hg and Au_3Hg . Mercury can also solubilise from 0.14% to 0.65% gold at room temperature and 100 °C respectively (GMP 2004).

120. Mercury is usually discharged with tailings and/or volatilized into the atmosphere. The magnitude of loss and means of mercury release from a specific site are defined by the Au-Hg separation procedures. A variety of amalgamation methods are used in artisanal mining operations. Typical amalgamation methods used by ASGM are as follows (GMP 2004):

- Whole ore amalgamation: Mercury is mixed with the whole ore in pump boxes; introduced in sluices during gravity concentration; added to the grinding circuit; or the whole ore is amalgamated using copper plates; and
- Amalgamation of only gravity concentrates: mercury is mixed with concentrates in blenders or barrels; separation of amalgam from heavy minerals is accomplished by panning in water-boxes, in pools or at creek margins.

121. Not all the mercury added to the amalgamation process combines with gold and forms amalgam. The excess mercury must be removed and can be reused. The most common system used by miners is to squeeze off the excess mercury through a piece of fabric. However, squeezing with bare hands is not enough to reuse all excess mercury and lets a part of excess mercury escape to the environment as tailings (GMP 2006).

Chemical Analysis of Mercury

122. Chemical analysis of mercury is one of the important parts to identify mercury level in mercury waste as well as the environment. In order to determine precision data, the following factors are required: a) appropriate sample collection; b) pre-treatment for analysis; c) selection of a measurement method and preparation method for sample test solutions suited to the samples; and d) enough experience and expertise to perfectly perform the above-mentioned fact. It is also necessary to regularly pay attention to prevention of contamination of samples by keeping the laboratory clean, installation and use of appropriate ventilation, and washing and cleaning of glassware, tools and containers (Japan Public Health Association 2001).

123. Quality control for chemical analysis of mercury should be undertaken because analytical data should be of sufficient known quality to withstand scientific and legal challenge relative to the use for which the data are obtained. The data acquired from quality control are used to estimate the quality of analytical data, to determine the need for corrective action in response to identified deficiencies, and to interpret results after corrective action procedures are implemented. Quality control should address both field and laboratory activities and be specified for estimating the precision and bias of the data (US EPA 1992).

124. The examples of chemical analysis of mercury in environmental samples, waste and flu gas can be found in the Good Practices for Management of Mercury Releases from Waste (in preparation).

Inventories

125. After identifying sources and types of mercury waste, activity volume data (“activity rates”) and process-specific information and data are gathered to be used to calculate estimated mercury waste from the identified source and type of mercury waste in a country (or area, community, etc.). An estimation of the average annual release of mercury from mercury waste to each pathway or vector (mercury in mercury waste, such as residues, solid waste, etc.) can be calculated by the following basic equation (UNEP 2005b):

Estimated mercury release to path way = activity rate × input factor × output distribution factor for pathway

126. For estimation of mercury-containing products, a number of obsolete mercury-containing product could be roughly estimated by the following equations:

Obsolete mercury-containing products per year (after an average life span) = a number of mercury-containing product users (e.g., per 1,000 people) in a certain year × population in the certain year: or

Obsolete mercury-containing products per year (after an average life span) = a number of mercury-containing products in a certain year after an average life span

127. If both of new and secondhand products or secondhand products are main consumer products, particularly developing countries and countries with economies in transition, each item should be estimated separately and finally combined together.

128. Although an estimation of mercury waste and obsolete mercury-containing products could roughly be calculated by the above-mentioned equations, it is very difficult to collect necessary data to estimate mercury waste and obsolete mercury-containing products, particularly in developing countries and countries with economies in transition due to lack (or no) of data. In addition, in those countries, small-scale facilities for mercury waste and factories to manufacture mercury-containing products would be main actors who do not collect weight of mercury waste or a number of manufactured mercury-containing products. In this case, a pilot programme for developing inventories is necessary in a limited area. Its programme would be composed of questionnaires to ask facilities and factories about weight of treated mercury waste or number of manufactured mercury-containing products (annually or monthly) and estimated weight of mercury waste and a number of mercury-containing products based on questioners.

129. UNEP Chemicals produced the Toolkit for Identification and Quantification of Mercury Releases in 2005. The toolkit assists countries to build part their knowledge base through the development of a mercury inventory that identifies sources of mercury releases in their country and estimates or quantifies these releases. The Toolkit is designed to produce a simple and standardized methodology and accompanying database to enable assembly of consistent national and regional mercury inventories (UNEP 2005b).

130. Cambodia, Burkina Faso, Madagascar, Pakistan, Philippines, Syria and Yemen in cooperation with UNEP Chemicals developed the mercury inventory in those countries by using the toolkit. The categories of mercury emission and input and output of mercury to and from the country were identified (UNEP 2008d).

Mercury Waste Prevention and Minimization

131. Following a conventional waste minimization approach, techniques and technologies for reducing mercury waste emissions are prioritized in three broad categories:

- 1) Source Reduction – Using alternative materials or alternative processes not requiring mercury:
- 2) Waste Minimization – Using mercury in existing processes more efficiently or completely; and
- 3) Emission Reduction/Treatment – Using end-of-pipe engineering controls to capture mercury before it can be emitted or treatment to reduce the amount or toxicity of the waste (preventing waste products containing mercury from flowing into waste stream).

Artisanal and Small-Scale Gold Mining

132. Studies of elemental mercury releases into the environment from ASGM carry a high degree of uncertainty because the practice occurs in many different countries and widely varying circumstances and techniques. In addition, many artisanal miners practice their craft individually or in small groups and in parts of the world with reduced governmental or industrial involvement. There is wide consensus that they will only be successful in concert with a robust initiative to educate artisanal miners, their families, and the surrounding communities of: (a) the health dangers; and (b) environmental destruction from mercury use in ASGM.

133. Mercury-free techniques are available: Gravimetric methods; Minataur process; Centre for Mineral Technology (CETEM); Combining non-mercury methods. In cases where organized

alternatives are unavailable, the best interim solution is to promote BMP: Centralized Processing Centres; BMP using Mercury. The details can be found in the following references:

- GMP (2006): Manual for Training Artisanal and Small-Scale Gold Miners, UNIDO, Vienna, Austria, www.cetem.gov.br/gmp/Documentos/total_training_manual.pdf; and
- MMSD Project (2002): Artisanal and Small-Scale Mining, Documents on Mining and Sustainable Development from United Nations and Other Organisations.

134. Although cyanide processing is also used to extract gold from ore or to leach mercury-contained tailings for further collecting gold, this process leads to an additional problem. Cyanide is highly toxic and at high concentrations would kill fish, birds and mammals (including humans). In addition, cyanide reacted with mercury to produce soluble chemical compounds is easily transported with water. Furthermore, it converts the mercury to a form in which it more easily enters the food chain and becomes more harmful when cyanide reacts with mercury. Thus, cyanide processing requires much more skill and technical control than amalgamation and not usually within the reach of individual or dispersed artisanal miners (GMP 2006). Having in mind the cyanide-catastrophe of the Hungarian river Tisza in January 2000 the cyanide processing cannot be regarded as BAT or BEP.

Vinyl Chloride Monomer (VCM) Production

135. Two processes are used to manufacture vinyl chloride. One process (acetylene process) uses mercuric chloride on carbon pellets as a catalyst, and the other (mercury-free) is based on the oxychlorination of ethylene (The Office of Technology Assessment 1983). Up to the 1960s, VCM was essentially produced by the gas-phase hydrochlorination of acetylene with hydrochloric acid over a mercuric chloride based catalyst. However, due to the high cost of acetylene, and the emergence of large steam-crackers providing abundant ethylene, the ethylene route has replaced acetylene. The acetylene process was closed down in Japan in 1989 and in Europe in 1993 (Weissermel 2003). Although nearly all production of VCM is now based on ethylene, the dominant process to produce VCM in China is based on acetylene produced from calcium carbide (Greer 2006; ICIS 2005). The advantage of the ethylene process to produce VCM is lower capital costs and simpler technologies compared with those of other processes (Cowfer 2005). On the other hand, the ethylene process produces various kinds of by-products, such as gaseous forms, organic liquid, and aqueous and solid streams, while ensuring that no chlorinated organic compounds are inadvertently released (Cowfer 2005).

136. VCM production using the acetylene process employs mercuric chloride as a catalyst. Waste minimization opportunities exist and fall into two primary categories: (a) alternative, mercury-free manufacturing methods; and (b) environmental controls to capture and recycle mercury-containing wastes.

137. Mercury-Free VCM Manufacturing: VCM is manufactured in a variety of ways including mercury-free methods based on the oxychlorination of ethylene (The Office of Technology Assessment 1983). While the mercury-free alternatives are used in various places in the world, the largest factor in its use in place of the mercuric chloride process has typically been the price of mercury (and therefore the incentive to recycle it) and the increasing environmental concerns.

138. Environmental Controls: Mercury used in VCM production can be released into the environment as a contaminant in waste produced during manufacturing. Mercury wastes include wastewater, air emissions, solid waste, and hazardous wastes. Waste minimization opportunities are focused on installing and operating environmental controls including:

- Wastewater: Mercury-containing wastewater is produced from VCM manufacturing and should be treated to remove mercury using activated carbon that can subsequently be processed to remove and recover mercury (International Finance Corporation 2007); and

- Air Emissions: Air pollution controls consisting of activated carbon should be used to adsorb mercuric chloride in flue gases for regeneration and mercury recycling (International Finance Corporation 2007).

139. Spent Catalyst: Spent catalyst containing mercury should be treated with lime or caustic soda solution and heated to drive off mercury vapours that can be treated with activated carbon and then regenerated to remove mercury for reuse (Scottish Environment Protection Agency 2004).

Chlor-Alkali Chlorine and Caustic Soda Manufacturing

140. Main types of processes used worldwide to manufacture chlorine and caustic soda are :

- Mercury cell;
- Diaphragm cell; and
- Membrane cell.

141. Membrane cell technology is the most cost efficient because of lower electricity input required and also eliminates the use and emission of mercury during manufacture – as a result, as older mercury cell factories are closed, membrane cell plants are reducing the amount of mercury emissions from chlorine and caustic soda manufacture. As of 2007, there were 70 plants using the mercury cell process in USA, Canada, Europe, Brazil, Argentina, Uruguay, and Russia (World Chlorine Council 2008). And in Japan, mercury cell process was no longer in use by 1986. Currently, about 50% of European production of chlorine use mercury cell technology. An example of this shift away from mercury cell production is evident in the European chlorine manufacturers committing to replace all mercury cell plants by 2020. (OSPAR 2006).

142. In the long-term, most or all of the mercury cell chlor-alkali chlorine plants will be replaced, but given the long useful life of the plants, the process will take decades. In the intervening time, there are many well-documented best management practices (BMP) that can be implemented to reduce mercury emissions. Table 3-3 summarizes those recommended BMP.

Table 0-2 Recommended BMP – Mercury cell chlorine and caustic soda plants

Source	Summary
Code of Practices - Mercury Housekeeping (Euro Chlor 1998)	The document describes a variety of practical BMP and “helpful hints” for operating a mercury cell chlorine plant with an emphasis on detection and cleanup of mercury leaks and emissions within the plant.
Integrated Pollution Prevention and Control (European Commission 2001)	This document details various pollution prevention and control technologies and techniques for all three types of chlor-alkali manufacturing facilities. Section 4.2 contains mercury emissions reductions for mercury cell plants; the recommendations are summarized below: <ul style="list-style-type: none"> • Monitoring of possible leakages and recovery of mercury; • Good Housekeeping; • Influence of human factors; • End-of-pipe measures; • During Normal Operation; and • During operations that require opening of the cells.

Products Containing Mercury

Mercury-free Products

143. Depending on the product and country, some barriers exist for phasing out mercury-containing products and replacing them with alternatives that use less mercury or are mercury free. The barriers associated with the alternatives include: cost, efficacy, and ease of use, as well as difficulties associated with locating and identifying mercury-containing products. Many kinds of mercury-free alternatives are available now. The detailed information about mercury-free alternatives is available in the following publications:

- Good Practices for Management of Mercury Releases from Waste (*in preparation*);
- Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury free products and processes (UNEP 2008d);
- Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society (European Commission 2008).

144. After instituting mercury-free alternatives and outright bans on mercury-containing products more commonly found in developed countries, reducing incidental mercury releases from incinerators and landfills can best be accomplished by segregation of waste containing mercury from the waste stream. The two most common waste streams containing mercury are MSW and waste generated at healthcare facilities. Relying on “end-of-pipe” engineering controls that scrub incinerator emissions or treat landfill leachate are necessary precautions, but it is much preferable to prevent mercury contamination of the waste streams in the first place. This is most successfully implemented by (a) product labelling to prompt proper end-of-life recycling and disposal; and (b) collection and “take-back” initiatives for common mercury-added products.

Products Labelling

145. The Quicksilver Caucus (a US-based coalition of state associations formed to address and resolve health and environmental problems resulting from the release of mercury to the environment) recommends a robust system of product labelling to any “mercury-added product” to:

- 1) Inform consumers at the point of purchase that the product contains mercury and may require special handling at end-of-life;
- 2) Identify the products at the point of disposal so that they can be kept out of the waste stream destined for landfill or incineration and be recycled;
- 3) Inform consumers that a product contains mercury, so that they will have information that will lead them to seek safer alternatives; and
- 4) Provide right-to-know disclosure for a toxic substance.

146. While governments and industry sectors have taken different approaches to what and how product labelling is most effective, the 1998 Conference of the New England Governors and Eastern Canadian Premiers developed guidelines in support of the Quicksilver Caucus’s four labelling goals outlined above. The general categories are summarized below and more details are available at;

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

147. In addition, under the Law for Promotion of Effective Utilization of Resources in Japan, manufactures and importers must label a symbol (J-Moss symbol: Figure 3-2) if any of the products (personal computers, air conditioners, television sets, refrigerators, washing machines, microwaves, home driers) contains lead, mercury, cadmium, hexavalent chromium, PBB and/or PBDE. The purpose for the labelling is to promote the use of recyclable resources and parts through providing information on the specific substances contained in electrical and electronic

equipment, and to promote Design for Environment (DfE) is required for importers, not only manufactures.



Figure 0-3 J-Moss symbol

148. It should be taken into account the issue of language barriers when mercury-containing products are exported to other countries where those products become waste, because local consumers, users and other stakeholders might not read English labelling on those products. In this case, importers, exporters, manufactures or national agency in charge of products labelling have to use appropriate products labelling in local language in order to ensure ESM of traded mercury-containing products.

Closed System for Utilization of Mercury

Separation of Waste Containing Mercury

149. The most effective way to minimize mercury releases from waste management is to phase out of mercury in products by introducing mercury-free alternatives. If technology or socioeconomic conditions make it difficult to replace mercury with mercury free-alternatives, it is desirable to establish a safe closed utilization system. Waste containing mercury is separated and collected, and then mercury is recovered from the waste and used for production (instead of using primary mercury) or disposed (see Figure 0-4). Such systems could divert waste containing mercury from waste stream which ends up in waste incinerators, landfills or open dumping sites.

150. Separation of waste containing mercury from MSW at source is important from the view point of utilising organic wastes in the MSW as compost. Composting of organic waste from households greatly contributes to waste volume reduction as well as improvement of hygiene conditions for waste collection/disposal workers. However, past experiences in promoting composting from MSW show that waste fluorescent lamps and batteries are likely to be mixed into the organic wastes. If the compost contains mercury and other heavy metals, it cannot achieve the intended use.

151. One should remember that it is difficult to complete such closed system if there is no manufacturer using mercury or disposal facilities for mercury waste. In that case, establishing a cooperation scheme with countries exporting products containing mercury or having disposal facilities is necessary. In addition, such closed system may not be established even if there is a manufacture using mercury because of economic conditions. In that case, waste containing mercury should be stored in a manner that mercury releases from the storage is minimized.

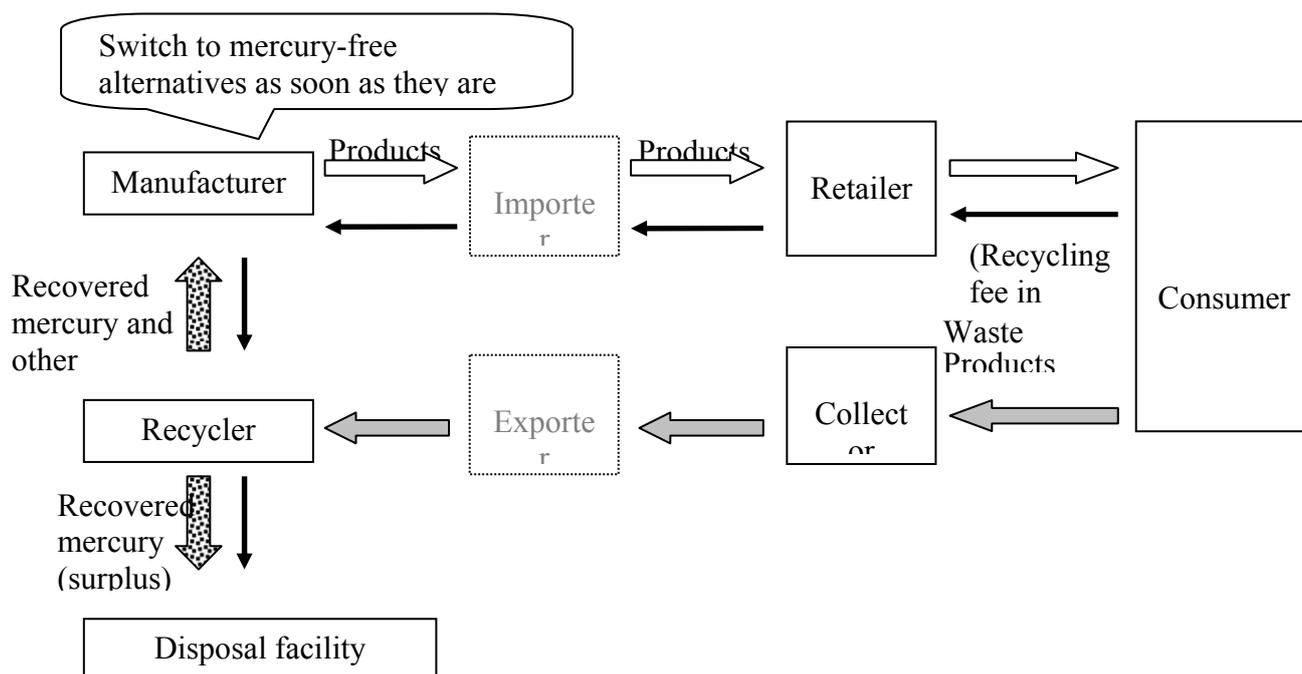


Figure 0-4 Closed System for Utilization of Mercury

Take-back Programme

152. A take-back programme is one of BEP. Generally, a take-back programme gives manufactures the physical responsibility for products and/or packaging at the end of their lives. By accepting used products, manufactures can acquire low-cost feedstock for new manufacture or remanufacture, and offer a valued-added service to the buyers. A take-back programme is voluntary or under requirements or guidelines. In addition, a take-back programme provides an opportunity for all stakeholders including manufactures, retailers and consumers as well as waste management sectors to increase their knowledge about why mercury-containing waste and products should be handled in an environmentally sound manner.

153. Generally, take-back programmes focus on household (obsolete or used) products which are widely scattered but have the adverse potential to cause the environmental pollution if they are dealt in an environmentally unsound manner (Honda 2005). The main purposes of a take-back programme for mercury-containing products are to phase out mercury-containing products and to promote using mercury-free products or mercury-containing products whose mercury contents are as low as practically possible.

154. A take-back programme fundamentally places the responsibility of the end-of-life product back to the manufacturers. An outcome from a take-back programme is utilization of market forces to create incentives for the manufacturer to re-design their product for recycling and to eliminate toxic inputs. Since inefficiency in re-manufacturing and toxic waste disposal is costly to manufacturers, presumably manufacturers will have an incentive to avoid these high costs.

155. In EU, fluorescent lamps including compact fluorescent lamps (CFLs) are one of the many 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 certain products that contain mercury, lead, cadmium, chromium, and such flame retardants. The retail price of a fluorescent lamp includes the cost for recycling, and manufacturers are required

to collect and recycle them. Manufacturers and retailers must also provide information to consumers about recycling of their fluorescent lamps. Some retailers have in-store collection facilities; however, most retailers rely on Designated Collection Facilities which are defined in the WEEE regulations as specific collection sites for receiving household electronic wastes, including CFLs (NEWMOA 2009).

156. Mercury-containing products, such as fluorescent lamps and other mercury-containing lamps, thermometers, mercury-containing batteries and mercury switches are typically the main target of a take-back programme, because these products are widely used and have the high potential to be recycled. At this moment, it is practically difficult to phase out use of all fluorescent lamps and other mercury-containing lamps and replace them with new technology, such as light emitting diode (LED) lamps. Alternatives of mercury-containing thermometers and batteries are already available.

157. Collection and recycling systems of waste products containing mercury are divided into two groups; one is legally binding, and the other is voluntary. Both groups require manufactures' responsibility for managing their products after being discarded based on extended producer responsibility (EPR⁴). When the number of importers and/or manufactures of target products containing mercury is limited or corresponding industry associations are established and negotiation with them is relatively easy, it would be possible to start with a legal collection system involving relevant players in the industry. On the other hand, when there are many large and small-medium scale companies and no industry association covering most of the relevant players in the industry, it would be practical to start with voluntary collection and recycling system by large scale importing and manufacturing companies and then gradually increase the number of companies participating in the voluntary system. Effective tools to encourage voluntary collection and recycling include requiring the public sector to give preferential procurement to the products provided by the companies participating in the voluntary system and encouraging the private sector to do the same. In addition, there is another option to establish a collection and recycling system through involvement of not only companies but also local government, other public sector, and residents.

158. To increase collection rate, introduction of deposit system could be working while keeping consumers informed about target collection products and collection methods through municipal information papers, posters, and mass media. Sometimes collection rate of waste containing mercury varies by region or local jurisdiction of a country; it is important to conduct benchmarking by locality and examine measures to increase collection rate according to the local conditions.

159. Deposit systems, which have been in place for waste cans and PET bottles collection, could be applied to waste products containing mercury. However, no case for waste containing mercury has been identified.

Establishment of Mercury Recovery Facilities

⁴ For detailed information about EPR, please refer to the following OECD reports:

[Guidance Manual for Governments](#): provides information about issues and potential benefits and costs associated with EPR

["Analytical Framework for Evaluating the Costs and Benefits of Extended Producer Responsibility Programmes"](#): proposes a framework for analysing the costs and benefits of EPR implementation

["EPR Policies and Product Design: Economic Theory and Selected Case Studies"](#): discusses the potential Design for Environment impacts of EPR policies and provides practical examples of the extent to which some EPR programmes are contributing to 'Design for the Environment'

160. Minimization of mercury releases to the environment from management of waste products containing mercury is achieved through recovering mercury from the waste products, replacing newly mined mercury with the recovered mercury for indispensable needs, and storing surplus mercury in an environmentally sound manner. In addition to mercury, other materials should be recovered and recycled to replace virgin materials for production.

161. To recover mercury from waste containing mercury, there are pretreatment facilities such as crushing plants, and mercury recovery facilities such as roasting facilities and purification facilities. These facilities should be constructed and operated in a manner that mercury releases to the environment is minimised. To ensure such construction and operation, relevant technical standards, permit system, and performance monitoring/reporting system should be established. These facilities should be under a permit system of hazardous waste treatment facilities.

162. Depending on possible volume of waste containing mercury to be collected, amount of mercury to be recovered, and recycling fees to be gained, it might be difficult to establish mercury recovery facilities in some countries. Possible options for these countries might be dismantling waste products containing mercury if the waste is bulky, collecting mercury containing parts, and then 1) storing these parts until the operation of mercury recovery facilities or 2) exporting these parts to the countries where mercury recovery and storage facilities are operated in an environmentally sound manner.

163. If it is not feasible to construct a special storage for the mercury containing parts until the operation of mercury recovery facilities, these parts should be placed in a drum with care, and the drum should be sealed tightly and placed under a roof to be protected from direct sunlight and rain.

Cost Sharing of Stakeholders

164. Indispensable part of establishing a sustainable collection and recycling system of waste containing mercury is to design cost sharing and payment methods for covering necessary costs and to build social consensus. When established EPR systems exist, necessary costs could be reflected in product prices, and manufactures could be fully responsible for collection and recycling of target waste products while environmental authority is in charge of monitoring performance of the system (e.g. collected amount of waste products, recovered amount of mercury, and costs accrued for collection, recycling and storage) and recommend changes of the system as necessary. Sustainability of the system would be jeopardised if the system allows existence of free riders (when a part of manufacturers and importers bears the costs disproportional to their product market share while many others do not share the costs).

165. When there is no existing collection and recycling system of waste products, it would be difficult to introduce EPR concept to waste containing mercury. The national government should take an initiative to guide target industry associations or large importers and manufacturers to establish a collection and recycling system and ask local governments to support such system by providing collection services and the like. In this case, costs to collect waste containing mercury by local governments should be compensated by the importers and manufacturers. Once the system is established, public intervention should gradually phase out, and then mainly importers and manufactures should operate the system.

Reduction of Discharge from Dental Mercury-Amalgam Waste

166. The best way to avoid discharging dental-mercury amalgam from dental facilities is to use the concept of BMP (American Dental Association 2007). BMP is the procedures or measures used in the dental office to help limit the release of mercury into the environment. The practices for dental mercury-amalgam include initiating bulk mercury collection programs, using chair side traps, amalgam separators compliant with ISO 111433 (ISO 1999) and vacuum collection,

inspecting and cleaning traps, and recycling or using a commercial waste disposal service to dispose of the amalgam collected.

167. The steps for BMP of dental mercury-amalgam waste are as follows (American Dental Association 2007):

- 1) Stock amalgam capsules in a variety of sizes to minimize the amount of amalgam waste generated;
- 2) Use personal protective equipment such as utility gloves, masks, and protective eyewear when handling amalgam waste because it may be mixed with body fluids, such as saliva, or other potentially infectious material;
- 3) Contact an amalgam waste recycler about any special requirements that may exist in your area for collecting, storing and transporting amalgam waste; and
- 4) Store amalgam waste in a covered plastic container labeled “Amalgam for Recycling” or as directed by your recycler.

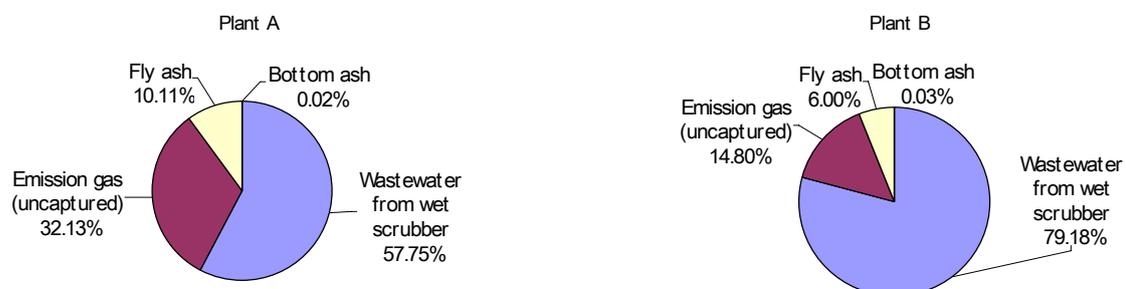
168. Mercury from amalgam separators is remobilised by certain disinfectants (Ulrich Kestel and Konstantina Pfarrer 1996). Using disposable traps and filters, and maintaining the unit according to the manufacturers’ instructions will prevent mercury from entering the wastewater. Deposits of amalgam are also found in wastewater pipes of dental offices and are disposed of together with these pipes as normal municipal waste (Slaby 2007).

Reduction of Mercury Releases from Waste Incineration and Disposal Sites

Reduction of Mercury Releases from Waste Incineration

169. When waste containing/contaminated with mercury is combusted, almost all the mercury in the waste is transferred to combustion gas due to its low melting point; little mercury remains in bottom ash. Most of the mercury in combustion gas within a waste combustion unit is a form of elemental mercury, but most of the elemental mercury transforms to divalent mercury after passing through the combustion unit and before flue gas treatment devices. In addition, part of the divalent mercury is transferred to fly ash. The divalent mercury is assumed to be mercuric chloride because of its water solubility. Since inside of the waste combustion unit is oxidizing atmosphere with HCl concentration of 400 - 1500 ppm, about 70 - 90 % of mercury in the combustion unit is considered to be transformed to mercuric chloride. Therefore, we should select flue gas treatment devices that can effectively remove such mercuric chloride and elemental mercury. In addition, waste having a possibility of containing mercury such as not-well segregated waste from healthcare facilities should not be incinerated in an incinerator without flue gas treatment devices (Arai et al. 1997).

170. Figure 0-5 shows distribution of mercury after treatment of combustion gas including treatment of wastewater from a wet scrubber. When a wet scrubber is used as one of the flue gas treatment methods, treatment of wastewater from a wet scrubber is indispensable.



Note: Amount of mercury in the waste incinerated is about 421 g/day for Plant A and 254 g/day for Plant B.

Figure 0-5 Mercury in residues after flue gas and wastewater treatment (Arai et al. 1997)

Reduction of Mercury Releases from Disposal Sites

Behaviour of Mercury

171. Mercury release channels from sanitary landfills to the environment are twofold; through leachate and landfill gas. It is reported that mercury releases through leachate is quite minimal compared to those through landfill gas (Yanase et al. 2009; Takahashi et al. 2004). Mercury transferred to leachate can be removed by leachate treatment, which is the same as that of wastewater from a wet scrubber of waste incinerators. So far, no case has been reported on mercury removal of landfill gas.

172. Mercury concentration of landfill gas increases as temperature increases. Figure 0-6 shows such trend at a landfill in Tokyo. In this case, mercury concentration ranges are 0.05-19 $\mu\text{g}/\text{Nm}^3$ (Takahashi et al. 2004).

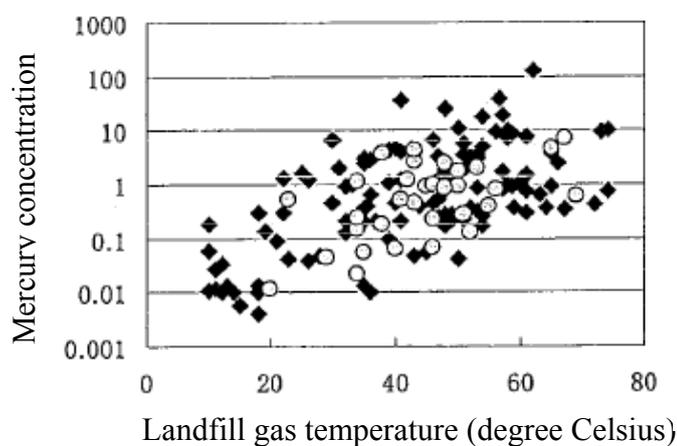


Figure 0-6 Relationship between mercury concentration in sanitary landfill gas and its temperature (Takahashi et al. 2004)

Prevention of Sanitary Landfill Fire

173. Mercury concentration of landfill gas is not so high, but it increases when fire occurs at sanitary landfills accepting wastes containing mercury. Landfill fire is attributed to flammable gas such as methane generated from organic waste landfilled. To prevent landfill fire, application of proper cover after landfilling, installation of landfill gas pipes to release landfill gas to the atmosphere or utilize it for energy recovery. Landfill fire also occurs when lighting cigarette is disposed (by waste pickers or landfill workers) or sunlight concentrated by glass pieces functioning as “lens” increases temperature of waste surface under the condition that landfill gas is emitted from unexpected parts of the landfill such as crack on the landfill surface and landfill pocket. Importance of soil cover should be emphasized (Japan Waste Management Association 2001).

174. Prevention of landfill fire depends on status of soil cover; therefore, soil cover plays an important role for prevention of landfill fire. 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 distinguishing purpose (e.g. dump truck, dozer shovel) should be set up.

Prevention of Open Burning and Dumping

175. Considering that landfill fire occurs even at sanitary landfills, it should be noted that open dumping sites are more vulnerable to open burning. Since open dumping is a common practice in developing countries, improving open dumping is the first step to prevent open burning.

176. It is important to establish a separate waste collection system to prevent waste containing mercury from going into MSW stream. However, it takes some time to establish such system; waste containing mercury would be brought into open dumping sites until the system is established. In addition, even if the collection and recycling system is established, small amount of waste containing mercury is mixed with MSW and goes into open dumping sites. When MSW is dumped without proper soil cover, mercury in the waste containing mercury that easily releases mercury into the environment when they are broken would be emitted into the air through burning of combustibles in the MSW and generated gas.

177. Basic policy to reduce mercury releases from waste management is owing to environmentally sound management of MSW such as banning of waste dumping in uncontrolled areas, applying soil cover, and installation of landfill gas pipes.

Handling, Collection, Packaging, Labelling, Temporal Storage, and Transportation of Mercury Waste

Introduction

178. Handling, collection, temporal storage, and transportation of mercury wastes are similar to those for hazardous wastes. Mercury has some physical and chemical properties that require additional precautions and handling techniques, but mercury in its elemental form is widely recognizable and there exist sophisticated and accurate field and laboratory measurement techniques and equipment that, if available, make detection and monitoring for spills relatively straightforward.

179. Specific guidance on handling mercury wastes are provided in this section, but it is imperative that generators consult and adhere to their own country's as well as local government's specific requirements. The general technical guidelines (GTG) for ESM of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs) identifies the following reference documents for transport and transboundary movement of hazardous wastes (SBC 2006):

- a) Basel Convention: Manual for Implementation (SBC 1995a);
- b) International Maritime Dangerous Goods Code (IMO 2002);
- c) International Civil Aviation Organization (ICAO) Technical Instructions for the Transport of Dangerous Goods (ICAO 2001); and
- d) International Air Transport Association (IATA) Dangerous Goods Regulations (IATA 2007) and the United Nations Recommendations on the Transport of Dangerous Goods Model Regulations (Orange Book) (UN 2001).

180. The following items should be considered for implementing a collection event (SBC 2006):

- a) Advertise the programme, depot locations, and collection time periods to all potential holders of mercury-containing products;
- b) Allow enough time of operation of collection programmes for the complete collection of all mercury-containing products;
- c) Include in the programme, to the extent practical, collection of all mercury-containing products;
- d) Make available acceptable containers and safe-transport materials to owners for those mercury-containing products that need to be repackaged or made safe for transport;

- e) Establish simple, low-cost mechanisms for collection;
- f) Ensure the safety both of those delivering mercury-containing products to depots and workers at the depots;
- g) Ensure that the operators of depots are using an accepted method of disposal;
- h) Ensure that the programme and facilities meet all applicable legislative requirements; and
- i) Ensure separation of mercury waste from other waste streams.

Safe Handling - Mercury-containing Products

181. Upon the disposal of mercury-containing products, such as fluorescent lamps, thermometers, electrical and electronic devices, etc., end users should not break, crush or take apart those. End users of mercury-containing products of liquid type, such as paints and pesticides as well as dental amalgam, should not discharge of those products into sink or toilets. Mercury-containing products should not be mixed with any other products, broken, disposed of as other wastes nor discharged into the environment until they are dealt with in environmentally sound manner. If mercury-containing products are accidentally broken or spilled, follow the cleanup procedure (see 0).

Temporal Storage of Waste Containing Mercury at End Users

182. Temporal storage at end users means that waste containing mercury is stored at end users' premises before the waste is collected for mercury recovery, stabilization/solidification treatment or disposal. Waste containing mercury should be safely stored and segregated from other wastes until final users bring them to waste collection stations or facilities. For household waste containing mercury, mainly fluorescent lamps, other lamps and mercury-containing thermometers, it is expected that consumers buy same new mercury-containing products when mercury-containing products are not functioning properly. In this case, there is a package for a mercury-containing product which is also available for packaging used mercury-containing product, such as a long-shape box for a fluorescent lamp and a package of thermometers. It is recommended to use these packages to temporally store used mercury-containing products at households. However, if these packages are not available, used mercury-containing products are carefully stored: for example, used linear fluorescent lamps should be vertically stored stood in a vertical-long boxes or containers, other types of used fluorescent lamps should be stored in a box fit for a shape of lamps, used mercury containing-thermometers should be stored in a small box exclusive for such waste, and the like. Liquid type of waste containing mercury, such as paints and pesticides should be kept in the original containers, and their lids should be closed tightly. Containers and packages enclosing waste containing mercury should not be placed in a trash for other wastes; those should be marked as "Hazardous Mercury Waste" and placed at a dry place, such as a warehouse or others where people do not usually use.

183. For large-scale users, such as governments, businesses, and schools, the principle to temporal storage of waste containing mercury is the same as that of households; packages for mercury-containing products can be used to safely store used mercury-containing products. However, a plan to store large numbers of waste containing mercury is necessary. If original boxes or packages fit for mercury-containing products are available, used mercury-containing products should be placed in these boxes or packages. In order for another case that original boxes or packages are not available, containers which are specially made to store mercury-containing products (e.g. fluorescent lamp containers) should be purchased. Containers or boxes to store used mercury-containing products should be marked a name and date, e.g., "Hazardous Mercury Waste (stored on 1 January 2010)", and located at a dry place inside a building. It is recommended to use a small room only for storing used mercury-containing products.

Segregation and Collection of Waste Containing Mercury

184. Segregation and collection of waste containing mercury are the key factors to implement ESM and most important in an environmentally sound management of mercury waste, because if waste containing mercury is simply disposed of as MSW without any segregation, mercury in the waste would be released into the environment due to landfilling or incineration. Waste containing mercury should be separately collected from other wastes without physical breakage or contamination to avoid mercury emission and stored into a recycle bin or container only for waste containing mercury. It would be better to separately collect waste containing mercury from households and other waste generators such as companies, governments, schools and other organisations, because the amount of waste containing mercury generated is different between those two sectors.

Collection from Households

185. There are three options to collect waste containing mercury, such as fluorescent lamps, batteries, thermometers, and electronic devices containing mercury, from households as follows:

At Waste Collection Stations of Municipal Solid Wastes

186. Waste containing mercury should be discarded into a special box only for waste containing mercury at a waste collection station in order to avoid mixture of waste containing mercury with other wastes. Waste containing mercury should be collected exclusively by authorised collectors, such as municipal collectors, private companies, and local collectors.

187. Boxes or containers for waste containing mercury should be set at the same places as existing waste collection stations. The most important thing is to set coloured-waste containers exclusive for waste containing mercury (marked as Mercury Waste or each name of waste containing mercury), such as used fluorescent lamps, mercury-containing thermometers, and mercury-containing batteries. It is noted to avoid breakage of used fluorescent lamps and thermometers.

188. For example, the residents in Minamata city where they have to segregate 22 kinds of wastes are supposed to place used fluorescent lamps and thermometers into a grey container exclusive for these wastes. The municipal collectors collect and transport all the segregated wastes from the waste collection stations to waste management centres. The cost of this collection system is covered by the tax revenue of the city (Minamata City Hall 2007).

At Public Places or Shops

189. Waste containing mercury, particularly used fluorescent lamps, mercury batteries and thermometers can be collected at public places or shops, such as city halls, libraries, other public buildings, electronic shops, shopping malls, and other retail shops. Collection boxes or containers for these wastes are necessary to be designed appropriate for properties of each waste containing mercury. Consumers can bring used fluorescent lamps, mercury batteries and mercury thermometers to those places for free of charge. Authorised collectors, such as municipal collectors or collectors of private sectors (e.g. collectors trusted by producers of those products), can only collect the waste containing mercury disposed of to the waste collection boxes or containers and transport to recycling facilities.

190. Boxes or containers for waste containing mercury should be always or regularly monitored because other wastes might be dropped off into the boxes or containers. Also labelling of waste containing mercury on boxes or containers is important. Those boxes or containers should be placed inside buildings, such as public building, schools, and shops where those boxes or containers can be monitored.

At Households by Collectors

191. This collection system is generally available for wastes which have the high potential to be recycled and reused, such as E-waste, in particular developing countries and countries with economies in transition because trading of E-waste makes local stakeholders get benefit due to high demand for second hand products. However, in terms of mercury, those wastes or second hand products contain very trace amount of mercury and does not attract local stakeholders to recover mercury as a raw material. This is because mercury recovery from these wastes requires investment in a special and advanced technology which is costly. In order to effectively collect waste containing mercury by local collectors, an initiative or legal mechanism should be in practice, e.g., governments, producers of mercury-containing products, or other agencies introduce a collection mechanism of waste containing mercury by local collectors.

Collection from Other Sectors

192. Other sectors include organizations which dispose of a large amount of waste containing mercury, such as used fluorescent lamps, thermometers, and mercury-containing products, as well as waste contaminated with mercury, such as sewage sludge, ash and residues which might contain mercury at low concentration. Primary collection of mercury waste for large-scale users of waste containing mercury is to internally collect those wastes at each organization. The solution can be seen at 0 Temporal Storage of Waste Containing Mercury at End Users. Mercury waste collected at each organization can be sent to waste management centres or recycling facilities where mercury waste is dealt with in an environmentally sound manner.

193. Sewage treatment plants and waste incinerators are generally designed to have equipment for collecting sewage sludge, ash and residues which might contain trace amount of mercury as well as other heavy metals. If mercury concentration in these wastes exceeds the criteria for hazardous waste set by the parties and others, these wastes should be stored in the environmentally sound manner.

Transportation

194. Transportation of mercury waste should comply with a national and/or local regulation. Mercury waste is transported by road, rail and water. Vehicles carrying mercury waste must be properly designed, engineered and maintained, and must be suitable for their load. Care must be taken to comply with the required packaging, labelling and manifest procedures.

195. Only an authorised transporter can transport mercury waste to authorised sites. An authorised transporter must check the wastes properly that described wastes were packed and labelled in compliance with regulations. An authorised transporter must have approved vehicles, trained drivers, vehicles marked with the appropriate hazard symbols and an emergency plan. Manifest system should be used, including: to provide a record of waste generated and its movement; to provide information for later disposal options; to serve as a “chain of custody” document; to carry signatures of the people handling the waste; to encourage responsible behaviour; to enable compliance with regulations; to observe ensure duty of care; and to increase responsibilities. Mechanism of emergency response should be established aimed at reducing probability of an accident occurring and minimising consequences of the accident (SBC 2002).

196. Transporting vehicles should have first-aid equipment, a fire extinguisher according to substances carried, and trained personnel. Authorised transporters shall manage mercury waste in a way that prevents breakage, releases of their components to the environment, and their exposure to moisture. In the event of a release, the transporter must determine whether the cleanup residues (e.g., cleanup equipment and contaminated soils) resulting from the release are hazardous waste.

Temporal Storage of Mercury Waste at Facilities

197. Temporal storage at facilities means that mercury waste after collection from end users is stored at facilities before mercury recovery, stabilization/solidification treatment, or disposal (R13: Accumulation of material intended for any operation in Section B in Annex IV of the Basel Convention; and D15: Storage pending any of the operations in Annex IV of the Basel Convention). All technical matters regarding hazardous chemical storage should be complied, including all national standards and regulations as well as international regulations. Storing of mercury waste containers should be constructed and maintained so that the risk of contamination to other products is avoided. Clear mark indicating mercury waste storage area should be shown with warning signs. A mercury waste storage area should be designed so that there is no unnecessary chemical and physical reaction to mercury. All mercury waste storage areas should be kept locked to avoid theft or unauthorized access. Regular inspection of the storage area should be undertaken, giving special attention to damage, spills and deterioration. Cleanup and decontamination shall be done speedily, but not without reference of safety information to authorities concerned (FAO 1985). Mercury waste storage facilities should not be built at sensitive locations, such as floodplains, wetlands, groundwater, earthquake zones, Karast terrain, unstable terrain, unfavourable weather conditions and incompatible land use, in order to avoid any significant risks of mercury releases and possible exposures to humans and the environment. Access to mercury waste should be restricted to those with adequate training for such purpose including recognition, mercury-specific hazards and handling. It is recommended that mercury storage building not be used to store other liquid wastes and materials. (US EPA 1997b).

198. In terms of security for facilities, site-specific procedures must be developed to implement the security requirements identified for mercury storage. A workable emergency plan, preferably multiple procedures, must 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 shall be a responsible person who can authorize modifications to the security procedures when necessary to allow emergency response personnel to function. 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).

Treatment of Mercury Waste and Recovery of Mercury

Introduction

199. Mercury-containing products and industrial uses of mercury tend to be phased out in many countries, particularly developed countries. In addition, it is promoted to replace normal fluorescent lamps with high frequency (Hf) ones in some countries in order to save energy consumption to address climate change. This results in an increase in the number of used mercury-containing products and mercury for industrial uses becoming waste. Mercury wastes from mercury-containing products and industrial processes should be treated in an environmentally sound manner to fully avoid the adverse effects to human health and the environment, because of the high probability of mercury wastes escaping to the environment if improperly managed. It is crucial to deal with mercury waste in an environmentally sound manner to avoid mercury emission to the environment.

Mercury Recovering Process – Solid Type of Mercury Waste

Introduction

200. Mercury recovering process generally composes of 3 processes: 1) pretreatment, 2) roasting process, and 3) purification, as shown in Figure 0-7. In order to minimize mercury emission from mercury recovering process, a facility should employ a closed-system. Entire process should be

under reduced pressure 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. Exposure limit of mercury vapour to workers is $25 \mu\text{g}\cdot\text{Hg}/\text{m}^3$ for long-term exposure as the time weighted average⁵ (TWA) (WHO 1991). In order to avoid any mercury exposure, workers should wear and use protective gears, such as helmet, goggles, masks (particulate respirator), gloves, protective clothing, and boots.

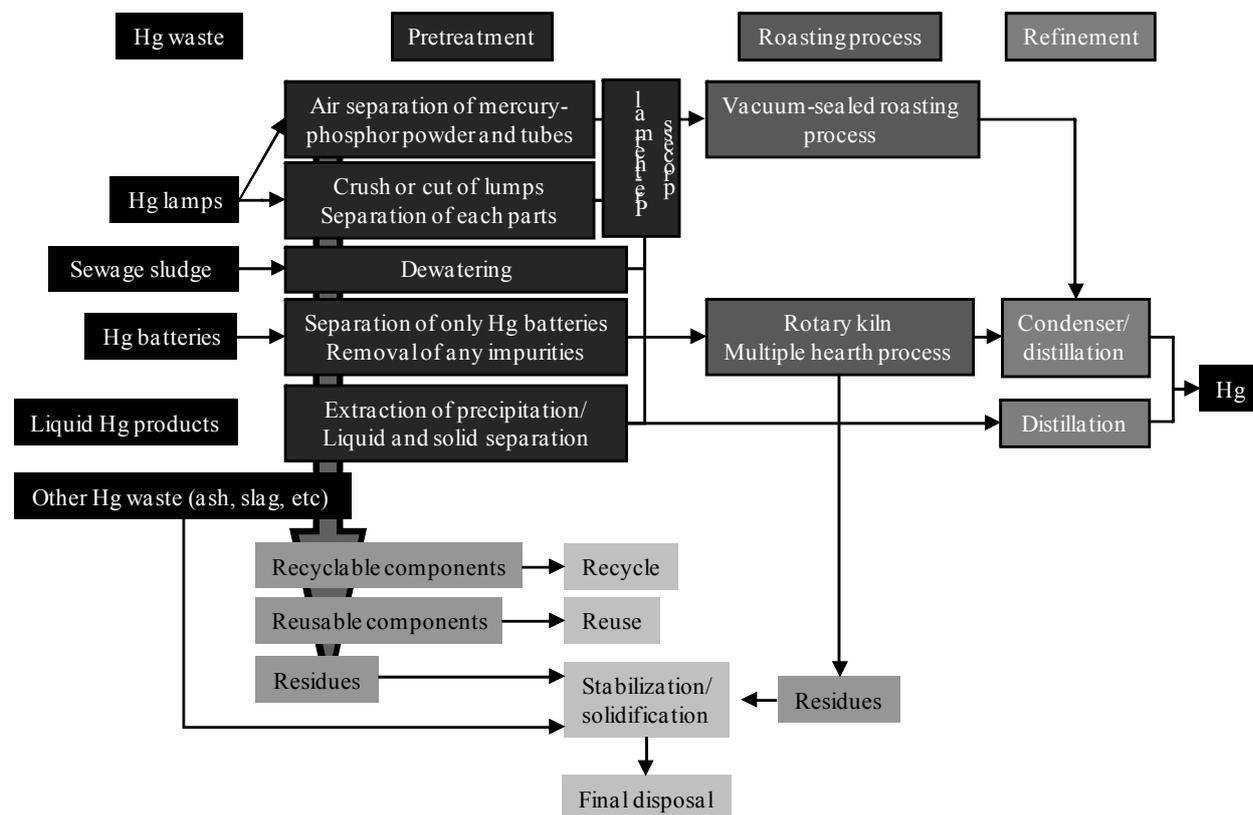


Figure 0-7 Flow of mercury waste treatment (Nomura Kohsan Co. Ltd. 2007)

Pretreatment

Fluorescent Lamps

Mechanical Crushing

201. Used/obsolete mercury-containing lamps are 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 are removed and sent for reuse in manufacturing. Mercury-phosphor powder is further processed to separate the mercury from the phosphor (Nomura Kohsan Co. Ltd. 2007).

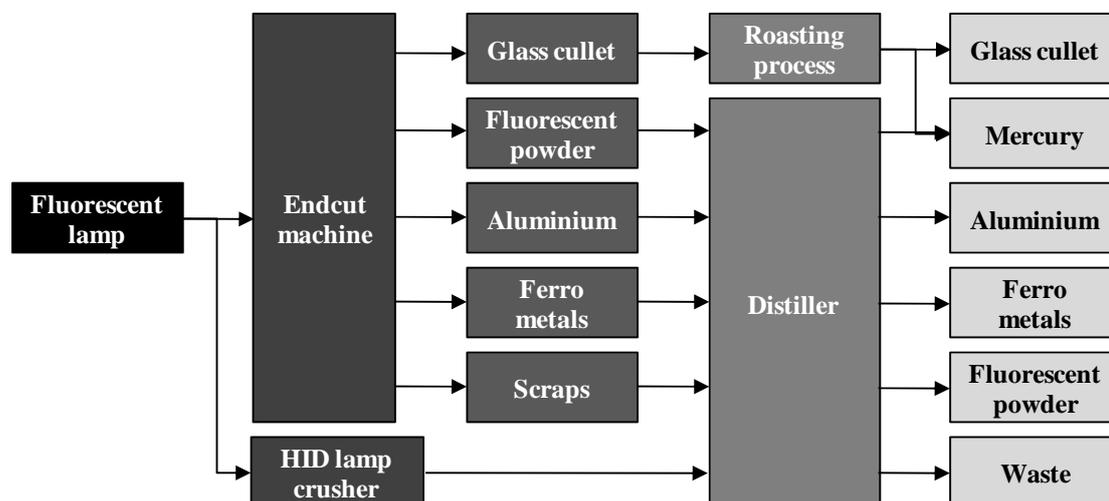
⁵ for a normal 8 hour-day and 40 hour-workweek

202. When crushing is not conducted in the sealed crushing chamber, mercury may be released from the crushing machine, which affects health and safety of machine operators. A study identified that most drum top crushers (DTC) used for compacting florescent lamps are designed to retain a large portion of the mercury released from used lamps when crushed, but if poorly designed or constructed, or if not assembled or operated properly, DTC use may result in significant releases of mercury and exposure to operators or others. Proper selection and maintenance of crushing machines, use of personal protective equipment, and adequate and isolated ventilation system are some of the methods to protect the workers (US EPA 2009).

203. Lamp glass from crushed mercury-containing lamps can retain significant amounts of mercury, and should be treated ideally thermally, or in other ways to remove mercury before sending it for reuse (Jang 2005). If this glass is sent for re-melting as part of its reuse, the melting unit should have air pollution controls specifically directed at capturing released mercury (such as activated carbon injection).

Air Separation

204. Aluminium end caps of fluorescent lamps (straight, circular and compact tubes) are cut by hydrogen burners (Figure 3-8). Air blowing flows into the cut fluorescent lamps from the bottom to completely 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 Batteries

205. In order to recycle mercury, mercury batteries should be separately collected or segregated before recycling. If mercury batteries are collected with other types of batteries, mercury batteries should be separated from other types of batteries in order to effectively treat mercury batteries. Before roasting treatment, impurities mixed with and adsorbed onto mercury batteries should be removed preferably by mechanical process. In addition, mechanical screening of size of mercury batteries is necessary for an effective roasting process. The process to recover mercury from mercury batteries is same as that of fluorescent lamps, except pretreatment (Nomura Kohsan Co. Ltd. 2007).

206. However, mercury batteries are easily mixed with other types of batteries during a battery collection scheme. The reason is that in most waste collection schemes, mercury batteries are mixed with other types of batteries, mixed with various hazardous wastes when mercury batteries are categorized as hazardous waste, or mixed with other wastes including municipal

Figure 0-8 Recovering flow of mercury from fluorescent lamps – Air separation
(Kobelco Eco-Solutions Co. Ltd. 2001)

solid waste when mercury batteries are categorized as non-combustible waste.

Sewage Sludge

207. Sewage sludge has high water content (more than 95%) and needs to be dewatered to about 20 to 35 percent solids before any thermal treatments. After dewatering, sewage sludge should proceed to roasting process (Nomura Kohsan Co. Ltd. 2007; US EPA 1997a).

Liquid Mercury-containing Products

208. Liquid mercury-containing products, such as thermometers and barometers should be collected without any breakage. Otherwise, it is impossible that liquid mercury-containing products are on ESM. After collection of liquid mercury-containing products, liquid mercury in the products is extracted, and extracted liquid mercury directly goes to distillation for purification under reduced pressure.

Roasting Process

Introduction

209. The pretreated mercury waste, such as mercury-phosphor powder, lamp glass from recycled lamps, cleaned mercury-batteries, dewatered sewage sludge, and screened soil, can be treated by roasting/retorting facilities including rotary kiln and multiple hearth process equipped with a mercury vapour collection technology to recover mercury. However, it is noted that volatile metals including mercury as well as organic substances 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 (See 0 Thermal Process of Natural Mercury Impurities in Raw Materials and Mercury Waste). Therefore, exhaust gas treatment devices should be equipped (See 0 Application of Thermal Processes).

210. The condition of roasting process for mercury waste should follow BAT for combustion as follows (UNEP 2006b):

- Mixing of fuel and air to minimize the existence of long-lived, fuel-rich pockets of combustion products;
- Attainment of sufficiently high temperatures in the presence of oxygen for the destruction of hydrocarbon species; and
- Prevention of quench zones or low-temperature pathways that will allow partially reacted fuel to exit the combustion chamber.

Vacuum-sealed Roasting Technology

211. A vacuum-sealed thermal process consists of a retort (electric furnace), water-cooled condenser, vacuum pump and activated carbon filters. Mercury-phosphor powder is heated under decompression, and only mercury is vaporized. And then, mercury is re-condensed and recovered as elemental mercury (Muroya 2001).

Rotary Kiln

212. A rotary kiln furnace incinerates combustible pretreated mercury waste as well as industrial wastes, particularly wastes with a high percentage of plastics, and can reduce the volume of wastes and decompose most of the hazardous materials into harmless except heavy metals. Mercury waste is fed into the inclined rotary kiln, and all mercury waste passes through the kiln with rotary motions (kiln action), wastes except heavy metal are thermally decomposed by heat radiation (600-800 °C) from a re-combustion chamber, and residues are burned at the rear end of the kiln and by the after-kiln. During the processing, mercury in mercury waste becomes mercury vapour during heat radiation processing at 600-800 °C. A vacuum carries the vapour to a cooling area, where the mercury is condensed to a liquid state. The mercury then passes through several other separator features prior to being decanted at the removal (Japan Society of Industrial Machinery Manufacturers 2001; Nomura Kohsan Co. Ltd. 2007). For further information, see the Basel Convention Technical Guidelines on Incineration on Land (SBC 1997).

Multiple Hearth Roaster

213. Multiple hearth roasters are vertical cylindrical refractory lined steel shell furnaces. It contains from 6 to 12 horizontal hearths and a rotating centre shaft with rabble arms. Mercury

waste enters the top hearth and flows downward while combustion air flows from the bottom to the top. Mercury waste is burned in the centre hearths and releases heat and combustion gas. The upper hearths comprise the drying zone in which mercury in mercury waste and some organic compounds are evaporated. The middle hearths comprise the combustion zone, in which temperature is typically 800 to 850 °C. A series of burners are installed in the combustion zone to maintain the combustion temperature. The lower hearths form the cooling zone. In this zone, the ash is cooled as its heat is transferred to the incoming combustion air. The temperature in this zone is typically from 400 to 460 °C. In the drying zone, some volatiles including mercury vapour are released from the mercury waste and exit the furnace without exposure to the full combustion temperatures (Dangtran 2000; Nomura Kohsan Co. Ltd. 2007; SBC 1997).

Flue Gas Treatment

214. During the roasting process, mercury and other air pollutants are released into flue gas. Basic flue gas treatment is comprised of removal of particulate, heavy metals, and dioxins/furans by dust collectors, neutralization/removal of HCl and SOx by adding neutralizing agent such as calcium hydroxide, and removal of NOx by selective catalyst reduction (Williams 2005).

215. The removal of mercury from flue gas is difficult because the removal efficiency of condensation or simple physical adsorption is insufficient due to the very high volatility of mercury (Takaoka 2005). To improve mercury removal, several methods are identified (see Table 0-3).

Table 0-3 Flue Gas Treatment Methods and Measures to Improve Mercury Removal

Type	Acid neutralization and removal (HCl, SOx)	Dust removal (particulate, heavy metals, dioxins)	Measures to improve mercury removal
Wet	Wet scrubber	Electrostatic precipitator	<ul style="list-style-type: none"> • Adding hydrogen peroxide, liquid chelating reagents with copper or manganese salts, or NaClO to wet scrubber solution.
		Fabric filter	
Dry	Semi-dry (slurry) Dry (powder injection)	Electrostatic precipitator	<ul style="list-style-type: none"> • Injection of activated carbon, sodium hydrogen carbonate, or calcium hydroxide upstream of a fabric filter; and • Activated carbon/coke filters.
		Fabric filter	

216. In general, incinerators are equipped with exhaust gas treatment devices not to release NO_x, SO₂ 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 for mercury removal at incinerators or coal fired power plant. Mercury adsorbed on activated carbons can be stabilised or solidified as a final treatment (see the subsection 0 Stabilization and Solidification).

217. The UNEP Global Mercury Partnership – Mercury Waste Management Partnership Area has been preparing Good Practices for Management of Mercury Releases from Waste. For the reduction of mercury emissions from waste incineration, the following documents also provide technical information.

- UNEP (2002): Global Mercury Assessment, <http://www.unep.org/hazardoussubstances/LinkClick.aspx?fileticket=Kpl4mFj7AJU%3d&tabid=3593&language=en-US>
- European Commission (2006): Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration, http://ec.europa.eu/environment/chemicals/mercury/pdf/study_summary2008.pdf

Recovery of Mercury – Purification

218. Mercury vapour emitted from mercury waste during thermal treatment directly goes to condenser (s) and condensed by cold water (10 °C or less are preferred) of heat exchanger supplied from a chiller. Roasting mercury waste involves introducing air to the hot waste which oxidizes mercury compounds and helps transport them to a condenser. Collected mercury is subsequently purified by successive distillation for resale or reuse (US EPA 2000). Purified mercury can be traded as a commodity and utilised generally for mercury-containing products.

Other Processes

Application of Thermal Processes

219. It is possible to use other types of incineration to treat mercury waste and collect mercury. General incinerators are available when a condenser to condense mercury in mercury vapour is equipped with other necessary equipment for flue gas treatment. However, it is noted that some countries have prohibited or banned waste incineration, and in these cases local laws or regulations should be followed.

Soil Washing and Acid Extraction

220. Soil washing is an *ex situ* treatment of mercury-contaminated soil and sediment. 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 sulfuric 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 the following publication:

- US EPA (2007): Treatment Technologies for Mercury in Soil, Waste, and Water, <http://www.epa.gov/tio/download/remed/542r07003.pdf>

Further Options

221. The environmentally sound technologies for solid type of mercury waste described in this section are some of the instances which are currently available. Other options would be available. However, it is noted that mercury should not be released into the environment whatever technologies are used for treating mercury waste.

Mercury Recovering Process – Mercury in Wastewater and Other Liquid Mercury Waste

Introduction

222. Mercury exists in wastewater due to accidental or intentional discharging of liquid mercury from thermometers, dental amalgams, or other industrial processes using mercury or mercury compounds. 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 and the causal toxic substance of Minamata disease.

Chemical Oxidation

223. Chemical oxidation of elemental mercury and organomercury compounds is to destroy the organics, to convert mercury to a soluble form and to form mercury halide compounds. It is effective for treating mercury waste. Chemical oxidation processes are useful for aqueous waste containing mercury and waste 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 and treated and sent for subsequent treatment, such as acid leaching and precipitation (US EPA 2007a).

Chemical Precipitation

224. 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 the following publication:

- US EPA (2007d): Treatment Technologies for Mercury in Soil, Waste, and Water, <http://www.epa.gov/tio/download/remed/542r07003.pdf>

Adsorption Treatment

Ion Exchange Resin

225. Ion exchange resins have proven to be useful in removing mercury from aqueous streams, particularly at concentrations on the order of 1 to 10 µg/L. Ion exchange applications usually treat mercuric salts, such as mercuric chlorides, 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. Thus the resin would have to be treated or disposed. 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 must be disposed in a hazardous waste unit (Amuda 2010).

Chelating Resin

226. Chelating resin is an ion-exchange resin that has been developed as a functional polymer, which selectively catches ions from solution 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 catch mercury in wastewater (Chiarle 2000).

Activated Carbon

227. Activated carbon is a carbonic material having many fine openings connected with each other. It can typically be of 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 features of the individual materials. Activated carbon adsorb mercury and other heavy metals as well as organic substances (Bansal 2005).

Stabilization and Solidification

228. Stabilisation processes change the dangerousness of the constituents in the waste and thus transform hazardous waste into non-hazardous waste. 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 2003a).

229. Solidification and stabilization (S/S) is used to treat waste elemental mercury and waste contaminated with mercury such as soil, sludge, ash, and liquid. This technology has been implemented at full scale and pilot scale. S/S reduces the mobility of contaminants in the media by physically binding them within stabilized mass or inducing chemical reactions (US EPA 2007b).

230. S/S is usually used for various mercury 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 mercury waste is landfilled and kept at landfill site for a long time as other metals and organic compounds do. Mercury in the solidified and stabilized waste in the landfill can leach (i.e., dissolve and move from the stabilized mercury waste through liquids in the landfill), migrate into ground water or nearby surface water and vaporise into the atmosphere under natural environmental conditions.

231. S/S is a process that has been used at full scale to treat waste contaminated with mercury. 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).

232. The stabilization 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).

233. Mercury concentration in solidified and stabilized mercury waste should be below acceptance criteria for final disposal. Otherwise, S/S process should be improved to the level that mercury concentration in waste after S/S process is below acceptance criteria for final disposal.

Amalgamation

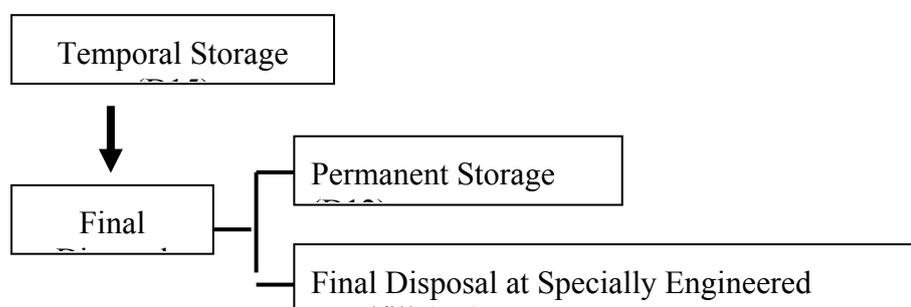
234. Amalgamation is the dissolution and solidification of mercury in other metals such as copper, nickel, zinc and tin, resulting in a solid, non-volatile product. It is a subset of solidification technologies, and it does not involve a chemical reaction. Two generic processes are used for amalgamating 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 liquid 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 hydrolysis. Therefore, amalgamation is typically used in combination with an encapsulation technology (US EPA 2007b).

Disposal of Waste Consisting of Elemental Mercury

General Introduction

235. If treated waste containing or contaminated with mercury does not fall into “hazardous waste” and meets acceptance criteria for non-hazardous waste landfills, it may be disposed of at designated landfills following national and local laws and regulations. In such case, treated mercury waste should not be disposed of with organic waste in the designated landfills. If treated waste containing or contaminated with mercury still falls into hazardous waste and meets acceptance criteria for specially controlled landfills, it may be disposed of specially engineered landfills designated by national and local laws and regulations. If treated or packed waste elemental mercury meets acceptance criteria for specially engineered landfills or permanent storage sites, it may be disposed of at such disposal facilities designated by national and local laws and regulations. Before disposal of mercury waste, it may require temporal storage in order to wait for the establishment of or transportation to disposal facilities. In this section, terms of temporal and permanent storage and final disposal at specially engineered landfill have the following meaning:



- Temporal storage: Mercury waste is temporarily stored in special containers at designated area (D15: Storage pending any of the operation in Section A limited to intermediate storage for D5 and D12 in Annex IV of the Basel Convention);
- Permanent storage: Mercury waste is permanently stored in special containers at designated area (D12: Permanent storage in Annex IV of the Basel Convention); and
- Final disposal at specially engineered landfills: to dispose of mercury waste at a specially engineered landfill (D5: Specially engineered landfill in Annex IV of the Basel Convention).

236. This section deals with temporal storage of waste consisting of elemental mercury and disposal of 1) waste consisting of elemental mercury and 2) treated waste containing mercury and contaminated with mercury that still fall into hazardous waste. Temporal storage of waste containing mercury at end users is described in 0 and temporal storage of mercury waste at facilities in 0.

Temporal Storage of Waste Consisting of Elemental Mercury

Introduction

237. Ideal type of mercury waste for temporal storage is elemental mercury as pure as possible in order to avoid any chemical reaction and degradation of containers.

238. Technical information about temporal storage of waste elemental mercury is available. The following publications provide comprehensive technical information on temporal storage of waste elemental mercury, including standards and procedures for operation of a storage facility and inspections of mercury containers, storage facilities, and facility equipment and materials. Although the guidelines provide basic knowledge and information on temporal storage of waste elemental mercury, it is recommended to refer to the guidance for further detailed information. The guidance is available at:

- US Department of Energy (2009): Interim Guidance on Packaging, Transportation, Receipt, Management, and Long-Term Storage of Elemental Mercury, [http://www.mercurystorageeis.com/Elementalmercurystorage%20Interim%20Guidance%20\(dated%202009-11-13\).pdf](http://www.mercurystorageeis.com/Elementalmercurystorage%20Interim%20Guidance%20(dated%202009-11-13).pdf)
- 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

239. Some reports on the case studies are available under the Mercury Storage Project under the UNEP Global Mercury Partnership:

- UNEP (2009c): Development of Option Analysis and Pre-Feasibility Study for the Long Term Storage of Mercury in Asia and the Pacific, <http://www.chem.unep.ch/mercury/storage/Mercury%20Storage%20Report-15Nov.doc>
- UNEP (2009d): Assessment Report of Excess of Mercury Supply in Latin American and the Caribbean, 2010-2050, http://www.chem.unep.ch/mercury/storage/LAC%20Mercury%20Storage%20Assessment_Final_1July09.doc

Mercury Containers

240. All containers should be designed exclusively for 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 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. On the other hands, protective coating (e.g. epoxy paint and electro plating) should be applied to all exterior carbon steel surfaces in a manner that will not leave the steel exposed. The coating is 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 is injected and corrosive label should be affixed to each container (US Department of Energy 2009).

Mercury Storage Facilities

241. The principle information can be found 0 Temporal Storage of Mercury Waste at Facilities.

242. Mercury containers should be stored upright on pallets off the ground, with overpacking. The aisle in mercury 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. 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 have any drains or

plumbing, although sloped floors could be used 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. Mercury storage facilities should have negative pressure environments to avoid mercury emission to outside the building. The temperature in mercury storage areas should be maintained as low as it is feasible, preferably at a constant temperature of 21 °C. Appropriate sprinkler system should be installed as fire protection requirements (U.S. Department of Energy 2009).

Permanent Storage of Mercury Waste

Introduction

243. If solidified and stabilized mercury waste meets acceptance criteria for permanent storage after S/S process, the waste can be permanently stored in special containers at designated areas, such as an underground storage facility.

244. Technology for underground storage is based on mining engineering which includes technology and methodology to excavate mining areas and construct mining chambers as tessellated grid of pillars. Disused mine would be possible to be applied to permanent storage of solidified and stabilized mercury waste after it is renovated appropriate for permanent storage of the waste.

245. In addition, principle and experience in underground disposal of radioactive waste can be applied to underground storage for solidified and stabilized mercury waste. Excavation of a deep underground repository using standard mining or civil engineering technology is possible but limited to accessible locations (e.g. under land 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 2009).

246. The following publications are the references for further detailed information of permanent storage for mercury waste:

- European Community (2003): Safety Assessment for Acceptance of Waste in Underground Storage, <http://faolex.fao.org/docs/pdf/eur39228.pdf>
- 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
- IAEA (2009): Geological Disposal of Radioactive Waste: Technological Implications for Retrievability http://www-pub.iaea.org/MTCD/publications/PDF/Pub1378_web.pdf
- World Nuclear Association (2009) :Storage and Disposal Options <http://www.world-nuclear.org/info/inf04ap2.html>

Underground Facility

247. The disposal of hazardous waste generally aims at the isolation of hazardous substances from the biosphere and groundwater. Related risks are possible due to the release and transport of hazardous substances from the storage or disposal site. The permeability/impermeability of the geological barrier depends on the site-specific hydraulic conductivity and the possible appearance of fractures of the host rock. Once mercury waste is temporarily or permanently stored, the risk of releases depends on the waste itself (substance/mixture and state of the substance) and the short and long term transmissibility of the artificial and geological barriers that separate the waste from the environment. The number and in particular the effectiveness of these barriers define the protection of the environment against adverse effects from the stored waste. 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 all providing barriers to prevent any mercury leakage from reaching humans and the environment (BiPRO 2010; European Community 2003; IAEA 2009; World Nuclear Association 2009).

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

Specially Engineered Landfill

249. Only if stabilized/solidified mercury waste meets acceptance criteria for specially engineered landfills defined by national or local regulations and specially engineered landfill technology is available, such waste can be disposed of at a specially engineered landfill site.

250. Specially engineered landfill means an environmentally sound system for solid waste disposal and is a placement where solid waste is capped and isolated from one another and the environment. All aspects of landfill operations are 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).

251. In principle, and for a defined time period, a landfill site can be engineered to be environmentally safe subject to appropriate site with proper precautions and efficient management. Preparation, management and control of the landfill must be of the highest standard to minimize the risks to human health and the environment. Such preparation, management and control procedures should apply equally to the process of site selection, design and construction, operation and monitoring, closure and post closure care (SBC 1995b).

252. For example, the landfill sites should be completely shut off from the outside natural world. The entire landfill is 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 0-9) (Ministry of the Environment, Japan 2007a).

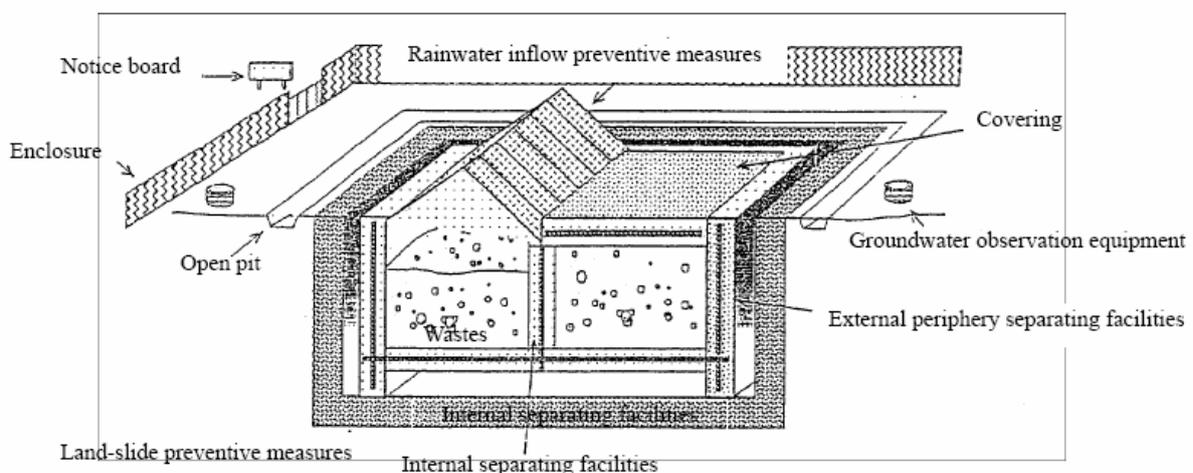


Figure 0-9 Specially engineered landfill (Ministry of the Environment, Japan 2007a)

253. It is noted that there are some regulations to define mercury waste in some countries that mercury waste whose mercury concentration exceeds a standard level should be disposed of at a specially engineered landfill. For example, treated waste containing or contaminated with mercury whose mercury concentration exceeds 0.005 mg/L (by Leaching Test Method: the 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). This means that treated waste containing or contaminated with mercury whose mercury concentration is less than the standard level would be disposed of landfill of leachate-controlled type. EU has also set acceptance criteria including mercury concentration of wastes to be landfilled in the specially engineered landfill (European Commission 2003b). In addition, disposal of certain mercury wastes to landfills is banned in some countries. A national or local regulation should be followed to dispose of mercury waste at landfill, or more strict regulation should be used.

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

Remediation of Contaminated Sites

Introduction

255. Sites contaminated with mercury are widespread around the world and are largely the result of industrial activities, primarily mining, chlorine production, and the manufacture of mercury-containing products. And of those sites, the vast majority of contamination is the result of ASGM using mercury that has largely ceased or has regulatory and engineering controls in developing countries, but that continues in the developing world at large sites and in the form of ASGM. The result of both historic and current operation is 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. This section summarizes:(a) both the established and newer remediation techniques available for cleanup; and (b) the emergency response actions appropriate when a new site is discovered.

Remediation Techniques

256. Remedial actions (cleanups) for mercury-contaminated sites 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, factors that affect selection include:

Environmental Factors:

- The amount of mercury released during operations – is the contamination the result of ASGM (if so, what type), large-scale mining, or manufacture of mercury-containing products?;
- The number, size, and location of mercury hotspots (requiring remediation);
- For mining operations, the properties from which the mercury is mined including, soil characteristics, etc.;
- Methylation potential of the mercury;
- Leaching potential of mercury from the contaminated media (e.g., soils and sediments);
- Background mercury contamination - regional atmospheric mercury deposition not related to localized sources;
- Mercury mobility in aquatic system; and
- Local/State/Federal Cleanup Standards: Water, soils/sediment, air.

Receptor Factors:

- Bioavailability to aquatic biota, invertebrates, edible plants; and

- Mercury levels in receptors – human, animal and plants to indicate uptake and bioaccumulation.

257. Once these factors have been assessed, then a more complete analysis of the appropriate remedial 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.

Emergency Response

258. Discovery of a mercury-contaminated site with immediate threat to human health or the environment occurs through the following observations:

- Visual observation of the site conditions or attendant contaminant sources;
- Visual observation of manufacturing or other operations known to use or emit a particularly dangerous contaminant;
- Observed adverse effects in humans, flora, or fauna presumably caused by proximity to the site;
- Physical (e.g., pH) or analytical results showing contaminant levels; and
- Reports from the community to authorities of suspected releases.

259. No matter how detected, mercury-contaminated sites are similar to other contaminated sites in that mercury can reach receptors in a variety of ways. Mercury is particularly problematic because of its dangerous vapour phase, its low level of observable effects on animals, and different toxicity depending of form (i.e., elemental mercury vs. methylmercury). Fortunately, mercury is also readily detectable using a combination of field instruments and laboratory analysis.

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

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

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

Health and Safety – Employee Training

263. Employees of treatment and disposal facilities are important actors in the ESM of mercury waste. They have two important responsibilities: 1) an actual actor on ESM of mercury waste; and 2) a final actor to deal with mercury waste before final disposal (or recycling). Therefore, employee training is mandatory to not only effectively implement mercury waste processing on ESM but also ensure employee's safety against mercury exposure and accidental injury during mercury waste processing.

264. As basic knowledge of mercury waste, employees should know:

- The definition of mercury waste and chemical aspects of mercury with its adverse effects;
- How to segregate mercury waste from other wastes;
- Occupational safety and health against-mercury;
- Use of personal protective equipments, such as body covering, eyes and face protection, gloves and respiratory protection;

- Proper labelling and storage requirements, container compatibility and dating requirements, closed-container requirements;
- How to technically deal with mercury waste by using equipments at facilities, particularly used liquid mercury-containing products, such as thermometers, barometers, etc;
- Uses of engineering controls in minimizing exposure; and
- How to take emergency response if mercury in mercury waste or used mercury-containing products is accidentally spilled.

265. It is important to take into consideration worker insurance and employer liability in cases of accidents or injuries sustained by workers in the facility.

266. In addition to the present technical guidelines, Awareness Raising Package (UNEP 2008e) which is easy reading is recommended as the materials for employee training and is available at:

- <http://www.unep.org/hazardoussubstances/Mercury/MercuryPublications/ReportsPublications/AwarenessRaisingPackage/tabid/4022/language/en-US/Default.aspx>

267. It is recommended to translate all training materials in local languages.

Emergency Response to Elemental Mercury Spill

268. Spillage of mercury accidentally occurs when mercury-containing products are broken. Most of these cases seem to be mercury-containing glass thermometers which are globally scattered but easily broken. Although 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 complains after mercury spill, immediately contact medical doctor and/or environmental health authorities.

269. In order to prevent mercury spill, mercury-containing products should be carefully and safely handled, used and disposed of until mercury waste is dealt with on ESM. If the spill is small and on a non-porous area such as linoleum or hardwood flooring, or on a porous item that you can throw away (like a small rug or mat), it can be possible to clean it 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 local environmental health authorities. If it is not sure whether a spill would be classified as “large”, contact local environmental health authorities 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 2002a).

270. Spills of elemental mercury in the course of commercial activities and in the home have the potential to expose workers and the general public to hazardous mercury vapours. In addition, the spills are costly to clean up and disruptive. Table 0-4 summarizes USEPA’s cleanup procedures for small mercury spills.

271. Critical to determining what type of response is appropriate for any mercury spill is evaluating its size and dispersal and whether the needed cleanup resources and expertise are available. If in doubt about the any part, solicit skilled and/or professional help if:

- The amount of mercury could be more than 2 tablespoons (30 milliliters): In the USA and many other countries, larger spills must be reported to authorities for oversight and follow-up;
- 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 elude cleanup efforts;
- 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 cleanup impossible short of complete removal and disposal of the surface; and

- The spill occurs near a drain, fan, ventilation system or other conduit: Mercury and mercury vapors can quickly move away from the spill site and contaminate other areas without easy detection.

Table 0-4 Mercury spill cleanup for household or minor spills (US EPA 2007c)

Mercury Spill Size	Comments
Up to the amount in a thermometer	<ul style="list-style-type: none"> ▪ Make everyone leave the area ensuring not to walk through the mercury; ▪ Remove pets from the area; ▪ Open all windows and doors to the outside; shut all doors to other parts of the building/house; ▪ DO NOT allow children to help you clean up the spill; ▪ DO NOT sweep or vacuum the spill; ▪ Mercury can be cleaned up easily from the following surfaces: wood, linoleum, tile and any similarly non-porous surfaces; and ▪ Carpet, curtains, upholstery or other absorbent surfaces, contaminated items should be thrown away in accordance with the disposal rules.
More than a thermometer, but < 2 tablespoons (30 ml)	<p>Follow the precautions for smaller spills, and:</p> <ul style="list-style-type: none"> ▪ Turn down the temperature; ▪ Shut all doors to other parts of the house, and leave the area; and ▪ Call your local fire department or emergency response agency. If they are unable to assist you, contact your local or state health or environmental agency.
>2 tablespoons (30 ml)	Notify emergency response agency and fire department with the approximate size of the spill.

Public Awareness and Participation

Introduction

272. Waste management services in most developing countries do not satisfy the full demand in urban areas. In the poorest countries, the service sometimes reaches only 10% to 40% of the urban population. In the better-organized middle-income countries, the services reach from 50% to 85% of the urban population. Most of the waste collected including hazardous waste and mercury waste is discharged to open dumping sites, which are often characterized by open burning and waste picking for recyclables. Mercury in wastes placed in open dumping sites would leak out, enter the environment, particularly the aquatic environment, be bioaccumulated and biomagnified and be finally taken by human through consuming fish and seafood (Honda 2005).

273. Public awareness and participation play key roles in implementing a successful effort in the ESM of mercury wastes. The reason is that mercury waste generation is closely related to life-style of citizens who are responsible for discharging such waste. When we start new activities such as collection and recycling of waste containing mercury, it is indispensable to ensure cooperation from consumers who generate waste containing mercury. Our experiences show that it is difficult to increase collection rate of waste containing mercury even in an established system. As times goes by, residents change due to social and natural population increase/decrease; therefore, continuous awareness-raising is a key to a success of collection and recycling of waste products containing mercury. Encouraging public involvement in designing a collection and recycling system of waste products containing mercury, which provides the participating residents with information about possible problems caused by environmentally

unsound management of waste products containing mercury, would be effective to increase awareness of consumers.

274. To ensure minimization of mercury releases from transportation, recycling, interim treatment, final disposal of mercury waste, it is important to raise awareness of relevant parties (e.g. transporters, recyclers, and treaters) so that they comply with standards and conduct BEP. Awareness raising activities targeting them include holding seminars to provide information about new systems and regulation and opportunities for information exchange, preparing and distributing leaflets, disseminating information through Internet.

275. For promoting public participation into ESM of mercury waste as well as raising public-awareness, awareness-raising and sensitization campaigns for local communities and citizens are very important elements. In order to raise the awareness of the citizens on the issues of mercury waste, authorities concerned, e.g. local governments, need to initiate various awareness-raising and sensitization campaigns to assist the citizens to have an interest in the issues of mercury waste to protect the adverse effects to human health and the environment. In addition, it is important to involve community based societies to the campaigns because they have closer relationship to residents and other stakeholders in the communities (Honda 2005).

276. Table 0-5 shows an example of programmes for public awareness and participation. There are four elements: publication, environmental education programme, PR activities and risk communication that citizens can easily access activities at public places. The programmes for public participation are generally developed based on a situation of waste management at national/local/community level (Honda 2005).

Table 0-5 Programmes for public participation (Honda 2005)

	Contents	Expected results
Publications	<ul style="list-style-type: none"> • Booklet, pamphlets, brochures, magazines, posters, web sites, etc., in various languages and dialects to easily explain mercury issues • Guidebooks how to dispose of mercury waste 	<ul style="list-style-type: none"> • Knowledge sources • Explanation how people can dispose of waste
Environmental Education Programmes	<ul style="list-style-type: none"> • Voluntary seminars • Community gatherings • Linkages with other health workshops • Demonstration of recycling programme • Scientific studies • Environmental tours to facilities, etc. • eLearning 	<ul style="list-style-type: none"> • Raising knowledge • Sharing common issues • Opportunities to directly expose environmental issues
Activities	<ul style="list-style-type: none"> • Take-back programmes • Mercury-free product campaigns • Waste minimization campaigns • Community gatherings • House-to-house visit 	<ul style="list-style-type: none"> • Implementation of environmental activities among all partners • Environmental appeal for citizens • Closer communications

	Contents	Expected results
Risk Communication	<ul style="list-style-type: none"> • Mercury exposure in general living environment • Safe level of mercury exposure • Mercury pollution levels • Fish consumption advisories (only for populations that consume large amounts of fish) 	<ul style="list-style-type: none"> • Proper understanding of safe and risk levels of mercury exposure, in appropriate circumstances • Avoidances of overreactions

Programmes

277. Publications for environmental activities are the basic element but plays as the most important tool to disseminate information about environmental issues, particularly for environmental education programmes. Publications provide basic knowledge of mercury properties, mercury toxicology, the adverse effects to human health and the environment, issues on mercury waste and mercury exposure way from mercury waste as well as how to deal with and dispose of mercury waste. It is crucial that publications are translated into the various languages and dialects to ensure information is efficiently communicated to the target population.

278. Environmental education programme is to develop a public that is aware of and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones (UNESCO 1977). Environmental education programmes can enhance critical thinking, problem solving, effective decision-making skills how to segregate mercury waste and enable individuals to think about environmental issues with regard to mercury waste. The components of environmental educations on mercury waste are as follows (Honda 2005):

- Awareness and sensitivity to the environment and environmental challenges;
- Knowledge and understanding of the environment and environmental challenges;
- Attitudes of concern for the environment and a motivation to improve or maintain environmental quality;
- Skills to identify and help resolve environmental challenges; and
- Participation in activities that lead to the resolution of environmental challenges.

279. Environmental education increases public awareness and knowledge about environmental issues or problems. In doing so, it provides the public with the necessary skills to make informed decisions and take responsible action. Environmental education does not advocate a particular viewpoint or course of action. Rather, environmental education teaches individuals how to weigh various sides of an issue through critical thinking and it enhances their own problem-solving and decision-making skills (Honda 2005).

280. Activities of public participations into mercury waste management should be implemented after environmental education programmes (after disseminating information about mercury waste). It is recommended that a demonstration programme of mercury waste be first implemented in a limited area before implementing large scale of activities. The activities of public participations into mercury waste management are a take-bake-programme and mercury-free product campaigns.

281. Risk communication is a tool for creating that understanding, closing the gap between lay people and experts, and helping people make more informed and healthier choices. However,

there are instances where this could be properly applied, as in the case of developed countries, while it may be inappropriate or inapplicable in cases of developing countries. The value of communicating dangers posed by mercury is to avoid misunderstanding about environmental issues, it is important to provide information about safe and risk levels of mercury exposure in general living environment as well as accidental mercury exposure, particularly to populations at-risk.

Identification of Players on Programmes of Public Participation

282. The partners for programmes on public participation are summarized as follows (Honda 2005):

- 1) Officials and staff in governments who work for environmental issues;
- 2) People who are interested in environmental problems and have high potential to understand quickly and disseminate to others:
 - Children and students at schools, undergraduate students at universities;
 - Teachers of primary and middle schools, sometimes the University professors;
 - Women at local communities and groups; and
 - Retired persons with a suitable education.
- 3) People who work at environmental fields of local and community level:
 - Non-governmental organizations (NGOs);
 - Small and medium enterprises; and
 - Local producers, collectors and recyclers, the disposal facility owners of mercury waste.
- 4) People who used to live at polluted sites:
 - Local organizations;
 - City residents; and
 - Enterprises.

Type II Initiative

283. In order to effectively implement programmes on public participation into ESM of mercury waste, it is important to collaborate among all stakeholders, such as governmental sectors, private sectors (producers of mercury-containing products), local communities, and consumers, namely a public-private partnership programme. Type II Initiative is the concept of “Local Capacity-Building and Training for Sustainable Urbanization: Public-Private Partnership”, namely the collaboration among all sectors to tackle common environmental issues. The type II Initiative is one of the most important concepts for ESM of mercury waste. Type II Initiative is one of the most attractive tools being used to help address the urban environmental crisis and is an effective tool to implement ESM of mercury waste. In addition, Type II Initiative helps governments and private sectors craft the approach that best fits their local needs for ESM of mercury waste. (Honda 2005; UNITAR 2006).

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