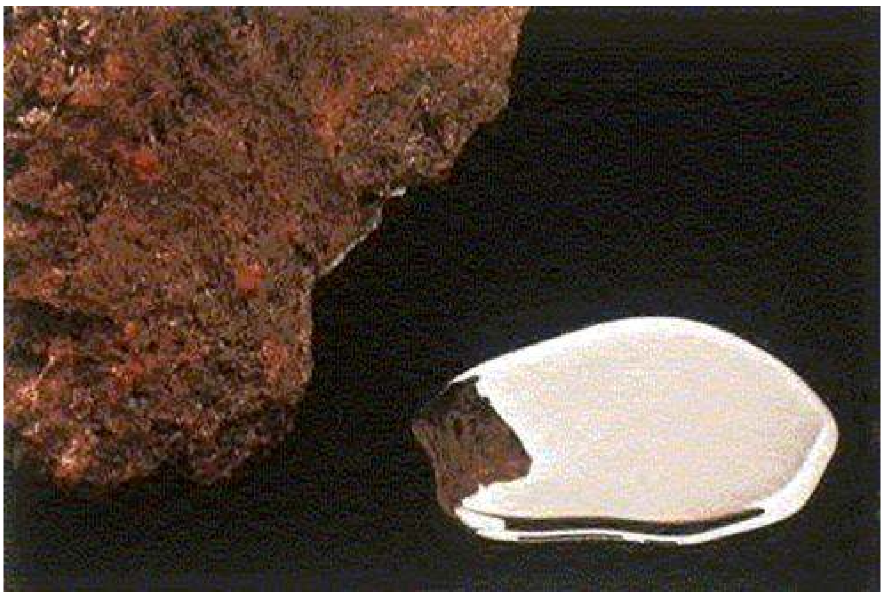
Options Analysis and Feasibility Study for the Long Term Storage of Mercury in Latin America and the Caribbean

FINAL DRAFT REPORT



LABORATORIO TECNOLÓGICO DEL URUGUAY – LATU

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EXECUTIVE SUMMARY

Mercury is a highly toxic metal. Being an element, mercury cannot be broken down or degraded into harmless substances. Mercury may change between different states and species in its cycle. Once mercury has been released from its sources, it can be highly mobile, cycling between the earth's surface and the atmosphere. Due to its high toxicity, mercury has been a concern for the international community for several years.

In 2001 the UNEP Governing Council (GC) decided to initiate a process to undertake a global assessment of mercury and its compounds. In the 22^{nd} session of the UNEP Governing Council in 2003, the representatives decided that national, regional and global actions were to be undertaken.

In 2005, the GC Decision 23/9 urged Governments, intergovernmental and non-governmental organizations and the private sector to develop and implement seven partnerships, including one dealing with "Mercury Supply and Storage".

UNEP Governing Council decision 24/3 concludes that further long term international action is required to reduce risk to human health and the environment. It also identified seven priority areas for action to reduce the risk from release of mercury including the two below:

- To reduce the global mercury supply, especially curbing primary mining and taking into account a hierarchy of source control; and
- To find environmentally sound storage solutions for mercury.

International strategies will corroborate the reduction of mercury consumption in LAC. The most important imply the ban of exports from the EU and USA.

On October 14, 2008 the American Congress signed on the Mercury Export Ban Act of 2008 (MEBA) that prohibits the exports of elemental mercury from the United States, beginning in 2013. The prohibition on exports of elemental mercury is intended to reduce the availability of elemental mercury in the global market.

On October 22, 2008 the Council and European Parliament adopted the Regulation on the banning of exports and the safe storage of metallic mercury - Regulation (EC) No 1102/2008. The exports ban starts on 15 March 2011 and affects metallic mercury, cinnabar ore, mercury (I) chloride, mercury (II) chloride and mixtures of metallic mercury with other substances.

With the support of the government of Norway, UNEP DTIE Chemicals Branch is implementing a "Mercury Storage Project".

This report, entitled "Options analysis and feasibility study for the long-term storage of mercury in Latin America and the Caribbean" gives a retrospective on the current state of affairs of the mercury issue and articulates recommendations for the countries in the LAC region with respect to a long term safe management and storage of mercury.

Three storage options were taken into account in this report:

a. Above-ground specially engineered warehouses

b. Below-ground storage in geological formation (e.g., mines, special rock formations)

c. Export to a foreign country/facility

The Latin-American Executive Committee requested the development of a short overview regarding the management and the final disposal of mercury waste and mercury-added products in their end of life.

METHODOLOGY

The methodology used by the consultants to develop this report included a technical review on legislation, technologies, state of the art of treatment and storage, and mercury surplus estimated to be produced in the Latin-American and Caribbean region.

A study was carried out to track the trans-boundary movement of mercury for the 2007 – 2009 period, using databases of COMTRADE (UNSD) and private consultants, such as TRANSACTION, SIAVI, and SIECA. The information used is official and comes from the customs agencies of the respective countries.

Several publications were consulted in order to identify the state of the art of the management and storage of elemental mercury globally. In addition, data concerning geology, legislation, research and scientific work were obtained from other sources in the LAC region.

RESULTS

Regarding mercury use, phase-out, trade and storage regulation, the degree of progress in LAC is diverse. Having developed their environmental legislation earlier, Brazil and México have advanced towards more specific matters. In other countries, however, legislation is still rather scarce. In some countries as Brazil, Mexico and Argentina the environmental legislation may include mechanisms to phase-out mercury in their states or provinces. Brazil has some control on elemental mercury trade and few countries have instruments to rule on the mercury contents in products. Some mechanisms promote substitution for mercury-free products.

Mercury exports were very high during 2007-2009, mainly due to the increased activity of mining companies and to the discontinuation of the use of the metal in the processes of a chlor-alkali plant.

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The consultants confirm Peter Maxson's estimation for both mercury supply and demand, as a preliminary scenario. In this context, an estimated excess of 8.300 tons of mercury to be permanently stored will be generated in the 2010-2050 period.

The information gathered indicates that the main importers of the Andean block (Colombia, Ecuador and Peru) are traders that distribute the product to miners. The main importers in Argentina are the manufacturers of chlorine – soda. In Brazil, in addition to chlorine – soda plants, other important distributors and users of mercury have been confirmed.

Countries with a recognized artisanal gold mining activity (Suriname, Bolivia) do not report significant amounts of mercury in their import statistics, suggesting that illegal flow of the metal through their borders takes place.

Official information regarding foreign trade is not homogeneous in the registry and/or communication, which makes it difficult to study intra- and extra regional exchanges. The current data on importers and exporters is reliable and easily available only in the following countries: Argentina, Chile, Colombia, Ecuador, Paraguay, Peru and Uruguay.

With the exception of Mexico and Chile, the LAC region tends to import mercury rather than to export it, and it is primarily imported to meet the needs of the chlor—alkali plants and informal mining.

Mercury storage

USA is the country with the longest and most consolidated experience storing mercury. Bulk elemental mercury is basically stored in over packed steel flasks kept in facilities which are compliant with the Resource Conservation and Recovery Act (RCRA) permitting requirements.

The European Community is currently investigating both facilities above ground and underground, in hard rock and salt dome geological formations. Underground options are preferred because mercury is sequestered from the biosphere. Germany and the UK have experience in the storage of underground waste in salt domes, while Norway recurs to hard rock formations for the disposal of solid waste. There is no experience in the storage of mercury in underground facilities. MAYASA in Spain has the greatest experience with above-ground storage in Europe.

Although underground storage is considered a permanent option, it requires a pre-treatment, since liquid elemental mercury needs to be stabilized and solidified before it is disposed of. Studies carried out in the USA prove that the technologies available are not mature and safe enough for big amounts of mercury.

At present, above-ground engineered warehouses are the most consolidated and technically the most feasible option for the longterm storage of mercury. Nevertheless, mercury stays in the biosphere. Political and institutional stability are key conditions to keep and ensure mercury sequestration in these facilities.

Underground facilities will probably not be available in most countries in the LAC region in the short term. Some countries might not meet the conditions required to host an underground facility, either because of geographic, legal and/or cultural conditions. Economic factors can influence the decision, as underground storage requires very significant investment. In Europe theses facilities share costs and space with the incorporation of other waste streams, to reduce operational costs. The insufficient development of the pre-treatments required to stabilize and solidify mercury is an additional constraint, since the current processes cannot guarantee the environmentally safe storage of mercury.

Exports can be a good short term solution, especially for countries with a very small mercury surplus, where a special construction is not an economical solution. Export also is the best solution for countries where risks due natural phenomena are important aspects to be considered. Anyway, the export solution to a safe mercury storage is a definitive solution for any country.

Landfills and monofills are not an acceptable option for elemental mercury, as it is a liquid and difficult to stabilize.

The improvement of waste management, together with initiatives aimed at phasing-out the use of mercury will accelerate the increase of a mercury surplus and the urgent need to implement storage facilities to sequester the mercury mostly used in mining, or to develop an export strategy.

Under the current scenario, the measures below would be recommended for the permanent sequestration of mercury:

TRADE:

- To harmonize the region's trade restrictions of elemental mercury, and mercury-containing products and salts, for instance, by prohibiting imports of goods for which there are mercury-free options available in the region;
- To encourage the adoption of the WCO Harmonized System (HS) in the LAC countries, and the specific position reserved exclusively for mercury compounds, in accordance with requirements set forth in the Rotterdam Convention;
- To open HS position 2852.00 to allow discrimination of the various chemical forms of mercury available (oxides, salts: chlorides, sulfates, nitrates and organic- mercurial compounds etc.);
- To promote the easy access to information about the identification of importers and exporters for foreign trade operations involving mercury;
- To promote accessible information regarding suppliers, brand and final application of mercury and its compounds, as well as their prices, to evaluate how this affects the market of the product in the region.
- To improve traceability by environmental authorities, as they request mercury distributors to furnish detailed reports on sales that include customers, quantities traded and carriers.
- To improve a custody chain of mercury that ensures tracking of the whole production chain from mining until its final sequestration;

LEGISLATION AND TECHNICAL STANDARDS

- To develop and harmonize the regional legislation for mercury limits in emissions and air monitoring, mainly in non ferrous metals mining and coal burning.
- To negotiate a gradual elimination of mercury in products and processes and to adopt BAT's; while cleaner production programs are implemented to minimize releases of mercury to the environment;
- To improve educational programs for national and local authorities, as well as stakeholders.

Countries must develop an specific legislation in order to create in the national legal framework mercury longterm storage as the more appropriate final disposal for elemental mercury

To develop technical standards for mercury handling, treatment, packaging and transport for storage purposes;

- To improve the technical standards for the management of mercury waste and mercury-added products in their end of life: treatment, packing, domestic storage, transport, quality for disposal, final disposal.
- To improve institutional capacity and networks to implement appropriate management of mercury until its sequestration.
- To implement an integrated program involving national and regional authorities, NGOs, private sector, health care professionals, universities and research centers seeking to improve the technical standards in mercury management and monitoring, and to raise awareness regarding mercury-free processes and products;

STORAGE

- National governments must urgently develop mercury national inventory, in order to determine realistic estimates about the need and sizes of storage facilities;
- As an emergency action, temporary storage needs to be planned in regions where mercury are already accumulated; aboveground warehouses are the faster solution for temporary storage;
- Exports can be an alternative to reduce the national mercury surplus, although before 21013, this solution does not guarantee that exported mercury is not available in the international market; in this respect, governments and the private sector should start negotiations with storage facilities in other countries as an alternative to sequester mercury;
- National governments should initiate and promote pre-feasibility studies about geologic national resources that can host underground facilities and possible dry and accessible useful areas to implement above-ground facilities;
- To develop a mercury website hosted by governments linked to the mercury pages of UNEP, and to mercury pages of other countries and institutions. These sites must provide all the necessary information on sequestration of mercury to citizens, professionals and authorities.
- To work jointly with cooperation agencies (World Bank, IDB, etc.) promoting the development of financial mechanisms aimed at raising awareness, fostering research, partnerships and capacity building, and to start designing a pilot project for the storage of mercury in LAC.

TABLE OF CONTENTS

TABLE OF CONTENTS *0*

Acronyms and abbreviations *2*

Glossary of terms *5*

PREFACE *7*

1 INTRODUCTION *9*

1.1 Legal framework in the countries and Regional Trade Agreements **13**

1.1.1 European Community Strategy and relevant legislation 13

1.1.2 USA - Mercury Export Ban Act of 2008 15

1.1.3 Legal Framework in the LAC Countries 16

1.1.4 Regional and international voluntary initiatives 18

1.1.5 Analysis of the legal framework in Latin America 19

1.2 Uses of Mercury in Latin America and the Caribbean (LAC) **20**

Future mercury consumption and/or production in Latin America and the Caribbean 24

1.3 Ongoing initiatives of the countries to prevent or minimize the use of mercury **25**

Artisanal Gold Mining 26

Mercury-added products 27

Chlor-Alkali sector 29

Non-Ferrous metals production 29

2 MERCURY TRADE FLOWS (EXPORTS AND IMPORTS) *29*

2.1 TARIFF CODING **30**

Mercury and its compounds in HS2007 32

2.1.2 Mercury containing products 33

2.1.3 Barriers for information collecting 33

2.2 Results from official export and import records **34**

2.3 Information about movements of elemental mercury **37**

2.3.1 PERU 37

2.3.2 COLOMBIA 37

2.3.3 CHILE 38

2.3.4 ARGENTINA 38

2.3.5 BRAZIL 38

2.3.6 ECUADOR 38

2.3.7 MEXICO 39

2.3.8 GUYANA 39

2.3.9 OTHER COUNTRIES 39

2.4 Analysis of information **40**

2.5 PRODUCTS WITH MERCURY **43**

2.5.1 Mercury Compounds 43

2.6 CONCLUSIONS 44

3 FACILITIES FOR THE SEQUESTRATION OF MERCURY 45

3.1 Elemental mercury management 46

3.1.1 Packaging 47

3.1.2 Transport 52

3.1.3 Acceptance, inspection and overpacking 53

3.2 Stabilization and immobilization, solidification and other appropriate technologies for metallic mercury 54

3.2.1 Sulphur stabilization 56

3.2.2 Sulphur Polymer Stabilization/Solidification SPSS 57

3.2.3 Amalgamation 57

3.2.4 Chemical bonded phosphate ceramic CBPC 58

3.2.5 Encapsulation techniques without pre-stabilization 58

3.2.6 Encapsulation with pre-stabilization 59

3.2.7 Other non-commercial investigations on Hg stabilization and solidification (S/S) processes 59

3.2.8 Conclusion about the state of art of Hg stabilization and solidification 60

3.3 Options for Mercury Storage and Disposal 63

3.3.1 Above-ground specially engineered warehouses 63

3.3.1.1 Concept and requirements 63

3.3.1.2 State of Art in Above-ground facilities 64

A. The Defense National Stockpile Center (DNSC) - USA 64

B. USA Department of Energy – DOE 69

C. Minas de Almadén - Mayasa - SPAIN - EU 73

3.3.2 Below-ground storage in geological formation 75

3.3.2.1 The concept of underground storage and requirements 75

3.3.2.2 Potential host rocks 77

3.3.2.4 Potential host rock formations for underground storage in LAC 86

3.4 Other options & relevant experiences 89

3.4.1 Export option for mercury waste storage 90

3.4.2 Temporary storage 92

3.5 Analysis of existing facilities 92

4 Technological options for mercury-containing wastes and end-of-life product management 105

4.1 Legal framework in LAC related with mercury-containing wastes 106

4.2 Transboundary Movement Restrictions 108

4.3 Mercury-containing wastes and end-of-life products management 109

4.3.1 Handling 109

4.3.2 Interim Storage at End Users....110
4.3.3 Segregation and Collection 110
4.3.4 Take-Back Program....112
4.3.5 Transportation....112
4.3.6 Waste management and storage 113
4.3.6.1 Emergency Plan 114
4.4 Treatment of Mercury Waste and Recovery of Mercury....114
4.4.1 Pretreatment....114
4.4.2 Roasting Process....115
4.4.3 Recovery of Mercury – Purification 116
4.4.4 Other Process 116
4.4.5 Treatment to prepare mercury wastes for final disposal 118
4.5 Experiences of mercury wastes final disposal in developed countries....118
4.6 Experiences in LAC with mercury wastes and mercury-containing products in their end-of-life 120
4.6.1 LAMPS, THERMOMETERS AND OTHERS....121
4.6.2 Other Products....124
4.6.3 Wastes destination 124
5 REGIONAL NETWORK FOR MERCURY MANAGEMENT....126
6 CONCLUSIONS AND RECOMMENDATIONS 127
6.1 CONCLUSIONS 127
6.2 RECOMMENDATIONS 128
6.2.1 LEGISLATION....128
6.2.2 TRANSBOUNDARY MOVEMENTS....129
6.2.3 MERCURY FINAL DISPOSAL 130
7 REFERENCES....132
ANNEXS 138
LIST OF TABLES....139
LIST OF FIGURES 140
LIST OF GRAPHS 140

Acronyms and abbreviations

ALADI: Asociación Latinoamericana de Integración (Latin American Integration Association).

ASGM: Artisanal and small-scale gold mining

ATSDR: Agency for Toxic Substances and Diseases Registry - USA

BAT: Best Available Technology

BEP: Best Environmental Practice

BRS: Biennial Reporting System

CAN: Comunidad Andina de Naciones (Andean Nations Community).

CARICOM: Comunidad del Caribe (Caribbean Community).

COMTRADE: United Nations Commodity Trade Statistics Database (http://comtrade.un.org/).

CONAMA: Comisión Nacional de Medio Ambiente de Chile (National Environmental Commission of Chile).

DINAMA: Dirección Nacional de Medio Ambiente de Uruguay (National Environment Directorate of Uruguay)

DOD: U.S. Department of Defense

DOE: U.S. Department of Energy

DTIE: Division of Technology, Industry and Economics

EU: European Union

GC: Governing Council

HCDCS/HS: Sistema Armonizado de descripción y codificación de mercancías. (Harmonized Commodity Description and Coding System)

IPCS: International Programme in Chemical Safety

LAC: Latin America & Caribbean.

LATU: Laboratorio Tecnológico del Uruguay

MCCA: Mercado Común Centro Americano (Central American Common Market)

MERCOSUR: Mercado Común del Sur (Common Market of the South).

MVOTMA: Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente de Uruguay (Uruguayan Ministry of Housing, Land Management and the Environment)

NGO - Non Governmental Organization

PRTR: Pollutant Release and Transfer Register

RCRA: Resource Conservation and Recovery Act.

TRI: Toxics Release Inventory

UNEP: United Nations Environmental Program

UNIDO: United Nations Industrial Development Organization

UNITAR: United Nations Institute for Training ans Research

UNSD: United Nations Statistics Division.

USA: United States of America

USAID: United States Agency for International Development

US EPA: United States Environmental Protection Agency

WCO: World Custom Organization

WHO: World Health Organization

Glossary of terms

For the purpose of this report, we will consider the following definitions:

Approved site or facility - a site or facility designed for the long-term or temporary storage of metallic mercury, as well as mercury-containing wastes, and authorized or permitted to operate for this purpose by a competent national or regional authority where the site or facility is located.

Area under the national jurisdiction of a State - any land, marine area or airspace within which a State exercises administrative and regulatory responsibility in accordance with international law in regard to the protection of human health or the environment;

Carrier - any person that transports elemental mercury or mercury-containing wastes;

Competent authority - the governmental authority or authorities designated by a Party to control the domestic and/or transborder movement of elemental mercury, as well to authorize the implementation of a mercury storage facility;

Custody chain - certification that ensures the tracking of the whole production chain, of mercury as an element, compound or amalgam, independently of its use. The mercury custody chain is a way to warrant that all the activities which produce, transport, use, stabilize or store the metal until it is sequestrated from the biosphere, as well all the necessary subsequent actions are done in accordance with an environmentally sound management and the legal and standards framework.

Disposal - any operation intended to confine mercury-containing waste definitively, without retrievability, typically in special landfills or underground facilities.

Disposer- any person to whom mercury-containing wastes are shipped and who carries out the disposal of such wastes.

Ecotoxic - 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. (7) ANNEX 2

Elemental Mercury or Metallic Mercury (Hg^0) – is the pure form of the element mercury, i.e., mercury not combined with other elements. Mercury is a shiny silver-white metal, which is liquid at room temperature. (9)

Environmentally sound management of elemental mercury – taking all practicable steps to ensure that elemental mercury is managed so as to prevent the releases of liquid mercury, vapor or any contaminated material to the environment;

Exporter - any person under the jurisdiction of the State of export who arranges for elemental mercury or mercury compounds to be exported;

Generator- any person whose activity produces mercury-containing wastes, if that person is not known, the person who is in possession and/or control of those wastes;

Hazardous wastes - are the wastes described in the Article I of the Basel Convention;

Importer - any person under the jurisdiction of the State of import who arranges for elemental mercury or mercury compounds to be imported;

Long term Storage Facility – facility above ground or underground, especially constructed and operated to safely sequester elemental/commodity mercury to avoid its re-introduction into commerce or into the biosphere

Mercury management - the collection, handling, transport, treatment and storage of elemental mercury or mercury-containing wastes, including after-care of disposal or long-term storage sites;

Mercury as a by-product – elemental mercury or mercury compound secondarily or incidentally produced in the mining of non ferrous metals, in a manufacturing process, a chemical reaction or a biochemical pathway.

Mercury-Containing Waste - waste containing mercury in concentrations in which they are considered as hazardous wastes;

Mercury Sequestration - permanent removal of mercury currently circulating in the economy through its disposal in a environmental safe and internationally controlled long term storage facilities (based on Asia Report).

Person - any natural or legal person; (7)

Political and/or economic integration organization - an organization constituted by sovereign States to which its member States have transferred competence in respect of matters governed by this Convention and which has been duly authorized, in conformity with its internal procedures, to sign, ratify, accept, approve, formally confirm or accede to it;

Standards - describe and establish measurable controls and requirements to achieve policy objectives or it indicates a degree or level of excellence or attainment required in certain areas.

Temporary storage – Short-term storage as needed to facilitate the handling and transportation of elemental or commodity mercury to the facility or facilities where mercury is ultimately sequestered

Toxic (Delayed or chronic) - Substances which, if inhaled or ingested, or if they penetrate the skin, may involve delayed or chronic effects, including carcinogenicity. (7) - ANNEX 2

Transboundary movement - any movement of elemental mercury from an area under the national jurisdiction of one State to or through an area under the national jurisdiction of another State or to or through an area not under the national jurisdiction of any State, provided at least two States are involved in the movement; (7)

PREFACE

In 2009, the Basel Convention Coordinating Center for Capacity Building and Transfer of Technology, hosted by Uruguay at its office at Laboratorio Tecnológico del Uruguay (LATU), signed an agreement with the DTIE Chemicals Branch of UNEP, commissioning the development of an "Options Analysis and Feasibility Study for the Long Term Storage of Mercury in Latin America and the Caribbean".

The study was to be based on the excess amounts of mercury estimated by the consultant Peter Maxson in his report "Excess Mercury Supply in Latin America and the Caribbean, 2010-2050"; such estimations could be updated with new official input disclosed after the publication of the consultant's report.

The study contemplates above-ground options, underground options in geological formations such as mines or rock formations, or exports of the mercury surplus, remarking that mercury-containing products are also sources of this pollutant; therefore, technologies for the extraction or conversion of mercury compounds into elemental mercury should also be contemplated.

The study should envisage the potential of central, regional or national facilities, requirements related to geology, hydrology, natural disasters, accessibility to facilities, long-term evaluations, physico-chemical criteria of waste for pre-treatment, infrastructure needed, prevention of leachates, evaporation, erosion, corrosion, monitoring systems, documentation, transportation, together with aspects concerning health, security, safety and legislation, and the economical, social and political analyses.

The main sources of consultation should come from the bibliography provided by UNEP and official national or regional sources.

The methodology used by the consultants to develop this report included a review of the environmental and trade legislation related to mercury and its final disposal, as well as the use of geological sites for the storage of waste. The survey included the surpluses and trade of mercury in the region, the state of the art of treatment and storage of mercury in the developed countries, as well as alternatives for the separation and storage of mercury-containing products and waste.

The authors compiled and analyzed the information available on the relevant national and the international legislation and national initiatives in the bibliography and in the national government, international institutions, and Non-Governmental Organizations websites. Consulting national or regional authorities also helped to identify specific rules for the ultimate disposal of mercury wastes and to understand some legal mechanisms in the management of mercury in the countries.

With respect the trade flow of elemental mercury and its compounds, LATU and the consulting team carried out a study for the 2007 – 2009 period. The databases of COMTRADE (UNSD) and of private consultants that provide information services to foreign trade (TRANSACTION, SIAVI, and SIECA) were used for this purpose.

The study was conducted based on the following criteria:

- Imports and exports for each of the countries in Latin America and the Caribbean were analyzed to determine both the intra-regional as well as the extra-regional flows.
- The information used is official and comes from the customs of the respective countries.
- The total in kilograms of the imports and exports of each country in the region was consulted, as well as the total exports by origin and destination in the globe, to verify the consistency of the declarations of each country based on COMTRADE statistics.
- Private statistics were also consulted, such as those of TRANSACTION, covering the total of import and export shipments for the South American countries (with the exception of the Guyana), identifying the companies involved in most of them.

Likewise, the consultants interviewed vendors of mercury for dentist use and representatives of the chlor-alkali industry, and searched relevant data on the websites of mercury traders and users.

Several publications were consulted to identify the current state of the art in the handling, pre-treatment and long-term storage of mercury. The main source of information was UNEP´s webpage, which posts the studies, the storage options already implemented and the main advances made in European countries and the United States of America, needed for complying with the legislation that bans mercury exports as of 2011 and 2013, respectively. Additional sources were also consulted, such as webpages from USEPA, EU, DOD, DOE, USA state governments, non governmental agencies, research laboratories and institutions, consulting firms and operators of waste storage sites, especially sites devoted to the storage of mercury waste.

For the identification of rock formations, the authors consulted experts from the academia and international organizations, and studied the geological charts provided by mineral research institutions in Brazil and the USA, and by other agencies devoted to the mapping of natural disasters.

Concerning mercury-containing waste and disposed mercury-containing products, the investigation included the analysis of various documentation related to the management and final disposal of waste, interviews and visits to operators of confinement facilities used for the final disposal of hazardous waste, mercury-recycling companies and firms that provide services to mercury waste generators, as well as to the environmental authorities of the countries in the region. Interviewees included agencies such as ABICLOR/CLOROSUR, BRASIL RECICLE, PROAMBIENTE, and ESSENCIS, and environmental authorities from Brazil, Peru, Chile and Mexico.

The information collected was analyzed by the consulting team.

1 INTRODUCTION

Mercury is a highly toxic metal. Being an element, mercury cannot be broken down or degraded into harmless substances. Mercury may change between different states and species in its cycle, but its simplest form is elemental mercury, which is harmful to humans and the environment, posing a particular threat to the development of the child in uterus and early in life. Once mercury has been released from it sources it can be highly mobile, cycling between the earth's surface and the atmosphere. Due to its high toxicity, mercury has been a concern for the international community for several years.

In 2001 the UNEP Governing Council (GC) decided to initiate a process to undertake a global assessment of mercury and its compounds. The Global Mercury Assessment (UNEP, 2002) was presented to the 22nd session of the UNEP Governing Council in 2003. Based on the key findings of the report, the Governing Council concluded that there was sufficient evidence of significant global adverse impacts from mercury and its compounds to warrant further international action to reduce the risks to human health and the environment. They decided that national, regional and global actions, both immediate and long-term, should be initiated as soon as possible, with the objective of identifying exposed populations and ecosystems, and reducing anthropogenic mercury releases that impact human health and the environment.

In 2005, the GC Decision 23/9 urged Governments, intergovernmental and non-governmental organizations and the private sector to develop and implement partnerships, as one approach to reducing the risks to human health and the environment from the release of mercury and its compounds to the environment.

The partnership areas currently identified include:

- Mercury Management in Artisanal and Small-Scale Gold Mining
- Mercury Control from Coal Combustion
- Mercury Reduction in the Chlor-alkali Sector
- Mercury Reduction in Products
- Mercury Air Transport and Fate Research
- Mercury Waste Management
- Mercury Supply and Storage

UNEP Governing Council decision 24/3 concludes that further long term international action is required to reduce risk to human health and the environment and additional measures have to be undertaken in order to make progress in addressing this issue. It also identified seven priority areas for action to reduce the risks from releases of mercury, two of which are:

- To reduce the global mercury supply, including considering curbing primary mining and taking into account a hierarchy of sources; and

- To find environmentally sound storage solutions for mercury.

Governing Council decision 25/5 requests the Executive Director of UNEP, coordinating as appropriate with Governments, intergovernmental organizations, stakeholders and the Global Mercury Partnership, and concurrently with the work of the Intergovernmental Negotiating Committee, to develop a legally-binding instrument on mercury, to continue and enhance as part of international action on mercury the existing work, including enhancing capacity for environmentally sound mercury storage.

With the support of the government of Norway, UNEP Chemicals Branch, and DTIE is implementing a "Mercury Storage Project" entitled "Reduce Mercury Supply and Investigate Mercury Storage Solutions". This project aims to address the objectives mentioned above: to reduce global mercury supply and to find environmentally sound storage solutions. The project is currently being implemented in the Asia Pacific Region and in the Latin America and the Caribbean Region. The first stage of this project was to estimate mercury surplus from various sources. For the Latin America and Caribbean region, the assessment report: "Excess mercury supply in Latin America and the Caribbean, 2010-2050", was prepared by consultant Peter Maxson and presented in the Inception workshop that took place in Montevideo, Uruguay, on 23-24 April 2009. In this instance, participants reached agreement to proceed with an options analysis and feasibility study as basis for a decision to be taken in the future on the preferred storage options.

This report, entitled "Options analysis and feasibility study for the long term storage of mercury in Latin America and the Caribbean" gives a retrospective on the current state of affairs of the mercury issue and articulates recommendations for the countries in the LAC region with respect to a long term safe management and storage of mercury.

Three storage options were taken into account in this report:

a. Above-ground especially engineered warehouse

b. Below-ground storage in geological formation (e.g., mines, special rock formations)

c. Export to a foreign country/facility

Mercury Chemistry

Mercury is a naturally occurring element that is found in air, water and in the earth's crust. It exists in three oxidation states: elemental or metallic mercury (Hg^{o}), mercurous (Hg^{+}) and mercuric (Hg^{++}) mercury. As mercurous form it exists as inorganic salts and in the mercuric state forms either as inorganic salts and organic mercury compounds.

Elemental or metallic mercury is a shiny, silver-white metal and is liquid at room temperature (boils at 356.9ºC). If not enclosed, at room temperature some of the metallic mercury will evaporate and form mercury vapors, since it has a high pressure vapor (0.155 Pa at 20ºC). Mercury dissolves to form amalgams with gold, zinc and many other metals except iron (only at very high temperatures).

Mercury forms a wide variety of salts, both as mercourous (Hg^{+}) and mercuric (Hg^{++}) state. Most common mercury salts are mercuric sulfide (HgS), mercuric oxide (HgO), mercurous chloride or calomel (Hg_2Cl_2) and mercuric chloride ($HgCl_2$). They differ greatly in solubility; at 25 °C, the solubility of mercurous chloride and mercuric chloride in water are 2 and 74 mg/liter, respectively.

When mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organomercurials. Among a large number of organic mercury compounds, methyl mercury is, by far, the most common organic mercury compound in the environment. Like the inorganic mercury compounds, both methyl mercury and phenyl mercury exist as "salts" (for example, methyl mercuric chloride or phenyl mercuric acetate). When pure, most forms of methyl mercury and phenyl mercury are white crystalline solids. Dimethylmercury, however, is a colorless liquid.

Methyl mercury could be generated by micro-organisms and natural processes from other forms. Methyl mercury is of particular concern because it can build up (bioaccumulation and biomagnifying) in many edible freshwater and saltwater fish and marine mammals to levels that are many thousands of times greater than levels in the surrounding water.

A summary with some physical and chemical properties of the main mercury salts is shown in Table 1.1.

There are certain characteristics that should be taken into account when considering the temporary or long-term storage and management of elemental mercury, especially highlighting solubility, incomptatibilities and reactivity, in order to reduce risks both for workers and the environment.

Table 1.1 – Physical and chemical properties of main mercury salts (ATSDR, IPCS)

Mercury compound	Melting Point (ºC)	Boiling Point (ºC)	Vapor pressure at 20ºC	Water solubility	Solubility in other solvents	Incompatibilities & reactivity
Mercury	-38,9	356,9	$1{,}2 \times 10^{-3}$ mmHg	Insoluble (56 μg/l at 25ºC)	Soluble in H_2SO_4 upon boiling, in lipids, readily soluble in HNO_3, insoluble in HCl, soluble in 2.7 mg/l pentane	Not flammable Not combustible. Incompatible with strong oxidizing agents. Incompatible with: acetylene, ammonia, chlorine dioxide, azides, calcium (amalgam formation), sodium carbide, lithium, rubidium, copper
Mercurous chloride Hg_2Cl_2 (White powder)	Sublimes at 400-500 ºC without melting	384	No data	0,2 mg/ 100 ml at 25ºC	Insoluble in ethanol, ether	Decomposes slowly under influence of light producing mercuric chloride and mercury
Mercuric Chloride $HgCl_2$ (White powder)	277	302	1 mmHg at 136.2 ºC	7,4 g/100 ml at 25ºC (IPCS) 6,9 g/100 ml at 20ºC 48 g/100 ml at 100 ºC (ATSDR)	soluble in alcohol, ether, acetone, ethyl acetate slightly soluble in benzene, CS_2	Not combustible. Not flammable but gives off irritating or toxic fumes (or gases) in a fire. Decomposes due to heating producing toxic Fumes of mercury and chlorine fumes. Reacts with light metals.[1]
Mercuric sulfide HgS (black or grayish-black – mercuric sulfide black); bright scarlet-red blackness on exposure to light (mercuric sulfide red)	Mercuric sulfide transitions from red to black at 386 °C. Black mercuric sulfide sublimes at 446 °C, and red mercuric sulfide at 583 °C.		No data	Insoluble (both red and black mercury sulfide)	Red mercuric sulfide is soluble in aqua regia with separation of S, and in warm hydriodic acid with evolution of H_2S Insoluble in alcohol, dilute mineral acids.	
Mercuric oxide	500ºC (decomposes)			Insoluble		Decomposes on exposure to light, on heating above 500°C producing highly toxic fumes including mercury and oxygen, which increases fire hazard. Reacts violently with reducing agents, chlorine, hydrogen peroxide, magnesium (when heated), and disulfur dichloride and hydrogen trisulfide. Shock-sensitive compounds are formed with metals and elements such as sulfur and phosphorus.[2]
Mercuric acetate (white powder)	178 ºC (decomposes)			soluble in water (250 g/liter at 10 °C; 1000 g/liter at 100 °C)	soluble in alcohol or acetic acid	Decomposes on heating and under influence of light. Attacks many metals

[1] IPCS-International Programme in Chemical Safety, Mercury Chloride International Chemical Safety Cards. International Occupational Safety and Health Information Centre. http://www.ilo.org/public/english/protection/safework/cis/products/icsc/dtasht/_icsc09/icsc0981.htm.

[2] IPCS-International Programme in Chemical Safety, Mercury Oxide Safety Sheet

1.1 Legal framework in the countries and Regional Trade Agreements

As was stated before, at the 2009 United Nations Environment Programme Governing Council the world's governments agreed to prepare a legally binding instrument on mercury. The Intergovernmental Negotiating Committee will be developing a comprehensive and suitable approach to mercury, including provisions to reduce the supply of mercury taking into account the circumstances of countries. Negotiations will be convened starting in June 2010 and are to conclude in 2013.

The international legally binding instrument will require an adaptation in the national legal framework of all countries. In Europe and the United States of America some steps have already been taken in order to address excess mercury supply. A brief review is done below.

1.1.1 European Community Strategy and relevant legislation

The EU strategy adopted (January 2005) by the European Community to reduce mercury levels in the environment and human exposure, especially from methyl mercury in fish has the following objectives:

• Reducing mercury emissions.

• Reducing the entry into circulation of mercury in society by cutting supply and demand.

• Resolving the long-term fate of mercury surpluses and societal reservoirs (in products still in use or in storage).

• Protecting against mercury exposure.

• Improving understanding of the mercury problem and its solutions.

• Supporting and promoting international action on mercury.

In 2008, the European Union adopted a regulation[3] banning by 15 March 2011, the export of

- Elemental mercury,
- Cinnabar ore
- Mercury (I) chloride
- Mercury (II) oxide, and
- Mixtures of metallic mercury with other substances, including alloys of mercury, with a mercury concentration of at least 95 percent by weight.

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1102:EN:NOT

The EU export ban provides exceptions for export of compounds above, which are for research and development, medical or analysis purposes. Also, the EU regulation prohibits mixing metallic mercury with a substance for the sole purpose of exporting metallic mercury.

The Regulation lays down that from 15 March 2011, metallic mercury from the following sources should be considered as waste (Article 2, Regulation (EC) No 1102/2008) and be disposed of in accordance with Directive 2006/12/EC on waste in a way that is safe for human health and the environment:

- Metallic mercury that is no longer used in the chlor-alkali industry
- Metallic mercury gained from the cleaning of natural gas
- Metallic mercury gained from non-ferrous mining and smelting operations
- Metallic mercury extracted from cinnabar ore in the Community as from 15 March 2011

In order to provide for possibilities for a safe storage of the above-mentioned metallic mercury waste within the Community, Article 3 of Regulation (EC) No 1102/2008 deems suitable options both for permanent and temporary storage in appropriate containments (by derogation from Article 5 (3)(a) of Directive 1999/31) the following:

- temporary storage for more than one year or permanent storage in
    - salt mines adapted for the disposal of metallic mercury, or
    - in deep underground, hard rock formations providing a level of safety and confinement equivalent to that of those salt mines; or
- Temporary storage for more than one year in above-ground facilities dedicated to and equipped for the temporary storage of metallic mercury.

In terms of storage, the EU regulation further requires that requirements for facilities as well as acceptance criteria for metallic mercury shall be adopted, before any final disposal operation concerning metallic mercury is permitted by the local authorities.

To that end, the European Commission (EC) asked a consulting company (BiPRO[4]) to carry out a report and propose relevant facility requirements and acceptance criteria and also research safe disposal options. EC also organized an information exchange meeting to discuss the report. The revised final report is available[5].

It is now expected that the EC will publish an appropriate proposal as soon as possible, taking into account the outcome of the exchange of information and the above-mentioned report.

[4] http://www.bipro.de/mercury/index.html
[5] http://www.bipro.de/mercury/sub/workshop.html

1.1.2 USA - Mercury Export Ban Act of 2008

The United States and state governments are working to reduce mercury in the environment and to prevent human exposure to it. The US Environmental Protection Agency has issued regulations to reduce mercury releases into air, water, and land; and state governments have enacted legislation to phase out the use of mercury in many products.

The Mercury Export Ban Act of 2008 (MEBA), signed into law on October 14, 2008, prohibits the export of elemental mercury from the United States beginning in 2013. It also prohibits the sale, distribution, and transfer of elemental mercury held by Federal agencies as of the date of enactment of this act. The bill allows the Administrator of the Environmental Protection Agency (EPA) to grant a time and quantity limited exemption from the export prohibition by rule, after notice and opportunity for comment, if the Administrator finds that certain conditions have been met.

The MEBA includes the following provisions:

- The export of elemental mercury from the United States is prohibited, effective January 1, 2013
- Effective immediately upon enactment, Federal agencies are prohibited from conveying, selling or distributing elemental mercury under Federal control or jurisdiction to any other Federal agency, any State or local government agency, or any private individual or entity
- **The Federal government must provide an option for long-term management and storage of any elemental mercury generated within the United States (private facilities are also allowed)**[6]
- US EPA and DOE are responsible for submitting the following to Congress:

  - A report on mercury compounds (submitted by US EPA on October 14, 2009);[7]

  - Annual reports on the previous year's incurred costs associated with the long-term storage and management of elemental mercury (to be submitted by DOE no later than 60 days after the end of each fiscal year);

  - A study on the impact of the long-term storage program on mercury recycling (to be submitted by DOE no later than July 1, 2014); and

  - A report on global supply and trade of elemental mercury (to be submitted by EPA at least three years after the effective date of the export prohibition but no later than January 1, 2017).

- DOE is to make available guidance related to the procedures and standards for receipt, management, and long-term storage of elemental mercury (no later than October 1, 2009 by DOE).

[6] The United States Department of Energy is charged with providing this facility. It recently published a draft Environmental Impact Statement which contains a facility description and evaluates the sites under consideration. A relatively remote site in the desert of West Texas is identified as the preferred alternative. See http://www.mercurystorageeis.com/. .
[7] EPA report is available at *http://www.epa.gov/hg/pdfs/mercury-rpt-to-congress.pdf*.

1.1.3 Legal Framework in the LAC Countries

Regarding the legal framework, two topics were considered during the research:

a. Specific regulation about mercury trade, storage and control of use or phase-out ;

b. Regulation about the management of mercury-containing products in their end-of-life or of other mercury-containing waste.

This second approach was a special request of Mercury Strategy LAC ExeCom, and will be analyzed in chapter 4. Furthermore, mercury relevant legislation in USA and EU about the storage and trade was evaluated in order to learn about world tendencies that would interfere in the trade, use and management of mercury in the region (presented in 1.1.1 and 1.1.2). The tables in ***Annex 1*** summarize the main laws and regulations related to trade, storage, use and phasing out of mercury applicable in the countries of the region. Below is an analysis of the legal framework available in the region to address the management of elemental mercury.

1.1.3.1 Legal framework in LAC related to mercury trade, storage and control of use or phase-out

Trade

Mercury trade has no restrictions in most countries of the region. Brazil is the only country whose regulation foresees the control of importers, producers and sellers of elemental mercury. Decree 97.634/1989 states the obligation for importers, producers or sellers of elemental mercury to be registered in IBAMA. Before applying for the import authorization, importers shall notify IBAMA about each lot they intend to import. The notification is necessary previously to the issuance of the import authorization form by CACEX (Foreign Trade Portfolio of the Banco do Brasil S.A.). Also, in the metallic mercury wholesale and retail operations the respective Documents of Metallic Mercury Operations shall be given to IBAMA. These obligations became even stricter when IBAMA implemented Order number 32 in 1995 which regulates conditions for registering and fees applicable to such importers, producers or sellers.

Other countries have legislation for the control of hazardous substances in general, that can be considered an indirect control of mercury trade. An example is the "Special Regulation of substances, residues and hazardous wastes" of El Salvador (Ex.Dec. 41 of 31/05/00) that requires that importers request an environmental permit from the environmental authority. Similarly, Panama Executive Decree 305 (09/04/2002) sets the automatic prior licensing, to regulate imports of certain chemicals, among which are compounds of mercury. Another example is the regulatory framework for the management of dangerous chemical products in Ecuador, which is integrated by the following phases: supply, which includes importation; transport, storage, trade, use and final disposal. The regulatory instrument sets forth the obligation to register the dangerous chemical products to be produced, developed or imported by the responsible parties with the Technical Secretariat of the National Committee (Book VI Title VI of the Unified Text of the Secondary Legislation of the Ministry of the Environment). In Annex 7 of Book VI the unified Text lists the Chemical Products Prohibited, Dangerous and of Severely Restricted Use in Ecuador, which include mercury, mercury oxides, mercury chloride and mercury sulfate.

Control of Uses and Phase Out

The use of elemental mercury in mining is forbidden or limited by law in some countries in the region.

In Brazil the use of mercury and cyanide in gold mines is prohibited by the Federal Decree 97.507/89 and resolution No. 8/1988 of CONAMA – the National Environmental Council, except in mines with environmental permit.

In the Province of Córdoba, Argentine, Law 9526 prohibits open-pit metal mining, mining of nuclear minerals and the use in mining of several hazardous chemical compounds including mercury (the prohibition encompasses all the products listed in Annex 1 of Law 24.051 (about hazardous waste) or those with characteristics of Annex II). This Law, however, is currently under the scrutiny of Justice due to allegations of it being unconstitutional.

In the Bolivian Environmental Regulation for mining activities (Supreme Decree 24782), mercury and its compounds are considered hazardous substances with controlled use. Concessionaries and operators that use hazardous substances must comply with the provisions established in Title IV of said regulation and with Supreme Decree 24176 that regulates activities with dangerous substances. Authorization is given through an Environmental Permit.

In Ecuador the Environmental Regulation for Mining Activities approved in November 2009 establishes that the use of mercury shall be avoided, and that in duly justified cases in which the process contemplates its use, methodologies that allow the sequestration of mercury for its reuse shall be used. It also establishes that mercury shall be carefully stored and kept in air-tight containers to prevent any leaks. The Regulation of the special regime for small scale and artisanal mining was approved at the same date. This regulation also sets restrictions for the use of mercury in this activity. Again, the use of mercury has not been banned, but it is discouraged , recommending implementation of methods that allow its sequestration when the miners choose the amalgamation technique..

In 2007 APROMAC – Environment Protection Association, a CONAMA's civil society councilor, in partnership with ACPO (Association of Combat against Pollutants) and ZMWG, submitted to the Brazil Council a proposal of motion asking the Federal Government, as a whole, to adopt goals of elimination of uses and reduction of anthropogenic emissions of mercury, to develop and implement national and regional plans towards these goals, including measures to control the mercury and mercurial waste trade and mercury-containing technologies. The motion asked the Ministry of Environment to establish clear rules on the destination of the existing stocks of mercury including mercury from the electrolytic cells of chlor-alkalis plants, returning this mercury back to its countries of origin.

Furthermore, the proposed motion called for the phase out of mercury cells in chlor-alkalis plants, of medical devices such as thermometers and other mercury-containing products, as well as requesting the development and implementation of a nationwide Mercury National Policy with a high level of commitment of the government and industry towards protecting public health and the environment. The motion also requested CONAMA to create a working group on Fluorescent Lamps, in order to discuss an environmentally sound collection and disposal management resolution for these products.

The motion was fully adopted by CONAMA and officially published as CONAMA's Motion number 85 of 2007.

Some countries in the region have legal mechanisms to reduce or eliminate mercury in a number of products.

In Brazil, Resolution 401/2008 of the National Environment Council (CONAMA), sets caps for the contents of certain metals in batteries, both locally manufactured and imported (the limit is 0.0005% of mercury for portable batteries and up to 2% for miniature button cells).

The Argentine Law 26.184 of December 21, 2006 prohibits the manufacturing, assembly and importation of batteries with mercury contents greater than 0.0005% (also providing limits for lead and cadmium), extending the prohibition to the marketing of batteries with these characteristics 3 years after the law was enacted.

Several countries have banned or severely limited the use of mercury-containing pesticides (Mercury compounds, including inorganic mercury compounds, alkilic mercury compounds and alcoxi-alkilic and arylic mercury compounds, as set forth in Annex II of the Rotterdam Convention). ***Annex 5*** provides a listing of the imports replies received by the Rotterdam Convention Secretariat from the LAC countries that are parties of the Convention, and through which each country reports to the Convention Secretariat about their status concerning the monitoring and banning of these substances.

In Chile, Supreme Decree Nº 239/02 of the Ministry of Health, considers a list of compounds prohibited in cosmetics, which includes mercury compounds.

On the other hand, legislation promoting to phase-out the use of mercury-containing products such as thermometers and sphygmomanometers is being developed. In Argentine Resolution 139/2009 of the Ministry of Health gives instructions to public hospitals indicating that new purchases of thermometers and sphygmomanometers should be free of mercury, and Resolution 274/10 prohibits to produce, import, trade or freely transfer sphygmomanometers with mercury column. The Province of Cordoba Law 9605 (12/03/2009) states the gradual elimination of mercury in Health.

No regulations or technical standards were detected in the region to address mercury storage. This was to be expected, since to date there is no obligation to store mercury; instead, it is freely traded as a commodity.

1.1.4 Regional and international voluntary initiatives

The Environmental Cooperation Commission (ECC)

In 1994, Canada, the United States of America and Mexico created the Environmental Cooperation Commission (ECC) in compliance with the North American Environmental Cooperation Agreement

(NAECA), derived from the North American Free Trade Agreement (NAFTA). In October 1997 a working group from North America was formed for the instrumentation of the Plan of Regional Action (PARAN) on mercury with the following objectives:

a) To reduce the levels of Hg in certain indicative environmental settings, as well as the flux between them in order for them to approximate natural levels and streams, and

b) To seek the reduction of the anthropogenic sources of mercury pollution through the implementation of life-cycle approaches.

In pursuance of the above the three parties will aim to reduce mercury discharges in certain human activities. These activities include reducing mercury releases from combustion sources, commercial processes, operations, products and waste streams.(INE 2004)

Since then, Mexico has developed inventories of mercury use and discharges, and programs related to the recovery of contaminated sites.

1.1.5 Analysis of the legal framework in Latin America

The degree of progress or complexity of the legal framework in LAC is uneven. There are countries, such as Brazil or Mexico, that have developed their environmental legislation earlier and thus have advanced towards more specific matters. In other countries, however, legislation is still rather scarce. The environmental criteria in the countries' legal framework may vary from a State or Province to another, such as is the case in Brazil, Mexico and Argentina.

In the current situation, only Brazil has some control on elemental mercury trade and few countries have instruments to legislate on products with mercury, mostly mercury content in the products. Some instruments promote the substitutions of products with alternate products free from this metal.

In the future, the region would have to work in establishing the legal framework necessary to better control mercury trade and mercury use in their countries, especially those that are major users or producers, and at the same time to develop legislation to phase out mercury. Specific legislation or negotiation to phase-out some uses, will accelerate the stock to be stored.

The experience of countries that have already implemented controls may be taken into account when drafting new legislation. This could be the case of the Brazilian experience in the control of trade in mercury, as a first step to end in a voluntary mechanism for use and trade ban, according to the UNEP. Countries must have adequate facilities for environmentally sound storage of the mercury they generate. This will require developing technical standards (for packing, storage, monitoring and treatment) that clearly define the requirements to comply with these facilities. Mercury storage is a potential highly pollutant activity not covered in current legislation; the activity needs environmental permit from environmental authorities. Besides, guardianship of elemental mercury has to be established in the legal framework; not necessarily will the reponsibility lie on the environmental authorities

When the government is in charge of running a storage facility, anindependent agency should be appointed for monitoring it, rather than any environmental authority. Any conflicts of interest between who controls and who is controlled should be avoided.

Another important issue is that in some countries, installation of long-term storage facilities would not to be possible because of technical or economical restrictions; therefore legislation has to consider exportation as a legal alternative that has to be regulated. In any case, being new activities, environmental authorities will require specific training for processing permits. For underground facilities, the permit process involves more than environmental authorities, which increases the complexity both of the process and the training needs.

1.2 Uses of Mercury in Latin America and the Caribbean (LAC)

Mercury consumption was estimated by Maxson in his report "Excess Mercury supply in LAC, 2010-2050". Table 1.2 below summarizes the key applications of elemental mercury in the Latin American and the Caribbean region, including mercury consumption for the manufacture of products for export (notably batteries, lamps and electrical and electronic equipment).

Table 1.2 - Mercury consumption in South America and the Caribbean, 2005 (tons). Maxson 2009[8]

	South America		**Central America and Caribbean**		**Latin America and Caribbean Total**	
	min	**Max**	**min**	**Max**	**Min.**	**Max.**
Small-scale gold mining	150	300	15	30	165	330
Chlor-alkali production	15	30	5	10	20	40
Batteries	10	15	5	10	15	25
Dental applications	40	50	20	25	60	75
Measuring and control devices	20	25	10	15	30	40
Lamps	5	10	5	10	10	20
Electrical and electronic equipment	5	10	5	10	10	20
Other	10	20	5	15	15	35
Totals	**260**	**470**	**70**	**130**	**330**	**580**

Artisanal and Small-scale gold mining (ASGM)

Clearly, artisanal gold mining represents not only the largest individual consumption of mercury in the region, but can match or exceed the sum of all other consumption combined (50-56% of total mercury is consumed by mining). Artisanal or small-scale gold mining is also the main user of Mercury in the world, especially since the boom of gold mining, supported by the increase in the price of gold in the last decades.

[8] The table was extracted from Maxson's report and updated in chlor-alkali mercury consumption

This consumption has been increasing in recent years. According to the analysis of the imports of mercury of each of the countries in the region during the last 3 years (results that are shown in Chapter 2), a sustained growth is observed in the imports of mercury, especially in Peru, Colombia and Mexico. In the cases of Peru and Colombia, most of the mercury is imported by traders (71 and 75% respectively), which would indicate that it would be destined to mining, making a total in those 2 countries alone, of 223 tons in the year 2008. Presumably, consumption will continue to increase, as there are no changes in the market.

In LAC, artisanal or small-scale mining represents a subsistence method for one million people in countries such as Bolivia, Brazil, Colombia, Ecuador, Peru, Suriname, French Guyana, Guyana, Venezuela, Costa Rica, Dominican Republic, Guatemala, Honduras, Mexico, Nicaragua and Panama. It is estimated that between 60,000 and 90,000 smallscale miners work in the region of Tapajos, Brazil, alone (UNIDO, 2008) There would be between 20,000 and 25,000 small miners active in Suriname (Heemsker, 2002) and from 6,000 to 10,000 in Guyana (UNIDO, 1998)

As mercury is readily available in most countries, it tends to be inexpensive and easily accessible to gold miners. According to the report *Global impacts of mercury supply and demand in small-scale gold mining* (UNIDO, 2007) mercury usually enters developing countries legally, i.e. for use in dental amalgams or for the chlor-alkali industry. However, evidence indicates that in many developing countries and countries with economies in transition, by far the majority of the mercury imported ends up being used in ASGM. This seems to be confirmed according to elemental mercury imports in the region, as it is analyzed in Chapter 2.

With support from NGOs and international agencies, some pilot experiences in artisanal mining have been developed to reduce mercury consumption and releases In 1.3 some of these projects are shown.

Chlor-alkali production

One of the largest mercury users in LAC region is the chlor-alkali industry. In LAC region there was a maximum of 16 plants still using the technology of electrolysis of brine in cathode mercury cells for the production of chlorine and soda in 2010. In Annex 3, the localization of active chlor-alkali plants is presented. The last in changing the technology was Solvay in Brazil during 2009, generating a surplus of 130 t of mercury that was exported to MAYASA, Spain. This decommissioning represents a slight decrease in mercury consumption specifically by the chlor-alkali industry, in reference to that reported by Maxson, which corresponded to 2005. When chlor alkali plants are decommissioned, large quantities of inexpensive mercury becomes available in the marketplace for other uses.

Regarding future trends, the plant installed in Cuba has a project to change his technology to be undertaken in the short term. The plant in Uruguay evaluates the change but no dates have been set yet. Anyway, due to the high prevalence of mining in other consumption, these decreases in consumption of mercury from chlorine-alkali plants do not significantly alter the estimates of total consumption.

Dental applications

This is the second consumer of mercury in the region. Although there are mercury-free alternatives already available for dentistry, including composites, (resin-free) glass monomer cements, ceramics etc., mercury amalgams are still widely used by dentists in the region, especially for economic reasons. National strategies and/or advisories have been in place against the use of mercury in dental fillings in Europe (e.g. in Sweden, Denmark, Germany, Austria, France and Finland).

Measuring and control devices

This category includes thermometers, barometers, manometers, sphygmomanometers, etc. Their mercury contents range from 0.5 g for a medical thermometer to 200 g for an industrial thermometer (UNEP, 2005). This category ranks third in consumption, with similar figures as chlor-alkali production. The use of measuring devices with mercury has been decreasing, driven by organizations such as Health Care Without Harm, who promote alternatives free of mercury. . The chapter Ongoing Initiatives depicts some of the initiatives being implemented in the region. This phase out will result in a surplus of mercury thay will need safe storage.

Electrical and electronic equipment

Switches and relays are found in a great variety of appliances and other home equipments, as well as in automobiles. Their mercury contents range from 1 g for a thermostat to 400 g for a displacement relay (UNEP, 2005). However, the trend is to substitute these devices with mercury free alternatives, following the European Union's Restriction on Hazardous Substances (RoHS) Directive, and similar initiatives in Japan, China and Korea. **(Peter Maxson)**

In Argentina, the Argentine Association of Medical Doctors for the Environment, with the support of the National Institute of Industrial Technology (INTI), made a survey of all electro domestic equipment, gas or electric appliances that contain switches or other devices with mercury, in addition to a range of products of mass or specific consumption that could still be in the market. This list can be consulted in http://crsbasilea.inti.gov.ar/mer-inventario.htm [9]

Lamps

There are several kinds of lamps containing mercury in the market, with mercury contents ranging from less than 3 milligrams to 40 mg (UNEP, 2005).The "Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive" (RoHS) (2002/95) bans the use of heavy metals, including mercury in the EU, but also provides for exemptions and sets maximum concentration values in different kind of lamps. Actual limits are shown in Table 1.3 but this exemptions are actually under revision, due to technology improvements that allow the production of lamps with lower mercury content. For example, the better CFLs now contain 1,2-3 mg of mercury and linear

[9] The list was developed by the Argentine Association of Medical Doctors for the Environment (AAMMA), with the auspices of Dr. Leila Devia of the Regional Center for South America of the Basel Convention and the technical cooperation of Adriana Rosso and Juan Carlos Gómez of the Instituto Nacional de Tecnología Industrial (INTI), based on the bibliographic review of the inventories published in different regions and countries.

fluorescents contain less than 5 mg.[10]However, the availability of this newer technology in the LAC region is uncertain.

In the case of mercury-containing lamps, even though their consumption accounts for only 3% of the total amount, it is expected to increase in the short- and medium- term in the region, as a result of government policy incentives for energy saving and control of climate change (e.g., Cuba, Uruguay, Argentina). A statistic made with a lamp recycler in Brazil, approximately 2 tons of mercury is discarded yearly into the sanitary landfills or dumps (180 million lamps with an average of 12 mg/lamp). The increased use raises concerns in society, due to mismanagement of the lamps from production to final disposal as municipal solid waste. This is of particular concern, considering that much of LAC municipal waste is disposed of in dumps with no or inadequate environmental protection. As mentioned by Peter Maxson, mercury-free alternatives such as light-emitting diodes (LEDs) will increasingly become available. Nevertheless, at present, for most lighting applications in the region this option is very limited and/or quite expensive.

Table 1.3 – Maximum Mercury content allowed in lamps Annex Directive 2002/95/EC

Light sources with mercury	Mercury mg Hg/item
Fluorescent tubes	
halophosphate	10
triphosphate with normal lifetime	5
triphosphate with long lifetime	8
Compact fluorescent lamp	5

Batteries

The consumption of mercury in batteries continues to be significant in spite of the progressive substitution of mercury for other alternatives.

The batteries that still have mercury are Mercuric Oxide Batteries and Button Cell Batteries (http://www.epa.gov/mercury/consumer.htm#bat). Mercury is currently used in most batteries to inhibit corrosion and prolong battery life. It is also used in mercury oxide batteries to conduct an electric charge (mercury represents between 20 and 50% of total weight). Mercuric oxide button cells are prohibited under federal law in USA. Larger mercuric oxide batteries are still produced for military and medical equipment, where a stable current and long service life is essential. Small amounts of mercury are still added to most zinc air, alkaline and silver oxide button cells batteries to prevent the formation of internal gases that can cause leakage (only lithium miniature batteries contain no intentionally-added mercury).

[10] http://rohs.exemptions.oeko.info/
[10] http://rohs.exemptions.oeko.info/
http://www.zeromercury.org/EU_developments/090831NGOs-RoHS-Review-of-AnnexHg-in-lamps-Consolidated.pdf

Future mercury consumption and/or production in Latin America and the Caribbean

In his report "Excess Mercury Supply in LAC, 2010-2050" Peter Maxson makes an estimation of the future consumptions and/or production for the period above, based on the estimation of the current values of consumption and/or production. The objectives for future reductions in mercury consumption are based on those agreed in the Mercury-Containing Products Partnership Area Business Plan (UNEP, 2008b), which is also based on the "Focused Mercury Reduction Scenario" of UNEP's Mercury Trade Report ("Summary of supply, trade and demand information on mercury") (UNEP, 2006). Table 1.4 summarizes the assumptions adopted with respect mercury consumption.

Overall, the course of the consumptions and/or production of mercury in Latin America and the Caribbean that will determine the surplus of mercury that needs to be stored must consider the national and global initiatives on mercury, as specified in partnership business plans and related UNEP and UNIDO global mercury initiatives, where available (Maxson, for UNEP, 2009b), as well as the expected negotiations that will lead to a leading binding instrument (LBI) on mercury by 2013.

The production of most mercury-added products is in general decline as countries and regions in many parts of the world implement legislation or voluntary initiatives to reduce or phase out various uses of mercury. (Maxson, for UNEP, 2009b). This decline will likely accelerate when the mercury LBI comes into force after 2013 and will followed by both voluntary and mandatory initiatives to reduce the manufacturing of products containing mercury. The mercury-added product sectors also represent significant potential for decreases in consumption during this time period because alternative mercury-free products are readily available, they are of equal or better quality, and prices are generally competitive.

Table 1.4 - Basic assumptions regarding LAC mercury consumption 2010-2050 (Maxson, for UNEP, 2009b)

Processes	Assumptions regarding future consumption
Small-scale gold mining	Reduce mercury consumption in small-scale gold mining globally by 50% over the next 10 years, with a subsequent decline after that of 5% per year. According to UNIDO, the 50% reduction can be met by eliminating whole ore amalgamation and encouraging greater mercury reuse (UNEP 2006). Supply restrictions are expected to help achieve this objective by raising mercury prices and otherwise encouraging greater efficiencies in mercury use.
Chlor-alkali production	Assume no new mercury cell facilities will be constructed in any region. Assume mercury cell capacity will be gradually phased out between 2010 and 2022. Therefore, industry consumption of 25-55 tons/yr. will gradually disappear during this period.
Products	**Assumptions regarding future consumption;**
Batteries	Assume a 75% decrease in mercury consumption by 2015, and the remaining demand phased out gradually thereafter until 2025.
Dental applications	Assume a 15% reduction by 2015, and a gradual reduction thereafter to 50% of present consumption by 2050.
Measuring and	Assume a 60% reduction of mercury consumption by 2015, the phase-out of

control devices	mercury fever thermometer and sphygmomanometers by 2017, and the phase-out of remaining demand by 2025.
Lamps	Assume a 20% reduction by 2015 and a gradual reduction of 80% overall by 2050.

On the other hand, mercury production in that period will come from the shut-down of chlor-alkali plants and the production of mercury as a co-product of non ferrous mining (zinc foundries, industrial gold mining) or eventually from natural gas, and to a certain extent, from the recycling of products. When mercury is recovered as a co-product, the amount of mercury produced will very much depend on the regulations developed by the countries to enforce the monitoring of mercury emissions in the above-mentioned areas. It is also essential to consider that given that the LAC countries continue (and will continue) to install large mining projects that apply mercury recovery mechanisms that accompany the mineral naturally, the amount of mercury that will need to be stored in the future will increase. In his report, Maxson estimates a 50-tonne increase for 2015 (from 150 to 200 tonnes) in mercury recovery from gold and copper mining. However, according to the information provided by Barrick concerning the company's mining projects currently under construction (one in the Dominican Republic and another in Argentina) this amount will be broadly surpassed. It is noteworthy that in 2009 Chile and Peru exported more than 220 tons of mercury from gold and copper mining, in both countries. In the Dominican Republic project, is expected to recover 30 to 50 tons of mercury over the life of the mine, estimated at 25 years. No data was found about the amount of mercury recovered in Veladero.

For mercury recovered as a coproduct in Zinc smelting, Maxson estimated a recovery of 80 tons per year, that correspond approximately to 10% of the total zinc produced by smelters. The production of this metal has remained relatively constant between 2004 and 2008, although it is estimated that global demand will grow, which also would increase the amount of mercury recovered by smelters (estimated by Maxson in 120 tons per year by 2020).

The responsibility for assessing the maximum amount of mercury to be recovered in each country as new projects are presented shall lie on the countries themselves. ***Annex 4*** shows the maps with the main gold and zinc mines that are currently operational in the LAC region. These are **potential** points of generation of mercury as a co-product, which does not imply they are currently co-products, or that they may be in a near future. As expressed above, it will depend not only on the projects executed by the companies, but also on the controls imposed by the local authorities to monitor the processes of gold recovery and zinc smelting. It is to highlight that the map shows active zinc mines, and not only the metal smelters, where the Hg would eventually be recovered.

1.3 Ongoing initiatives of the countries to prevent or minimize the use of mercury

UNEP is the organization that coordinates the global efforts to reduce global mercury, demand, and releases. This program encourages the development of alternative technologies to the products and processes with mercury. As it was mentioned before, several partnerships were developed in different areas, among others: Mercury Management in Artisanal and Small-Scale Gold Mining, Mercury Reduction in the Chlor-alkali Sector, Mercury Reduction in Products and the most recent, Non-Ferrous metals production. Each of these partnerships has specific objectives of minimization of mercury uses or environmental and human impacts. To meet these goals, each partnership have developed his Business Plan that describe the activities to be carried out. Detailed information on these activities can be found in the web page of Mercury Project.

http://www.chem.unep.ch/MERCURY/partnerships/new_partnership.htm

In LAC there are many initiatives that have been implemented for several years to reduce or eliminate the use of mercury and the products that contain it. Many of these initiatives are supported by international organizations such as the NGO Health Care Without Harm, UNIDO, and the World Health Organization (WHO) that support initiatives in the health sector, or projects in small-scale gold mining. Although there has been progress in this regard, there is still much to be done in the region, particularly in artisanal mining, where mercury consumption is more significant, scattered and where it generates greater harm.

The most relevant initiatives of mercury reduction in the region are presented below. They are grouped by the sector they address.

Artisanal Gold Mining

- In Bolivia and Peru, the “Artisanal and Small Scale Gold Mining Regional Projects in South East Asia and South America" are being undertaken with the support of the Quick Start Programme (QSP) Strategic Approach to International Chemicals Management (SAICM) The objectives in each are: to secure government commitment to address mercury issues in ASGM; to bring stakeholders together to use guidance prepared within the projects to develop national strategic plans for mercury reductions in the sector; to enhance regional collaboration and coordination. (UNEP, 2009b)

- The Association for Responsible Mining (ARM) - Standard Zero proposes a process to support the miners’ organizations to minimize the use of mercury and cyanide over an agreed period of time, through implementation of responsible practices and technologies to mitigate impact on the environment and human health. ARM is working on field-testing the Standard Zero in four countries in Latin America: Bolivia (2 cooperatives in Cotapata), Colombia (Chocó – 2 community councils, and Nariño – 2 cooperatives), Ecuador (Bella Rica), and Peru (Central Peru – 3 community miners companies). Both Nariño and Peru have demonstrated important reductions. Chocó does not use it at all (UNEP, 2008d).

- The United States, local governments in Brazil, UNIDO and UNEP have partnered to reduce mercury emissions from gold processing shops in the Amazon. The Partnership has verified baseline measurements in the Amazon, and developed options for locally-manufactured appropriate technology solutions for the capture of mercury vapors in the gold shops (with the support of US-EPA and Argonne National Laboratory). A prototype technology was installed in 6 gold shops in 2 cities in the Brazilian Amazon and tested at over 80% efficiency of mercury vapor capture. This experience is being applied for gold refining in the Peruvian Amazon (UNEP, 2008d)

- The Peruvian environmental organization, Project GAMA (Gestión Ambiental en la Minería Artesanal – Environmental Management in Artisanal Mining) and the Ministerio de Energía y

Minas del Peru has also tried to reduce mercury releases by providing free retorts and mercury reactivates.

- Ecuador has developed a Mercury Risk Management Plan which include a Management Plan for mining activity. This Plan propose Politics and Strategies for mercury use and waste generation reduction by implementation of Cleaning Production processes and use of cleaning technologies.

Mercury-added products

In the Health Sector, the international organization Health Care Without Harm and the World Health Organization are leading a joint global initiative to replace medical devices with mercury. Countries that started to eliminate mercury from hospitals or health centers are: Argentina, Brazil, Chile, Costa Rica, Ecuador, Honduras, Mexico, Panama and Uruguay.

In general, the projects implemented in the hospital have a phase to inventory the equipment with mercury, another phase to train the hospital staffs on the management of the new thermometers and the adequate management of mercury, and also the stage of substitution of the thermometers. Since there are no options for the long term storage, the thermometers are temporarily stored in the same hospitals, where they developed safe storage procedures and places. In the project in Costa Rica for example, a system of triple pack was implemented to contain the broken thermometers. When a fever thermometer breaks up, the glass pieces are picked up separately from the drops of mercury, and they are introduced in the original plastic packaging, which is subsequently deposited in gallon containers made of high density polyethylene (2, HDPE) (Figure 1.1a), which are in turn introduced into a larger container (Figure 1.1b).(BLH, 2009)

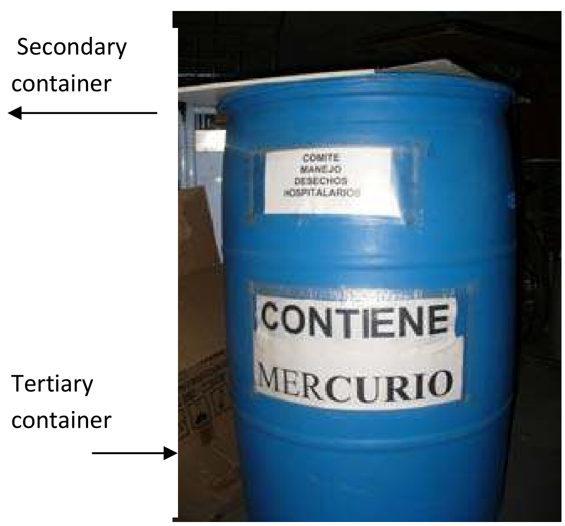


Figure 1.1a

Figure 1.1b

There are also initiatives applied in several countries, such as the project "Regional Campaign to Minimize the Domestic Sources of Mercury with Interventions in the Community for the Protection of the Health of Women and Children in Argentina, Chile, Paraguay, Uruguay, Bolivia and Peru". SAICM, Quick Start Programme Trust Fund, which has the Argentinean Association of Medical Doctors as it Coordinating Organization.

Two projects are being implemented to develop waste management strategies for mercury. The one coordinated by UNEP Chemicals will include Chile, along with other countries to be determined; the other, coordinated by the Secretariat of the Basel Convention, will include Argentina, Costa Rica and Uruguay.(US-EPA – BCCC)

One very interesting work proposal is being carried out in Chile, where some companies develop and implement Cleaner Production Agreements in sectors such as the chemical sector, aiming at eliminating mercury salts in paints.

Some countries, such as Ecuador, Chile and Panama are developing **National Plans for Mercury Risk Management**, with the support of UNITAR, in the framework of its project: **"Mercury Pilot Projects (2007-2009): A Contribution to the Global Mercury Partnership".**

The specific objectives of this project were:

- Developing a mercury emissions inventory report
- Developing a strategy to institutionalize a mercury emissions reporting system within the framework of a national PRTR system
- Designing a plan for mercury risk management taking into account emission inventory data (and mercury-containing products); and
- Engaging stakeholders in partnerships for mercury emission reporting and risk reduction

Similarly, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Dominican Republic developed an analysis of situation for the implementation of a regional PRTR, with financial support of USEPA and USAID and technical support of UNITAR. Another project aims strengthen capacities for mercury inventory development and risk management plans in Central American countries, in two pilots countries: Nicaragua and Dominican Republic (from October 2008 to march 2010). The main components of this project are:

- Conducting a situation analysis of Hg Management that provides information about the strengths and gaps for managing national Hg
- Development of a mercury inventory
- Institutionalization of the inventory in a regional PRTR, to give regular report on mercury releases.

In reference with initiatives for the regional sources of metallic mercury, two partnerships are developed and implemented: Mercury Reduction in the Chlor-alkali Sector and Non-Ferrous metals production.

Chlor-Alkali sector

The objectives of the mercury partnership developed in this sector, are to minimize and where feasible to eliminate global mercury releases to air, water, and land that may result from chlor-alkali production facilities.

In Veracruz, Mexico, an international mercury stewardship workshop was conducted to share methods and guidelines for calculating mercury releases and consumption, share best practices for reducing releases, and encourage adoption of best management practices to facilitate reductions in consumption. Following the workshop, WCC provided the Mexican facilities with a technology mentor for six months to help identify process improvements. The facilities are now considering how to implement best practices at their facilities. Additionally, several Mexican industry representatives traveled to Brazil to tour a state-of-the-art mercury cell facility and to discuss possible future improvements in Mexican facilities.(UNEP, 2008c)

Non-Ferrous metals production

This UNEP global partnership, was established more recently, and it has not identified their leadership yet; their Business Plan should be considered a draft. These two elements have to be considered in the development of the objectives: To minimize unintentional mercury releases from non-ferrous metals mining and smelting through the application of sound environmental technologies and practices; and and to increase the capture and sound management of by-product mercury from non-ferrous metals mining and smelting.

No project have been detected for this sector. It is important to state that this partnership would have to coordinate efforts with the Mercury Supply and Storage partnership, given its close link. (UNEP, 2008e)

2 MERCURY TRADE FLOWS (EXPORTS AND IMPORTS)

LATU and the consulting team carried out a study of the trade flow for LAC, both about elemental mercury as well as its compounds, for the 2007 – 2009 period. The databases of COMTRADE (UNSD) and of private consultants who provide information services to foreign trade were used for this purpose.

This section is intended to provide information about trading of elemental mercury and mercury compounds complementary to that presented in former studies as “Summary of supply, trade and demand information on mercury” (UNEP, 2006) and “Excess mercury supply in Latin America and Caribbean”, (UNEP, 2009b, report prepared by Maxson).

The objectives of this study are:

- To update data about mercury trade in LAC. The first cited report has information about mercury trade for the entire World until 2005. The present study records imports and exports corresponding to 2007 – 2009 period.
- Determine the main importers and exporters in LAC and the relationships with final destinations. One of Maxson’s basic assumptions (and the most significant) is to reduce mercury consumption

in small-scale gold mining globally by 50% over the next 10 years, with a subsequent decline of 5% per year. Small scale miners buy mercury from traders, so it is important to look for evidences about the amounts of mercury traded, origin, prices and other parameters related to these operators.

- Provide a set of suggestions regarding the information system of the mercury transboundary trade. Some inconsistencies were detected in customs registration of operations. The authors consider that best communication practices, based on official records, must be applied during the next years in order to improve traceability of mercury.

The following criteria were followed for the study:

- Imports and exports were analyzed for each of the countries in Latin America and the Caribbean to determine both the intra-regional and the extra-regional flows.
- The information used is official and comes from the customs of the respective countries.
- The data include the total imports and exports in kilograms of each country in the region, as well as the total exports by origin and destination in the globe, to verify the consistency of the declarations of each country, base on COMTRADE statistics.
- Private sources were also consulted, such as the statistics produced by TRANSACTION, which covers the total import and export shipments to and from South America (with the exception of Suriname, French Guyana and Guyana), identifying most of the companies involved in those shipments.

2.1 TARIFF CODING

The Harmonized Commodity Description and the Coding System (HS) created by the World Customs Organization (WCO) are presently used in over 200 countries.

Most of the LAC countries use the HS as the basis for tariff coding of their goods (this is the term generally used in LA). Sixteen of them have signed the HS convention, another nineteen apply it, and the remaining twelve are not reported by the WCO. In turn, the system is applied by several associations or communities of nations: Common Market of the South (MERCOSUR), Andean Nations Community (CAN), Caribbean Community (CARICOM), Latin American Integration Association (ALADI) and Central America Common Market (MCCA).

Table 2.1 presents the situation of each country in the region with relation to the different regional associations.

Table 2.1 – Membership of the countries of the LAC region (Source: MERCOSUR, CAN, CARICOM, ALADI, MCCA).

REGION	COUNTRY	HS	MERCOSUR	CAN	CARICOM	ALADI	MCCA
SOUTH AMERICA	Argentina	+	M			M	
	Bolivia	+	MA	M		M	
	Brazil	+	M			M	
	Chile	+	MA	MA		M	
	Colombia	+	MA	M		M	
	Ecuador	+	MA	M		M	
	French Guyana						
	Guyana	■			M		
	Paraguay	+	M			M	
	Peru	+	MA	M		M	
	Suriname	■			M		
	Uruguay	■	M			M	
	Venezuela	+	MA			M	
NORTH/CENTRAL AMERICA	Belize	■			M		
	Costa Rica	■					M
	El Salvador	■					M
	Guatemala	■					M
	Honduras	■					M
	Mexico	+				M	
	Nicaragua	■					M
	Panama	+					
CARIBBEAN	Anguilla				MA		
	Antigua and Bermudas	■			M		
	Aruba						
	Bahamas	■			M		
	Barbados	■			M		
	British Virgin Islands				MA		
	Caiman Islands				MA		
	Cuba	+				M	
	Dominican Republic	+					
	Dominica	■			M		
	Granada	■			M		
	Guadalupe						
	Haiti	+			M		
	Jamaica	■			M		
	Martinique						
	Montserrat				M		
	Netherlands Antilles						
	Puerto Rico	+					
	St. Bartholemy						
	Saint Kitts and Nevis	■			M		
	Saint Lucia	■			M		
	Saint Martin						
	St. Vincent & the	■			M		
	Trinidad and Tobago	■			M		
	Turks and Caicos Islands				MA		
	U.S. Virgin Islands	+					

+: Signed agreement with WCO

■: Sign no agreements but applies the HS

M: Member,

MA: Associated Member.

The HS uses numeric codes organized by chapters (the first four digits) and subchapters (the first six digits). These codes, as well as their description, are compulsory for all the states that accept the HS, and cannot be modified. The system allows the states to include up to four more additional digits, which can be individually determined by each country, with the aim of classifying, their products of interest more specifically.

The HS is revised periodically by the WCO through its technical committees and made suitable to the new realities. General revisions were carried out in 1992, 1996, 2002 and 2007; each version is identified by the prefix HS and the year (e.g.: HS2007). The latter is currently in force, and it will include a series of suggestions aimed at leveraging its use as a tool to trace mercury stocks in the region.

2.1.1 Mercury and its compounds in HS2007

Chapter 28 of the HS2007 includes all the chemical elements (except for some metals) and the inorganic compounds of definite composition, from the chemical industry.

Elemental mercury has been classified in 2805 and its HS code is 2805.40 ever since at least the HS1992. Thus, LAC importers and exporters declared elemental mercury operations using that position, without any significant identification issues.

The situation regarding mercury compounds is different. The Rotterdam Convention that entered into force in February 2004, establishes the following in its Article 13: "*1. The Conference of the Parties shall encourage the World Customs Organization to assign specific Harmonized System customs codes to the individual chemicals or groups of chemicals listed in Annex III, as appropriate. Each Party shall require that, whenever a code has been assigned to such a chemical, the shipping document for that chemical bears the code when exported..*" Annex III includes, among an extensive list, the following substances: "*Mercury compounds, including inorganic mercury compounds, alkyl mercury compounds and alkyloxyalkyl and aryl mercury compounds.*"
The 2007 version of the HS took into consideration these suggestions and created a specific position for mercury compounds (with exception of amalgams). The new position is the 2852.00. Previously the inorganic mercury compounds, as well as the organo-mercurial, were classified in diverse positions, according to whether they were oxides or salts and in this last case, according to the anion with which mercury was combined (chlorides, sulfates, etc.). In the previous version mercury compounds were declared in twenty-nine positions and with the new system they were grouped into one, facilitating the control of transboundary movements.

The application of the new system (HS2007) regarding mercury compounds is heterogeneous in LAC. Some countries (e.g., full members of MERCOSUR) have added two additional numbers to position 2852.00 and thus have been able to discriminate the movements of the compounds according to one more specific sub classification. Table 2.2 presents the codes adopted by the MERCOSUR countries.

Table 2.2 - Codes adopted by the countries of MERCOSUR (**Source: MERCOSUR)**

HS CODE	COMPOUND CORRESPONDING TO THE CODE
285200	INORGANIC OR ORGANIC MERCURY COMPOUNDS, EXCEPT AMALGAMS.

28520011	Inorganic mercury compounds: Oxides
28520012	Inorganic mercury compounds: Mercury I chloride (mercurous chloride)
28520013	Inorganic mercury compounds: Mercury II chloride (mercuric chloride) for photographic use, in doses or conditioned for retail sale, ready to be used.
28520014	Inorganic mercury compounds: Mercury II chloride (mercuric chloride) presented in other forms
28520019	Inorganic mercury compounds: All others
28520021	Organic mercury compounds: Mercury acetate
28520022	Organic mercury compounds: Thimerosal
28520023	Organic mercury compounds: Mercury stearate
28520024	Organic mercury compounds: Mercury lactate
28520025	Organic mercury compounds: Mercury salicilate
28520029	Organic mercury compounds: All others

This classification has the notorious advantage of being able to determine under which chemical and/or physical form mercury is traded, which allows a more precise analysis when framing an assessment of the element.

In other countries, although they adopted position 2852.00 for mercury compounds, they still allow other mercury free compounds to be shipped under this code (e.g., Chile, Peru) and this yields values above the real ones.

There are countries (e.g., Venezuela) that have not yet adopted this classification and declare mercury compounds in the previous positions (HS2002).

2.1.2 Mercury containing products

Mercury containing products are traded through several tariff codes. In general, these products are classified according to the use and they do not have a specific position. They share the same tariff code with mercury free products.

For example, position 9025.11 is dedicated to liquid thermometers not discriminating between mercury and other liquids (alcohol, etc.). Instruments for blood pressure measuring are dispatched on position 9018.90. It includes sphygmomanometers and other mercury free instruments.

The same is for instruments for atmospheric or closed vessel pressure measuring which are included in the position 9026.20.

One exception is the situation of batteries. HS 2007 position 8506.30 is exclusive for mercury oxide based batteries.

In the case of lamps there exists a partial classification. Position 8539.32 corresponds to discharge lamps based on mercury or sodium not allowing distinguishing between both metals.

2.1.3 Barriers for information collecting

During the process of getting information, innumerable difficulties were found which could present a barrier to monitor the movements of elemental mercury and its compounds. Next are detailed some of the most important difficulties detected at the moment of gathering information on the international trade of mercury in the region:

1) COMTRADE's databases offer global information on the countries, not allowing to know the details about who the exporters and importers are. It is also impossible to know the number of operations, their volume, or the price of each operation.
2) As a consequence of the above, COMTRADE provides no indications regarding the final use of mercury.
3) COMTRADE provides no real indication of the origin of the merchandise or of its final destination. For example, no data can be retrieved when querying about the movements of countries recognized as mercury exporters (e.g., Kyrgyzstan). On the other hand, there are registries of exports of mercury to countries that do not declare matching importation, possible due to transhipment operations, operations in free zones, or black markets.
4) In some countries like Brazil, Bolivia and Venezuela, although the customs offer the details of the corresponding shipments of these substances, they do notdisclose the name of the importers or the exporters.Consequently, these data cannot be identified through the private databases that operate based on official statistics. In the case of products that could affect human health or the environment and that could be subject of a possible international binding instrument, as is the case with mercury, the right of the communities, researchers or consultants to know the name of the stakeholders in the market should precede upon that of protecting trade secrets.
5) The problems already mentioned regarding the declaration of mercury compounds in positions other than the one officially established by WCO, which prevent the monitoring of these compounds.
6) The associated colonies or states (e.g., French Guyana, Puerto Rico, etc.) do not appear as countries either in COMTRADE or in the private databases, is making it impossible to calculate their importations.
7) The lack of specific positions in Harmonized System 2007 for mercury containing products does not allow getting trustable statistics from Customs information.

2.2 Results from official export and import records

Due to the difficulty to monitor all derivates of mercury, a revision was made of the total movements of elemental mercury in all the countries of the region, through a consultation of the COMTRADE database and other sources, such as the Ministry of Foreign Trade of Panama, TRANSACTION – an information system fed with the statistics provided by national customs, SIAVI –Tariff Information System via Internet of Mexico, SIECA – Central America Trade Statistics System.

Tables 2.3 and 2.4 indicate the movements of elemental mercury in the countries of the region, according to their last update (February 2010).

Table 2.3 – Imports of elemental mercury (CODE: 280540 of HS2007)

REGION	COUNTRY	2007 (kg)	2008 (kg)	2009 (kg)	SOURCE
SOUTH AMERICA	Argentina	15778	23820	15506	TRANSACTION
	Bolivia	264	238	4	TRANSACTION
	Brasil	35775	23895	37986	TRANSACTION
	Chile	1426	476	1318	TRANSACTION
	Colombia	67847	79039	130393	TRANSACTION
	Ecuador	12269	15513	10998	TRANSACTION
	Guyana Francesa				COMTRADE
	Guyana	40258	60023	62214	COMTRADE
	Paraguay	3019	10	5	TRANSACTION
	Peru	85815	119303	175956	TRANSACTION
	Suriname	0	0		COMTRADE
	Uruguay	25	5405	2	TRANSACTION
	Venezuela	11	8	2	TRANSACTION
NORTH AND CENTRAL AMERICA	Belize	0	0	0	COMTRADE
	Costa Rica	179	56	27	COMTRADE
	El Salvador	235	1425	746	COMTRADE
	Guatemala	644	952	8277	COMTRADE
	Honduras	124	274	401	COMTRADE Y SIECA
	Mexico	4035	15335	26092	COMTRADE
	Nicaragua	1110	1221	2742	COMTRADE Y SIECA
	Panama	64	154	1	COMTRADE Y COMERCIO EXTERIOR PANAMA
CARIBBEAN	Anguilla	0	0		COMTRADE
	Antigua and Bermudas	0	0		COMTRADE
	Aruba	0	0	5	COMTRADE
	Bahamas	0	0	0	COMTRADE
	Barbados	19	7	11	COMTRADE
	British Virgin Island	0	0		COMTRADE
	Islas Caimán				COMTRADE
	Cuba				COMTRADE
	Dominican Republic		1	0	COMTRADE
	Isla Dominica	0	0		COMTRADE
	Granada	0	5	0	COMTRADE
	Guadalupe				COMTRADE
	Haití				COMTRADE
	Jamaica	0	0	1	COMTRADE
	Martinica				COMTRADE
	Montserrat	0	0	0	COMTRADE
	Antillas Holandesas	1	0		COMTRADE
	Puerto Rico				COMTRADE
	St. Barthelemry				COMTRADE
	Sant Kitts and Nevis	0			COMTRADE
	Saint Lucia	0	0		COMTRADE
	Saint Martin				COMTRADE
	St. Vincente & Granadinas	0	0	0	COMTRADE
	Trinidad and Tobago	22	278	109	COMTRADE
	Turks and Caicos Islands	0	0	0	COMTRADE
	U.S. Virgin Islands	0	0		COMTRADE

Table 2.4 – Exports of elemental mercury (CODE: 280540 de HS2007)

REGION	COUNTRY	2007 (Kg)	2008 (Kg)	2009 (Kg)	SOURCE
SOUTH AMERICA	Argentina	563	431	63	TRANSACTION
	Bolivia	0	0	0	TRANSACTION
	Brasil	0	3795	135837	TRANSACTION
	Chile	2070	0	117641	TRANSACTION
	Colombia	4	0	1	TRANSACTION
	Ecuador	2450	0	0	TRANSACTION
	Guyana Francesa				COMTRADE
	Guyana	0	0	0	COMTRADE
	Paraguay	0	0	0	TRANSACTION
	Peru	59576	86545	106569	TRANSACTION
	Surinam	0	0		COMTRADE
	Uruguay	0	0	0	TRANSACTION
	Venezuela	0	0	0	TRANSACTION
NORTH / CENTRAL AMERICA	Belize	0	0		COMTRADE
	Costa Rica	0	0	169	COMTRADE
	El Salvador	0	0		COMTRADE
	Guatemala	0	276		COMTRADE
	Honduras	0	0		COMTRADE Y SIECA
	México	21346	58476	36688	COMTRADE Y TRANSACTION
	Nicaragua	0	0		COMTRADE Y SIECA
	Panamá	0	0		COMTRADE Y COMERCIO EXTERIOR PANAMA
CARIBBEAN	Anguilla	0	0		COMTRADE
	Antigua and Bermudas	0	0		COMTRADE
	Aruba	0	0		COMTRADE
	Bahamas	0	0		COMTRADE
	Barbados	0	0		COMTRADE
	British Virgen Island	0	0		COMTRADE
	Islas Caimán				COMTRADE
	Cuba				COMTRADE
	República Dominicana		0		COMTRADE
	Isla Dominica	0	0		COMTRADE
	Granada	0	0		COMTRADE
	Guadalupe				COMTRADE
	Haití				COMTRADE
	Jamaica	0	0		COMTRADE
	Martinica				COMTRADE
	Montserrat	0	0		COMTRADE
	Antillas Holandesas	0	0		COMTRADE
	Puerto Rico				COMTRADE
	St. Barthelemry				COMTRADE
	Sant Kitts and Nevis	0			COMTRADE
	Saint Lucia	0	0		COMTRADE
	Saint Martin				COMTRADE
	St. Vincente & Granadinas	0	0		COMTRADE
	Trinidad and Tobago	0	0		COMTRADE
	Turks and Caicos Islands	0	0		COMTRADE
	U.S. Virgin Islands	0	0		COMTRADE

2.3 Information about movements of elemental mercury

2.3.1 PERU

Peru is the main importer of elemental mercury in the region. Destination of mercury is mainly ASGM. The importing operations are strongly concentrated on traders who distribute to final users. No follow up is reported of the purchasers of the mercury sold, and this makes it difficult to identify them. The main market operators are indicated next:

TMC TRIVEÑO: Concentrates 38 % of the volume of elemental mercury imported in the period 2007-2009. The sources are varied, mainly the United States but also Chile, Ecuador, Mexico and the Netherlands. Its main supplier is the same group, but it also imports from other companies such as Mercury Waste Solutions LLC from the USA, Bethlehem Apparatus Company from the USA, DFG Mercury Corp. from the USA, Claushuis Metaalmaatschappij BV from the Netherlands, and Grupo Minero Rago from Mexico.

M & M TRADING. With 33 % of the imports, M&M Trading is the exclusive distributor of Minas de Almadén and Arrayanes S.A. from Spain in Peru.

Others. Taken individually, the rest of the companies do not reach 7 % of the market share for the period under consideration. The more outstanding ones are: International Industrial Products, General Chem, Alvior Negocios Generales, and Mercantil S.A., among others.

Peru is also the greatest exporter of mercury in the region. The destination of the exportations is, almost exclusively, to the United States. The operations are on the account of gold mining companies. The main exporter is Minera Yanacocha SRL, with 63 % of the volume for the period; ranking second is Minera Barrick Misquichilca, with 36 %. TMC Triveño exports less than 1 %, mainly for dental use.

The increasing amount of mercury exported by Peru reflects a big capacity of producing elemental mercury from gold and other metal mines. This fact could be critical at the moment that ban exports in USA and EU start to be applied, because Peru (and other countries) could be an alternative supplier for miners.

2.3.2 COLOMBIA

This is the second importer of mercury in the region. Similarly to Peru, the operations are concentrated in distributing companies. The main importers are:

INSUMINER S.A. – had 37 % of the imports for the 2007-2009 period. It imports mercury and cyanide for the mining industry. It gets its supplies mainly from the Netherlands (Claushuis Metaalmaatschappij BV) and to a lesser extent from Spain (Minas de Almadén y Arrayanes S.A.).

JOSE SANTIAGO VILLA ESTRADA - imports 22 % of the mercury. Its main supplier is the company Pedro de Verona Gómez Flores from Mexico, and it also imports from Spain (Minas de Almadén y Arrayanes S.A).

DISTRIBUIDORA DE QUIMICOS INDUSTRIALES – has 16 % of the market. It imports from different places: The Netherlands, Germany, Belgium, and Spain.

OTHERS - The rest of the importers do not make 8 % individually. The most important are: New Stetic S.A., Ferretería El Pedalista, Pacific Chemical Corporation and Refinadora de sal REFISAL.

Colombia not reports almost mercury exports.

2.3.3 CHILE

Mercury imports in Chile are relatively minor, and they are concentrated in dental applications (CENTRAL DE ABASTEC.DEL S.N.S.S) and testing laboratories (MERCK S.A.). Mercury has been occassionally imported by metal recycling companies (Comercial Hual S.A.).

Regarding exports, the operations in 2009 of Compañía Minera Mantos de Oro to the United States stand out, with a total of 117,640 kg, after five years with no mercury export operations. Similar considerations made for the production of mercury in Peru could be made for Chile.

2.3.4 ARGENTINA

Mercury imports to Argentina are strongly concentrated on manufacturers of chlorine and caustic soda. The main importers are: Solvay Indupa SAIC (manufacturer of caustic soda and polyvynyl chloride), Atanor S. en C. (manufacturer of chlorine and caustic soda), Keghart S.A. (manufacturer of chlorine, caustic soda and sodium hypochlorite) and Transclor S.A. (manufacturer of chlorine, caustic soda and sodium hypochlorite). These industries are responsible for 89.7 % of the country's total importations of mercury. In second place are the laboratories manufacturing dental inputs (Calamante, Laboratorios SL S.A. and Macrodent S.A.), with 9.6 % of the imports for the period.

The very small quantity of exports corresponds almost exclusively to mercury for dental applications.

2.3.5 BRAZIL

There is detailed information about the different exporting and importing shipments through the software TRANSACTION. Aliceweb, of the Ministry of Development, Industry and External Trade, does not provide information about the importers (Resolution SRF nº 306, of March 22, 2007) or exporters to the public.

Through ABICLOR, it was known that during 2009, the company Solvay (Brazil) exported to Spain a total of 130,632 kg of mercury derived from the deactivation of its mercury-based processes . The product was sent to MAYASA for storage purpose.

2.3.6 ECUADOR

Imports of mercury are in the hands of small distributors dedicated to supplying inputs and machinery for mining (RF Importaciones, Bestmina S.A., Crecicorp S.A., Gallardo Romero, Figueroa Ordoñez, Jimenez Astudillo, among others) and only a small proportion is destined for dental use.

2.3.7 MEXICO

Imports of mercury to Mexico come almost exclusively from the United States. Exports in the 2007-2009 period outweigh imports and their main destinations are: Colombia, Peru, Argentina, Nicaragua and Brazil. Exporters are companies that produce or recycle mercury. The most important ones are: Grupo Minero RAGO de México, Metalúrgica Lazcano, Pedro de Verona Gómez Flores, and Comercializadora Carl Karm.

Once export bans in USA and EU enter into force, Mexico will probably strengthen its positions in the rest of the region as their supplier, as long as the country does not develop an export ban.

2.3.8 GUYANA

According to Telmer (Telmer and Veiga, 2008), Guyana is one of the most important consumers of mercury for artisanal mining. It gets its supplies mainly from the United States and in a little quantity from Peru. It was not possible to obtain the data about exporters or importers.

Guyana is the third importer of mercury in the region having grown more than 50 % in the 2007 – 2009 period.

2.3.9 OTHER COUNTRIES

SURINAME is an important producer of gold through artisan mining, but it was not possible to obtain official information regarding movements of mercury. Since 1996 Suriname does not report information on mercury imports to COMTRADE. Since 2005 there are no exports records from the rest of the world to Suriname. According to statistics from COMTRADE, in 2007 the United States exported 118 tons of mercury amalgam, but this is not officially recorded in the corresponding importations. It is one of the most worrisome cases, due to the involvement of high level officials, and the multiple reports about pollution cases (VEIGA for UNIDO 1997a, UNIDO 1997b, WWF 2004) and the scarce official information available about mercury trade.

GUATEMALA shows a very important growth in mercury imports. In 2009 imported more than 8 tons of elemental mercury. It is the bigger mercury consumer in Central America. Guatemala is reported as one of the main artisanal gold miners in the region.

NICARAGUA has duplicated its demand of elemental mercury in 2009 being the second importer in Central America.

BOLIVIA, in spite of having a vast artisanal mining network that uses mercury in the amalgamation processes (Bocangel, 2001), the levels of mercury imported are extremely low (approximately 200 kg/year). It is assumed that there is a considerable illegal flow from some of the neighboring countries.

URUGUAY presents occasional imports of mercury for the only manufacturer of chlorine – soda (Efice Cloro Soda S.A.). Mercury is also imported for dental use in small quantities (tens of kg).

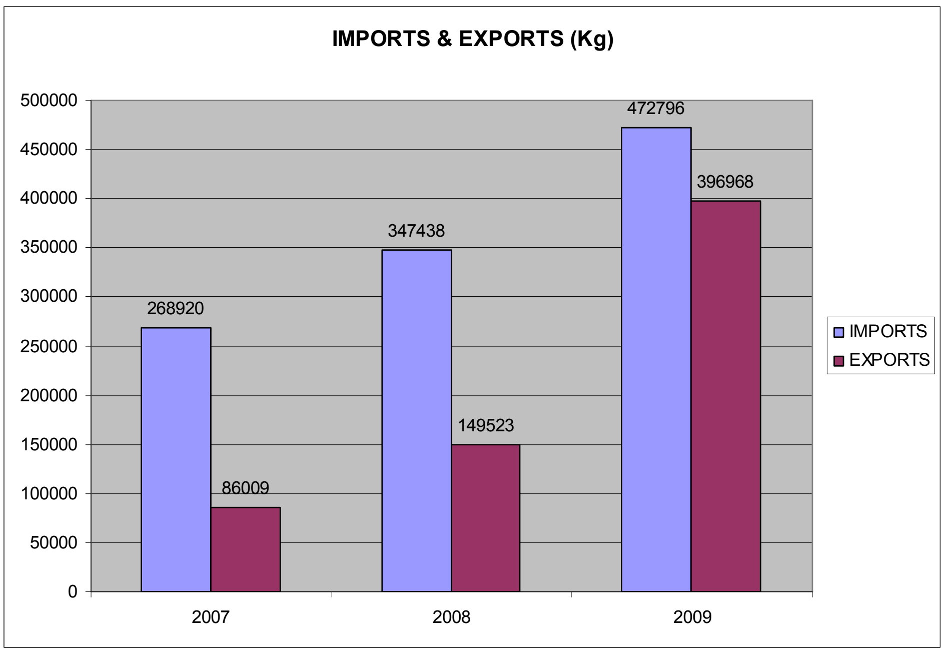
2.4 Analysis of information

The following table shows the total elemental mercury traded both intra and extra regionally.

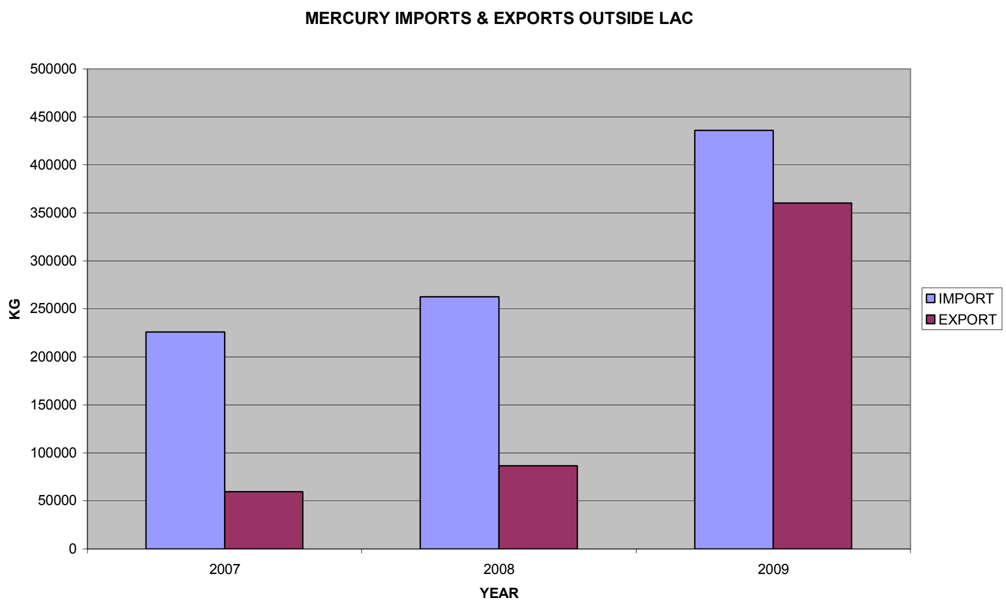
Table 2.5 - Elemental Mercury traded intra and extra region

	IMPORTS (kg)		EXPORTS (kg)		BALANCE (kg)	
	TOTAL	OUTSIDE LAC	TOTAL	OUTSIDE LAC	TOTAL	OUTSIDE LAC
2007	268920	225685	86009	59597	182911	166088
2008	347438	262683	149523	86544	197915	176139
2009	472796	436167	396968	355072	75828	81095

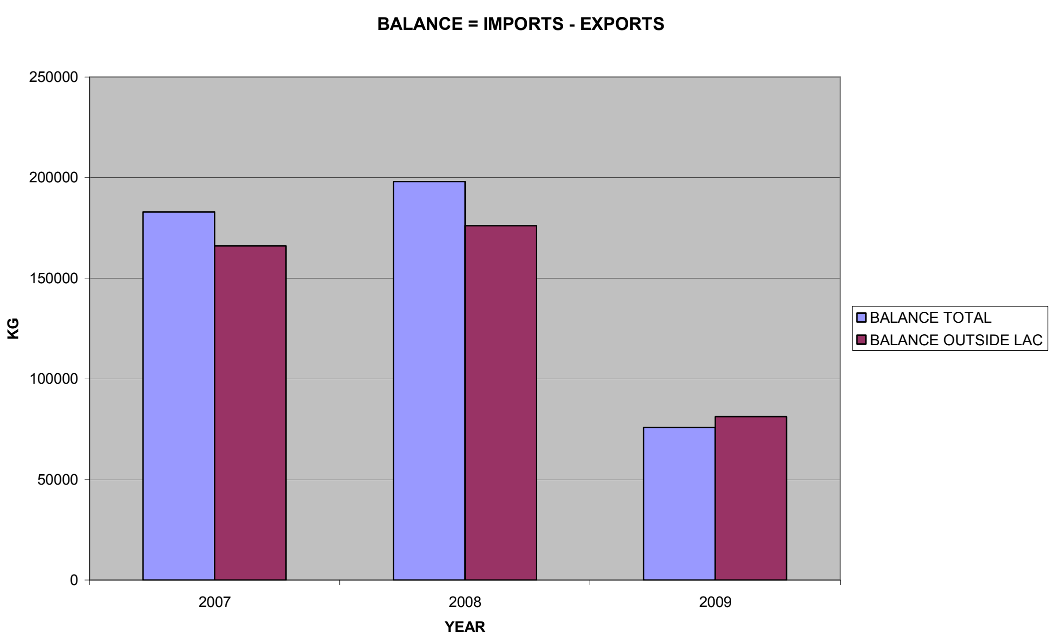
Graph 2.1 – Mercury total imports & exports



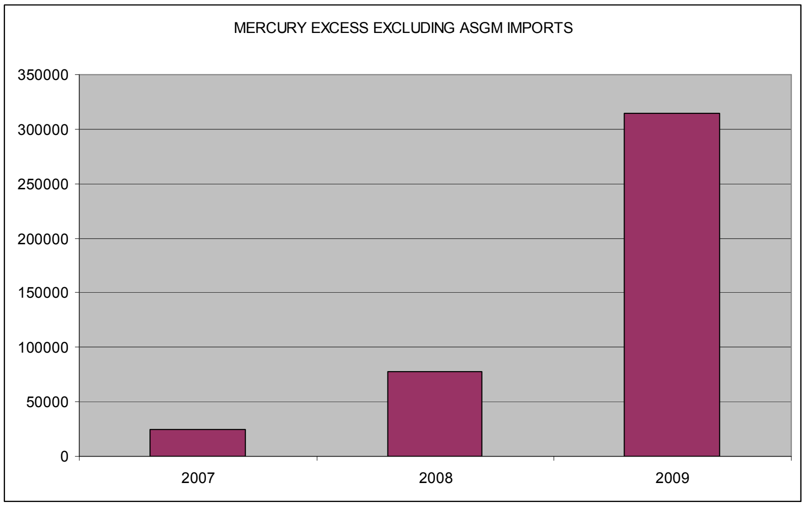
Graph 2.2 – Mercury imports & exports outside LAC



Graph 2.3 – Balance = imports - exports



Graph 2.4: Mercury excess excluding ASGM



Some general conclusions can be drawn from these data. First of all, both mercury demand and supply increased during the last three years. The gap between them was clearly reduced in 2009.

2009 shows high values in imports and surprising ones in exports. Based on statistics, the reported export of Solvay Brazil to Spain were approximately 130 tons, showing that almost 260 tons were exported by the region. Such a huge quantity, in the hands of just a few companies, warrants a careful interpretation before any conclusion can be drawn about any changes in trends.

As it was stated by Maxson, the mining sector is the most relevant player in mercury trade. This sector is responsible for practically all the imports in Peru, Colombia, Ecuador and Guyana. Some Central America countries (Guatemala and Nicaragua) have raised their imports dramatically in the last year. The USA is the main supplier for these countries, followed by EU countries (mainly Spain and the Netherlands). This industry accounts for the continuous growth of imports in LAC. Future export bans will certainly affect the supply of mercury to these producers.

Exports from Peru and Chile correspond to mining companies too. USA is practically the only destination.

Maxson has estimated the consumption of mercury by the mining sector to range around 165 and 330 tons /year (reference 2005). The average demand for the 2007 – 2009 period falls between this ranges, in spite of the unusual levels reported in 2009. According to Maxson assumptions, demand will fall in the forthcoming years.

Regarding supply, Maxson says: “In total, while the present production of mercury appears to be in the range of 150 tons/year, the potential in the near- to mid-term is significantly higher. For the purpose of this analysis it is assumed that mercury recovery from Latin American mines (other than zinc) will increase to around 200 tons/year by 2015 and remain more or less at that level into the future.” The increasing supply of elemental mercury showed in 2009 would be consistent with the high potential estimated. The average supply is close to Maxson’s estimation, but the very high levels reported in 2009 require a careful follow up of future operations, mainly in Peru and Chile, to detect whether that reflects a change in the trend or merely a spot sales. It is still too early to draw any conclusions about it.

2010 will probably be an unusual year, too, due to the USA exports ban that will enter into force as from 2011. Some companies could bring imports forward and reinforce stocks.

Mercury consumption by chlor alkali plants remained almost constant during this period.

UNIDO and other experts have determined that mercury supply reductions can contribute to significant demand reductions in artisanal and small-scale gold mining; supply and demand reductions for this sector are mutually reinforcing, and to some extent supply reductions must precede demand reductions in order to work most effectively (Maxson for UNEP, 2009).

Graph 2.4 shows the result of excluding current ASGM mercury imports. The mercury surplus resulting from this simulation clearly evidences that urgent actions related to storage have to be taken.

Export bans in USA and EU will help to reduce supply to LAC. On the other hand, the increasing capacity of processing showed by some mining companies in the region could be considered as a threat for the supply reduction policies. Very strict controls must be applied on production and local sales of these companies together with proposed actions about information and control of foreign trade.

2.5 PRODUCTS WITH MERCURY

2.5.1 Mercury Compounds

The difficulties mentioned above regarding the inclusion of position 2852.00 of products that do not contain mercury do not allow estimating the real trade of these commodities. In the case of those countries where it is possible to know the detail of the shipments, records were debugged to obtain the values corresponding exclusively to mercury compounds. Table 2.6 details the corresponding imports.

Table 2.6 – Mercury compounds imports

REGION	COUNTRY	2007 (kg)	2008 (kg)	2009 (kg)	Source
SOUTH AMERICA	Argentina	535	3645	2070	TRANSACTION
	Bolivia	94	258	82	TRANSACTION
	Brazil	2741	2155	1325	TRANSACTION
	Chile	76	102	91	TRANSACTION
	Colombia	24	138	71	TRANSACTION
	Ecuador	4	28	0	TRANSACTION
	Paraguay	130	152	101	TRANSACTION
	Peru	107	104	76	TRANSACTION
	Uruguay	114	31	58	TRANSACTION

Studies carried out by US-EPA include monitoring exports of mercury compounds, especially those more likely to become sources of elemental mercury, such as mercury chloride I (calomel).

Overall, the current volume of import operations is found to be small in relation to elemental mercury.

However, with the enforcement of the Export Ban in Europe and USA, it is important to monitor these compounds.

Imports are concentrated in companies that supply testing reagents analysis. The most traded compound is mercury chloride (II). Particularly highlighted are the importations of the company Laboratorios Químicos S.R.L. (Laboratorio Gihon) of Argentina, which manufactures Thimeroral; the firm imported 6,134 kg of mercury chloride (II) in the 2007 – 2009 period.

2.6 CONCLUSIONS

From the analysis of the information presented herein it is possible to extract the following conclusions:

a) Both imports and exports have increased during 2007 – 2009. 2009 showed very high levels of exports.

b) The faster growing exports of mercury, mainly by mining companies and chlor-alkali plants that discontinue the use of the metal in their processes, start to reduce the net entry of mercury into the region, to the point that in 2009 imports for the first time equate exports (provisional numbers), according to local information;

c) Real figures are similar to Maxson's estimation for both supply and demand at the beginning of estimated period (2010 – 2050) for the base case scenario, with an estimated excess of 8.300 tons of mercury to be stored. Maxson's estimation of the elemental mercury excess for the 2010-2050 period is presented in Annex 2.

d) The production and sales from mining companies that produce elemental mercury as a byproduct have to be monitored carefully. The volume is increasing and it could substitute the supply from USA and Europe.

e) The information gathered indicates that the main importers of the Andean block (Colombia, Ecuador and Peru) are traders that distribute the product to miners.

f) The main importers in Argentina are the manufacturers of chlorine – soda.

g) In Brazil, there is evidence showing that in addition to chlorine – soda plants, there are other important distributors of mercury; however their names could not be identified because of the reasons explained above.

h) Countries with a recognized artisanal gold mining activity (Suriname and Bolivia) do not report significant amounts of mercury in their imports; that suggests an illegal flow of the metal through their borders.

i) Official information regarding foreign trade is not homogeneous in the registry and/or communications, hindering the study about intra- and extra- regional exchanges. At present, importers and exporters can be easily identified only in the following countries: Argentina, Chile, Colombia, Ecuador, Paraguay, Peru and Uruguay.

3 FACILITIES FOR THE SEQUESTRATION OF MERCURY

According to the scenarios proposed by the consultant Peter Maxson, an excess of the supply of mercury over its demand in Latin America and the Caribbean is expected to be seen sometime between 2013 and 2019, with figures of 1,260 t of mercury to be sequestered in 2020.

Various scenarios assume gradual demand reductions throughout the period of 2010-2050. Assuming the mercury supply is restricted at the same time, this would advance the need for storage capacity, as estimated in the Base Case Scenario at 8,300 tons for all LAC countries in 2050.

In his report “Excess mercury supply in Latin America and the Caribbean, 2010-2050”, Peter Maxson concludes that despite the significant potential mercury excess in the region, the Latin American and the Caribbean region is actually a significant importer of mercury, mostly for the use in small-scale gold mining, in chlor-alkali industries and dental care, with lesser amounts incorporated in mercury-added products. These facts have been confirmed in the previous section by the revision of the transboundary movements of mercury and compounds in the region.

Maxson also concludes that mercury supply reductions can contribute significantly to curb the demand, especially in artisanal and small-scale gold mining. In consequence, for the Latin American and Caribbean region, the planning of mercury storage may be especially important as an initiative to further encourage demand reduction.

To help reduce mercury consumption, Peter Maxson suggested that regional authorities should accelerate the storage of excess mercury, whereby mercury recovered from decommissioned chlor-alkali facilities would be stored first, and then by-product mercury recovered from metal ore processing would be stored in a second step, thus following a certain hierarchy of storage priorities.

The present study is based on the above mentioned scenario and for the most important sources of mercury surplus it identifies the methodology, places, costs and restrictions for elemental mercury long term storage as a final objective.

Considering the information exposed before, two main options that are being considered the best alternatives for mercury long term storage in the EU, USA and other regions, will be analyzed: above-ground special engineered warehouses and underground storage in geological formations. Mercury exports outside and within the region will be presented as alternative option.

The review of the state of the art of the facilities for mercury storage and the necessary specifications for construction, operation and preliminary treatment offers to the LAC governments a new look on the issue and supplies to decision makers technical criteria already tested in other parts of the world.

The report presents the techniques and technologies that are considered as most appropriate for mercury management before storage in accordance with the international criteria for environmental safety and health.

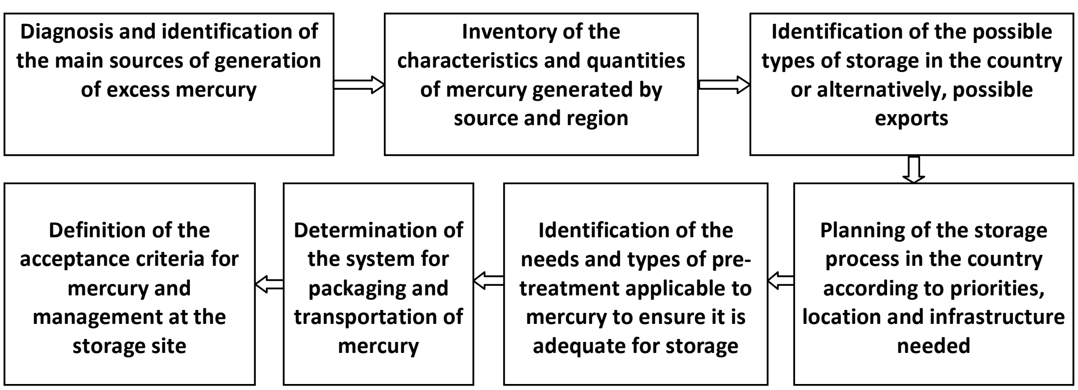
In that sense, the countries in the region must have the diagnoses of their main sources of mercury and records of the movements of metal across their borders. Once these data are available, the governments can develop the inventories of the amounts of mercury that will need to be stored in the period of 2010-2050. Storage priorities must be set in accordance with the amounts, levels of exposure of the community and main risks resulting from the potential use of mercury for other purposes that entail a greater environmental risk, such as gold mining.

It is important to know the characteristics of mercury to be stored, such as the degree of purity, sodium contamination and degree of humidity. Those features determine the need and type of pre-treatment required to facilitate costs abatement and to contemplate the environmental and social requirements for storage.

There are some conditions that must be considered when defining the storage model to be adopted by the countries in the region, such as location, concept of storage or final disposal, annual costs, investment needed and requirements specific to each country. Mercury may be transiently stored in liquid form, duly packed and protected.

Figure 3.1 defines a sequence of actions the countries of the region must consider in their decision-making process:

Figure 3.1 – Sequence of actions to be adopted for the storage of mercury



The chapters below provide details on the earlier stages of storage, such as management, packaging and transportation, treatment, potential storage options and the excess mercury generated in the LAC region.

3.1 Elemental mercury management

The storage of elemental mercury is preceded by various operational steps: packaging, labeling, transportation, reception and acceptance, over packing and placement.

3.1.1 Packaging

Elemental mercury requires special containers for internal and international transport and storage. The packaging system is an integrated element of the safe storage of metallic mercury. It is an engineered barrier, which is designed to ensure operational safety during interim storage, transport and waste package handling operations. It may also provide a long term containment function (BIPRO, 2010a).

The International Air Transport Association (IATA) Packing Instruction 803 allows transporting flasks containing less than 35 kg of mercury. The flask must pass the 95 kPa pressure test for liquids exposed to air traffic (IATA 5.0.2.9) (Oak Ridge Laboratory, 2009b).

Within the International Maritime Dangerous Goods (IMDG) Code (Amendment 33-06), the Packing Instruction P800 (version valid until December 31, 2009) allows transport via ocean vessels for flasks containing less than 3.0 L of mercury.

Larger Containers which are transported by ground transportation are designed, manufactured, and tested for elemental mercury (99.5% by volume or better) and must work at containing pressures of under 15 psig (100 kPa above atmosphere).

Metallurgical threats to permanent storage in steel flasks, like external corrosion due to moisture/condensate and poor quality or improper welds, were identified by the Corrosion Science and Technology Group of the Oak Ridge National Laboratory (Oak Ridge Laboratory, 2009b). Their main recommendations are:

- Use of mild steel and stainless steel containers immune to pure Hg for anticipated exposure conditions and appropriate for long-term storage;
- Construction of new containers requires appropriate specifications and quality assurance, including design considerations for handling and stacking as necessary;
- Management of external corrosion, avoiding acceptance of “unknown” compositions of Hg.
- Evaluation and special handling or inspection is required for transport on older vessels.

Mercury Storage Containers are designed for volumes of 3L, 1 Mt, 2Mt and 10 Mt. The reliability of the container design has to meet the following criteria:

- Depth of mercury should be less than 0.7 m from the top of fill port. (Maximum height a vacuum pump can raise mercury is 0.76 m).
- Avoid using a drain valve to allow mercury removal from container.
- Welds are likely to be the weakest point in container construction and require greater focus in design and quality control during manufacturing. Newer flasks are made without welds.

- Use of a National Pipe Thread (NPT) plug with Teflon® tape provides excellent seal at low cost.

- Use of two ports on top of the container provides the fastest filling method (as shown on 10-MT example). One port is connected with a vacuum pump, while the other is the mercury inlet.

- Carbon Steel (ASTM A36 minimum) is the recommended steel choice.

Recommendations for 3L container design are:

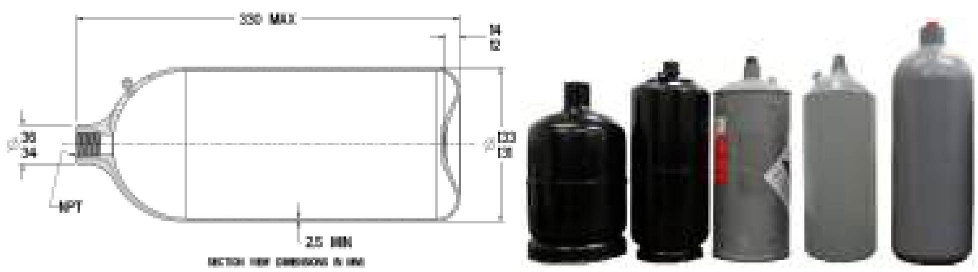
– Seamless container (no welding, similar to gas cylinder).

– Interior volume between 2.9 L to 3.5 L.

– Estimated empty mass, 9 kg.

Container storage provides the highest cost per volume of mercury stored. It is a good choice for small mercury generators and can be easily transported by ocean vessel, ground, or air. The storage is generally executed in pallet boxes, typically 49 flasks per pallet (pallet size 1.25 m x 1.25 m). The reported cost is approx.US$ 20.00/ flask.

Figure 3.2 - Design of 3L flask - 76 lb or 34.5 kg (**SOURCE:** Oak Ridge Laboratory, 2009)



The 1-Metric, 2-Metric and 10-Metric Ton containers must be constructed with Carbon Steel (ASTM A36 minimum). A protective coating (epoxy based paint) against exterior corrosion must be applied. The containers cost more than twice the 3L flask. The advantage being a reduced cost per volume of mercury stored when compared to 3-L flasks. They are easy to transport and handle with a forklift. Figure 3.3 shows a model presented by Oak Ridge Laboratory and is similar to 2-Metric Ton design. The 10-Metric Ton container design is presented in the Figure 3.4.

Figure 3.3 - 1-Metric Ton Container (**SOURCE:** Oak Ridge Laboratory, 2009)

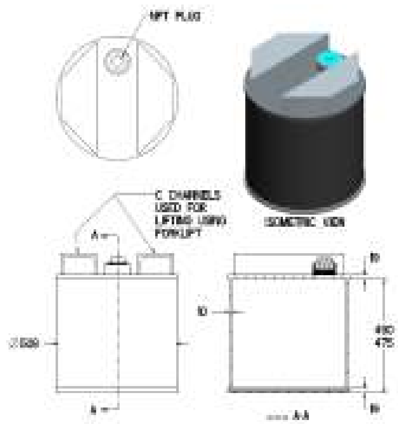
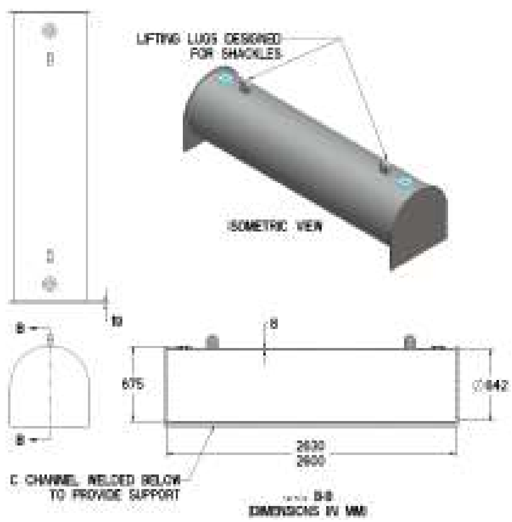


Figure 3.4 – 10-Metric Ton Container (**SOURCE:** Oak Ridge Laboratory, 2009)



According to BiPRO, in the report "Requirements for facilities and acceptance criteria for the disposal of metallic mercury" for the European Union, steel flasks (34.5 kg net) and containers (1 metric ton net) are the main packing for the transport and stockpile of liquid mercury in Europe. Both are UN-approved and meet the requirements for transport on the road (ADR), by rail (RID) and ship (IMO). In addition, the smaller flasks meet the requirements for the shipment by air (IATA). Both containers are made of steel with a lacquered interior. Other requirements for European Union are: container has to be gas and liquid tight; outer side of the container must be resistant against the storage conditions; containers should be certified for the storage of mercury; welds should be avoided as far as possible.

Figure 3.5 - Standard mercury steel containers used by Mayasa- Almadén (SOURCE: BiPRO, 2010a, 2010c)

The flasks are suitable for stockpiling on standard wooden pallets (115 cm X 115 cm x 13.5 cm). The 1 metric ton containers have a height of 66.2cm and a diameter of 70cm. The costs for the current carbon steel flask commonly used (34.5 kg) is approx. €10 (US$ 13.5 /flask), for a 1 ton container the costs are around €700 (US$ 945). Other cost estimates vary from €600 to €1,100 (stainless steel) for the 1 ton container (BiPRO report).

There are no reports of packaging costs in LAC. Mexican consultants report figures of approx. US$ 70 / flask. Some recyclers in the USA offering services to Latin America include the cost of US$ 26 packaging and documents, such as a safety sheet and a manifest. In Brazil, the only mercury recycler uses re-used flasks from importation, which are discarded by chlor-alkali industries and other importers.

Handling - Health and Risks control

Mercury exposures occur at various stages in the handling process in a facility. Improper handling of metallic mercury may result in mercury emissions with adverse effects to workers and the environment. Established occupational and health regulations have to be taken into consideration. Workers exposed to mercury are the primary focus of an occupational exposure assessment.

Occasionally, workers can bring mercury into their homes through contaminated clothing and shoes and in this way their families are exposed to the metal contamination. In a saturated atmosphere, at a temperature of 24 ^{o}C, the mercury concentration is 360 times superior to the maximum average permissible in an occupational exposition (Limit value WHO - average concentration of mercury vapor in an 8-hour journey – 25 µg/m^3) (CPEHS, 1987). Therefore a screening assessment can provide information regarding exposure, with and without technological devices.

UNEP promotes occupational joint committees to discuss elevated mercury exposures related to the activity areas and place of work. In Brazil these committees are called CIPA (in English: Internal Committee for Accident Prevention). These internal committees are active in most big companies in LAC. Important issues for the committees include ventilation, clean-up procedures, mercury and mercury wastes storage techniques, containers, work shifts, rotation on the different tasks performed by the workers (some tasks being more at risk of exposure), personal protective equipment, and education related to mercury vapor exposure. Comprehensive information about mercury must be available for appropriate handling of mercury and mercury compounds in all establishments. In most countries in LAC safety information regarding mercury and mercury compounds is available, (may be not in the establishment where mercury is used). In some countries, such as Mexico, Ecuador and Brazil, the safety sheet must comply with national standards.

Air in the workplace must be monitored in order to prevent and control mercury release. DOE – USA uses Lumex and Tekran technologies for air monitoring. Both are available in LAC.

An initial characterization phase, using a data collection sheet can provide qualitative information about the potential for exposure of workers to mercury vapor through inhalation. Blood and urine are the usual biomarkers of exposures to metallic mercury in the workplace or through other exposure scenarios. Blood mercury can be a good indicator of recent exposure to metallic mercury. According WHO, the reference values are:

- Standards: max 10 ng/mL
- Toxic concentration: more than 50 ng/mL
- Individuals exposed (urine): less tan 35ug/g de creatinine

No mercury specific provisions are implemented on EU level, nevertheless the general established occupational and health regulations have to be taken into consideration during the handling and transport of metallic mercury (e.g. compliance with existing occupational limit values for mercury).

BiPRO (2010a, 2010c) reports the specific requirements for the safe handling and transport of liquid mercury established by the Euro Chlor Voluntary Agreement on Safe Storage of Decommissioned Mercury. Being the appropriate handling of elemental mercury a new issue for most countries in LAC, we present the following requirements below:

- *Mercury shall be delivered to the storage site as a liquid in hermetically sealed containers ready for storage.*
- *The containers will be placed in a dedicated area in the storage site.*
- *The containers will be made of steel, with top connection only (no bottom valves) and should have ADR/RID approval for transportation. The containers will normally have a capacity in the range of 1 ton of mercury. Containers of other capacities may be used if appropriate.*

- *The containers will be used for transportation and storage to avoid further manipulation of mercury on the storage site.*
- *The containers will have a visible indication of their empty and full weights.*
- *Before filling the containers, residual sodium concentration in the mercury will be checked to ensure that there is no risk of hydrogen production.*
- *The container shall not be completely filled to avoid overpressure by thermal expansion.*
- *After filling, the container will be hermetically closed. The filled containers will be weighed for the quantity of mercury; sealed and properly identified: product with UN code, danger signs, amount, sender, and date and reference number to trace the origin.*
- *During loading and unloading trucks or rail wagons, all precautions will be taken to avoid any spill and emergency aspiration equipment will be ready to collect accidental spillage.*

3.1.2 Transport

The specific requirements for the transport of mercury by truck, rail, vessel and air are provided by each country regulation on hazardous or dangerous substances transportation. In LAC some of the countries have their own legislation for transport, manifest systems, packaging and truck labeling, as well as training programs for hazardous substances transportation (UN and/or CAS codes). International regulations are applied for international shipment.

The air shipment requirements are established by International Civil Aviation Organization regulations and the air carrier's requirements are defined by the International Air Transportation Association (IATA) regulations.

Specific stipulations for water transport are determined by the International Maritime Dangerous Goods (IMDG) regulations.

Before a hazardous substance may be shipped off-site, the generator must determine its proper identification, packaging, and the labeling, marking, and placarding requirements; and the information necessary to complete and sign the manifest for the substances shipment.

Specific requirement for transport of mercury is defined by the USA Department of Transportation: 49 CFR 173.164 addresses the specific requirements for transporting mercury; Subsection 173.164(a) addresses air transport; Subsection 173.164(d) addresses transport other than by aircraft; and subsection 173.164(e) discusses exempt quantities.

In the USA the primary means of mercury transport is by ground. For all transportation, mercury packaging must meet the regulation requirements. The most accepted method is non-specification reusable metal packaging.

It is very important to ensure that all the general requirements and specifications for hazardous materials packaging are met. Referring to container size, an approximately 0.75-gal (3-L) size holds around 76 lb (32 kg) of elemental mercury and an approximately 19.5-gal size holds approximately 2200 lb (1 MT) of elemental mercury.

Additionally, secure outside packaging may include steel drums, steel jerricans, wooden boxes, plywood boxes, reconstituted wood boxes, fiberboard boxes, plastic boxes, plywood drums or fiber drums.

It is recommended for inner and outer packaging, to use linings or bags of strong leak proof and puncture-resistant material impervious to mercury, completely surrounding the contents, so that the escape of mercury will be prevented irrespective of the position of the package.

Except for air transport, packages containing less than 0.45 kg (1.0 lb) net weight of mercury are exempt from the hazardous materials transport regulations.

Training programs regarding transport and management of hazardous substances are required for employer and employees.

3.1.3 Acceptance, inspection and overpacking

Before a mercury shipment is accepted in a storage facility, the generator must comply with the local or national legislation, including an approval for sending the shipment to the mercury storage. The documentation requirements of environmental authorities and of the technical requirements for mercury shipment to the storage facility must be met.

Upon arrival at the mercury storage facility, initial inspections of containments, manifest and documentation are checked if they are acceptable. Containers and pallets that pass the acceptance/verification process will subsequently be transferred to a long-term storage area. Containers that fail inspection will be returned to the generator (sender).

In order to avoid corrosion and hydrogen production, it is recommended that metallic mercury to be stored complies with the following requirements, some already regulated in USA and Europe (BiPRO, 2010):

- Purity – superior than 99,5% per weight;
- Metallic contaminants (iron, nickel, copper) : <20 mg/kg of Hg
- Sodium: < 1 mg/kg Hg
- No residual radioactivity;
- No measurable impurities capable of corroding carbon or stainless steel (e.g. nitric acid solution, chloride salts solutions, or water)

In the process the mercury will then be moved to a receiving area, where additional inspections and samples are taken. If the requirements are not fulfilled, the mercury needs to be purified before the storage (distillation process).

For mercury stored in flasks, proper outside packing may be required. The flasks are inspected/ cleaned, and rearranged 6 flasks each, into epoxy-coated steel drums, with layered protection:

- Absorbent pads
- Plastic liners
- Half inch rubber gasket
- Air & liquid tight/locking ring

The system helps to protect the flasks against corrosion and prevents mercury vapor emissions.

Figure 3.6 shows the storage area and the packaging and over packing system to be used in the Hawthorne Army Depot.

Figure 3.6: Storage area and packaging (**SOURCE:** DNSC- 2003)

3.2 Stabilization and immobilization, solidification and other appropriate technologies for metallic mercury

The physical properties of elemental mercury present significant challenges to its long-term management. Mercury cannot be destroyed. Elemental mercury is easily vaporized due to its high vapor pressure at room temperatures. Elemental mercury is not significantly soluble (solubility of elemental mercury is 0.056 mg/L at 25 ^{o}C - MERCK Index) and therefore not readily detected by short term leachate tests.

Disposal of large amounts of mercury and mercury compounds must avoid the release of vapor emissions to the environment, leaching or contaminated solids, depending on the option for storage selected.

In the USA mercury is stored for more than 40 years in warehouses above ground without any pre-treatment.

A Study carried out by USEPA, drew on information prepared by SENES, the Canadian Consultants (SENES, 2001 by US-EPA, 2002) on the development of retirement and long-term storage options for mercury. SENES evaluated 67 technologies and reviewed a further 9 technologies but failed to rank them because of the paucity of information (US-EPA, 2002). Although in this study US-EPA selected

11 options for the pre-treatment and final disposal of mercury, the USA chose to avoid pre-treatment and to dispose of mercury in above-ground facilities.

The European Union looks for permanent mercury storage in underground facilities, options with pre-stabilization and solidification are under consideration in order to guarantee mercury isolation from the biosphere.

A recent screening analysis contemplating 8 options or combination of options such as underground or above ground storage, with or without pre-treatment, temporary or permanent storage was presented to the EU by the consultant enterprise BiPRO (BiPRO – 2010c).

This report will consider the main alternatives of elemental mercury stabilization and encapsulation evaluated in Europe based on the research for underground and above ground storage, commonly regarded as the main alternative for mercury sequestration. In this context the EU consultants BiPRO immersed themselves in extensive and in-depth research on all types of treatment, patents, and suppliers in Europe and USA. Two documents (BiPRO, 2010a,b) were prepared for the European Union. BiPRO consultants use extensive criteria to determine the minimum requirements, taking into account technical (> 1kg Hg can be treated), environmental (Vapor pressure < 0,003 mg/m^3) and economic (< US$ 26.000/TM) and legal aspects.

We present in this report some commercially available options for the elemental mercury pre-treatment (stabilization and solidification) and other alternatives used or tested by institutions like US EPA.

Stabilization refers to techniques that chemically reduce the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms. The physical nature and handling characteristics of the waste is not necessarily changed by stabilization (US EPA 1999, by SBC, 2010).

In practice, a stabilization process involving metallic mercury, blends it with a substance (e.g. sulphur) or substances which react chemically to a new, less volatile, soluble or toxic compound.

Solidification refers to techniques that encapsulate the waste, forming a solid material. The process does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. The product of solidification may be a monolithic block, a clay-like material, a granular particulate, or some other physical form commonly considered “solid” (US-EPA 1999, by UNEP 2010). In the case of mercury, it is embedded in a solid matrix without forming a new mercury compound by a chemical reaction (SBC, 2010).

For EU Commission Decision - 2000/532/EC of 3 May 2000, stabilization 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 (e.g. liquid into solid) by using additives without changing the chemical properties of the waste. A waste is considered as partly stabilized if, after the stabilization process, dangerous constituents which have not been changed completely into non-dangerous constituents could be released into the environment in the short, middle or long term.

Encapsulation is commonly used in the treatment of hazardous waste. It prevents hazardous waste from coming into contact with potentially leaching agents. Encapsulation techniques can further be divided into microencapsulation and macroencapsulation.

Microencapsulation means a process of surrounding or enveloping one substance with another substance on a very small scale, yielding capsules that may range from less than one micron to several hundred microns. In the case of metallic mercury, the core material is mercury with a wall / coating material around it.

Macroencapsulation involves pouring the encasing material over and around a large mass of the core material which needs to be encapsulated, thereby enclosing it in a solidified block. The two processes can also be combined.

These technologies are being tested in Europe and USA in cooperation with interested enterprises and under various patents. A short description of the main principles of mercury stabilization and solidification is presented below.

3.2.1 Sulphur stabilization

Mercuric sulphide (HgS Cinnabar) is the most stable form of mercury and is the most commonly occurring natural mercury ore. This is the reason why researchers investigate a solution to reconvert metallic mercury into its natural state.

HgS can be produced in two forms: Firstly, the red salt alpha-HgS and secondly, beta-HgS (black), slightly more soluble than the first one.

A variety of companies or research centers are currently working on the industrialization of a mercury stabilization process. Since the main subject of this report is to identify the principles that can be potentially used for mercury stabilization, we have not concentrated on the individual efforts so far reported in scientific journals. Most of the work so far done is on a laboratory scale and protected by various patents.

The two following companies are reported by the BiPRO (2010) as working on pilot or commercial scales which seem to be promising:

1. SAKAB/DELA – The German company is a specialist for the treatment of mercury-containing wastes, working mostly in Europe. DELA has recently registered a patent for Hg stabilization process using sulphur to produce cinnabar (Patent No. EP 2072 467 A2 -batch process). They obtained good stabilization results of metallic mercury by mixing it with sulphur between 90 to 240 min and the result was a salt 16% heavier than elemental mercury. In February 2010 a large-scale application (installed capacity: 1,000 t/year – 3 t/d) has been announced. At the moment no test results of the product had been provided. The expected cost for treatment is approximately US$ 2400/t, including packaging, transport and final underground disposal of the produced HgS. The final product has a density between 2,5 – 3,0 g/cm^{3}. The advantage of this technique is that it is a simple, low energy consuming process that can be easily installed once the parameters have been adjusted. Another advantage is the high mercury concentration (86 wt %) and high stability of the resulting product. At present, tests are being carried out. The technology is not yet commercially established.

2. Bethlehem Apparatus is an American recycler enterprise that works mainly in USA. In the company webpage, services are offered at costs about 10,400 to 11,700 US$/tons of elemental mercury. Costs of implementation are about US$ 910,000 for a facility to stabilize 300t per year. The final product is cinnabar with a density 5-6 g/cm^3. The consultants noticed that this technology is not yet approved in the USA and is not currently in use.

According to BiPRO's report (2010), the studies made proved that the quality of the stabilized product of both processes is comparable. The leaching value is in the same range and no un-reacted metallic mercury could be detected when analyzed with x-ray diffraction or by computer aided tomography.

3.2.2 Sulphur Polymer Stabilization/Solidification SPSS

This technique is similar to the sulphur stabilization mentioned before, but it uses some modified input materials. Instead of elemental sulphur, a mixture of elemental sulphur (95 wt %) and sulphur polymer cement (SPC) (5 wt %) is used. The elemental mercury and the sulphur compounds are mixed in a two step process and heated to an elevated temperature (~ 135 °C) at which the reaction product turns liquid. The liquid is cast into a mould and the product is set to harden. The shape of the product can be chosen arbitrarily, only defined by cooling behavior limitations.

The final product has a low surface to volume ratio, which is advantageous for the leaching behavior and includes about 33 wt% of mercury. The vapor pressure and leaching results of the final product from the SPSS process are comparable to the products from the sulphur stabilization.

The Sulphur Polymer Stabilization Solidification (SPSS) process is based on a process of sulphur stabilization with the advantage that, in the case of SPSS, the final product is monolithic and has a low surface area. According to BiPRO the costs vary between US$ 2.7 and US$ 16/kg of treated elemental mercury.

3.2.3 Amalgamation

Amalgamation is typically used to immobilize elemental mercury by dissolving the mercury in another metal to form a semisolid alloy known as an amalgam. The process is a physical immobilization and is often combined with encapsulation to prevent volatization of mercury from the amalgam. For this technique elemental mercury and fine powder of elemental metals are mixed together. The metals used are in particular zinc, nickel, tin or copper, with copper being the most recommended metal. The ratio of mercury to metal powder can be as low as 1:1, but it is often suggested to be 1:3, which means that the weight increase of the resulting product is about 400%. The elemental mercury bonds to the corresponding metal forming an alloy, the so called amalgam. The amalgams have comparatively poor leaching behavior and high vapor pressure. To achieve better leaching values and lower vapor pressures, a subsequent treatment (encapsulation) has to be applied.

Apart from the poor performance of amalgam concerning its stabilization, the huge input of elemental metal leads to high costs of this process and the additional cost of the final disposal renders this technique as uneconomical. USEPA has identified amalgamation as the best demonstrated available technology (BDAT) for the treatment of liquid elemental mercury contaminated with radioactive materials. (US-EPA, 2007a)

A subgroup of the amalgamation process is the use of selenium, which is a semi-metal. The reaction with elemental mercury takes place in the vapor phase at a temperature above 580 °C (above boiling point of elemental mercury). The resulting product has good leaching behavior but the input of the expensive selenium (~ 35.000 €/t) is five times the input of elemental mercury, resulting in very high costs for this process. This technology described, is therefore more promising to be used for mercury contaminated wastes instead of elemental mercury. In a study conducted in the USA it was demonstrated that sulphur selenide is unstable in the presence of chloride.

The prices of the metals used for the amalgamation (Cu US$ 4/kg, Zn US$ 1.3 /kg, Sn US$12/kg) as well as the adverse raw material/elemental mercury ratio of 3:1, results in relatively high costs for this technology. (HgCu = US$ 12/kg treated mercury, HgZn = US$ 4/kg and HgSn US$ 36/kg).

3.2.4 Chemical bonded phosphate ceramic CBPC

This stabilization process consists of two reactions, including a chemical bondage of the elemental mercury, as well as microencapsulation within a matrix. Both reactions take place at the same time.

In one reaction the elemental mercury is bond to the phosphate. In a second reaction the ceramic matrix is build up, within which the mercury compounds are microencapsulated.

This technique can be improved by previous stabilization forming HgS in a first step, by adding a small amount of sodium sulphide (Na_2S) or potassium sulphide (K_2S). For this reason, the process becomes comparable to the sulphide technique, followed by an encapsulation process. Even so the mercury phosphate products have relatively low water solubility, the leaching values of the resulting product is quite high and therefore an uncompleted reaction and/or impurities can be expected. The technique is well established for mercury-containing waste, but promising data even at a laboratory scale for treating elemental mercury are still to be seen.

The total costs, including raw materials, labor and disposal for the CBPC process is about US$ 15,45/kg elemental mercury (US-EPA, 2002).

3.2.5 Encapsulation techniques without pre-stabilization

Encapsulation techniques for mercury-containing solid waste are already well known and established on the market using asphalt, cement, ladle furnace slag, Portland cement or polyethylene as matrix material. Encapsulation of liquids such as elemental mercury is, however, a more challenging task. Even if the encapsulation of liquid mercury is successful, cracks due to aging or mechanical loads can lead to leaching of mercury. This results, in consequence in the same environmental and human risks as those known to be produced by elemental mercury without encapsulation. Due to the shortcomings of this technique no tests for the encapsulation of elemental mercury have been done so far.

In the USA encapsulation without pre-stabilization is recommended for low mercury waste. Materials used in this process are: Synthetic elastomers, Polysiloxane, polysiloxane or ceramic silicon foam, sol gels, DolocreteTM, calcium carbonate and magnesium oxide ($CaCO_3$-MgO). The hazardous waste material is mixed with the stabilizing material to a settable composition forming slurry. Subsequently the slurry hardens and encapsulates the waste material. The settable composition has most commonly a powdered cement composition, containing calcium carbonate and a caustic magnesium oxide. Different additives such as aluminum sulphate of citric acid can be added to increase the performance. Encapsulation with ladle furnace slag is realized in an alkali-activated (2M NaOH) process with thermal treatment.

3.2.6 Encapsulation with pre-stabilization

Any type of stabilization can be used as a first step before encapsulation. The combination of both techniques often leads to acceptable leaching values and low vapor pressures. The sequence of stabilization and then encapsulation of mercury waste has several benefits. One of these benefits is the reduced surface to volume ratio compared to the pre-treated powdery product and therefore the lower leaching value. Another benefit is, usually the increased physical strength and bearing capacity of the encapsulated product. One major disadvantage of the combined process is however, the reduced concentration of mercury in the final product, which in turn increases the total amount of waste to be disposed of. Furthermore, additional steps in the combined process have the disadvantage of increasing production costs. Therefore an encapsulation step should only be taken into account when the first pre-treatment step did not fulfill the criteria for a safe disposal.

The estimated cost is $16.37 per kg for conventional Portland cement stabilization (including disposal). The process was developed in the context of the EU Life-Project Mersade. The technology is until now only performed on a semi-laboratory scale. A larger up-scaling has not yet started.

3.2.7 Other non-commercial investigations on Hg stabilization and solidification (S/S) processes

There are some modifications of the main standardized techniques trying to improve the Hg S/S processes. The text below shows a brief review on these improvements.

Zhang and Bishop (2001) have been investigating a novel approach taking in account the very low solubility of mercury phosphates. In the preliminary stage of the study, soluble phosphate (Na_2HPO_4) was proved to successfully stabilize mercury both in pure solution and in surrogates. Phosphate/Hg molar ratios of 3-5 were found to be effective for Hg stabilization and an optimal pH range for the phosphate process was found to be pH 2-5, with stabilization efficiency higher than 99%. At higher pH values, less mercury was precipitated decreasing the stabilization efficiency to 80%. For Hg-doped surrogate samples Bentonite was found to improve mercury stabilization. However, the phosphate process alone was unable to stabilize mercury-containing surrogate well enough to pass TCLP test.

Other stabilization/solidification (S/S) processes were suggested by Zhang and Bishop, 2003 for high mercury wastes. These processes consisted on stabilizing mercury using low-cost powder re-activated carbon (PAC) before its solidification with cement. To improve the mercury adsorption capacity, PAC may be impregnated with sulfide. The authors concluded that the S/S process by reactivated carbon and cement is a robust and effective technology for immobilization treatment of high mercury wastes.

Xin-Yan et al. (2009) investigated stabilization/solidification (S/S) of mercury-containing solid wastes using thiol-functionalized zeolite (TFZ) and cement. TFZ was used to stabilize mercury in solid wastes, and then the stabilized wastes were subjected to cement solidification to test the effectiveness of the whole S/S process. The results show that TFZ has a high level of –SH content and this specie seem to be responsible of the Hg stabilization. The mercury adsorption capacity is greatly enhanced upon thiol grafting, the maximum of which is increased about ten times. Though Cl^{-} and PO_4^{3-} have negative effects on mercury adsorption by TFZ, the Portland cement solidification of TFZ stabilized surrogates containing 1000 mg Hg/kg can successfully pass the TCLP leaching test. The authors concluded that the stabilization/solidification process using TFZ and Portland cement is an effective technology to treat and dispose mercury-containing wastes.

More recently, a process of stabilization /encapsulation was developed under the European LIFE Program by López-Gómez et al. (2009). The process consists of the obtainment of stable sulfur-concrete matrix which allows the immobilization of mercury. The final product containing up to 30% of Hg exhibits excellent mechanical properties. The durability of these materials was analyzed in different aggressive environment, thus their behavior in alkaline medium, the ageing in salt mist environment and the resistance to freeze-thaw conditions were essayed. Any kind of degradation or deformation was observed in the matrix after these tests.

Data related to costs and pilot scale is not available yet about these new improvements.

3.2.8 Conclusion about the state of art of Hg stabilization and solidification

Many studies regarding mercury stabilization and solidification tested mercury wastes instead of elemental mercury.

In 2003 the US EPA published a note with the conclusions of two studies conducted on the treatment of mercury wastes which stated that changes to national regulations were impractical at that time because no technology demonstrated adequate stability across the plausible range of pH conditions found in landfills.

In these two studies four patented pre-treatments were tested by simulating the contact of entire and crushed mercury stabilized pellets with leachate in the most common pH range in a landfill (2-12) at different concentrations of leachate(US-EPA, 2003).

Even though the tests were made with waste, the results clearly showed that there are **significant differences in the effectiveness of various treatment technologies**. More importantly, the results showed that **leaching of stabilized elemental mercury is pH dependent.**

In summary, the treatability studies led the US EPA to conclude that treatment and land filling of elemental mercury could **not** be done in a manner protective of human health and the environment.

In Europe, the BiPRO consultants concluded that technologies based on sulphur stabilization have been assessed as a suitable pre-treatment option. They considered that the availability in Europe of at least one technology on an industrial scale in 2011 as very probable. They suggested as environmental minimum requirements for stabilized mercury acceptance:

- vapor pressure of the stabilized metallic mercury < 0.003mg/m³

- leaching value below 2mg/kg dry mass (L/S=10 l/kg).

The main considered commercial feasibility criteria are:

- Implementation time before March 2011
- Capacity: approx. 1,000t/year
- Permit from the competent authority (as solid waste).

Technologies that have been assessed as not feasible by 2011 are not necessarily excluded in the future. They recommended elaborating BAT-Reference documents for pre-treatment technologies.

Table 3.1 summarizes the main pre-treatments under evaluation in the EU for use in underground storage.

Table 3.1 - Overview of existing pre-treatment technologies for liquid mercury

	Existing pre-treatment technologies						
Process	Company	Costs (US$/t)	Elemental mercury per batch	Daily through put for one existing line	Complete stabilization	Hg content in product	Comments
Sulphur stabilization	DELA[1]	2600-3900	5 kg	60 kg/day	✓	86 wt%	Large scale application available but not tested yet. Include salt mine disposal.
	Bethlehem apparatus	11000 – 13000 (U$S 1008000 investment for 300t/y)	50 kg	275 kg/day	✓	84 wt%	No up scaling is planed but the generation of many small lines is proposed to meet quantity needs, when needed
SPSS	M&CE - Oak Ridge	2700000 (investment)	50 kg	250 kg/day	✓	50 wt%	10 tons already stabilized
	DOE	2880	20 kg	40 kg/day	X	33 wt%	Incomplete reaction, presence of elemental mercury in the product
Amalgamation (Kg of metal)	X	4 - 12 Cu 1,3 – 4 Zn 12 – 36 Sn	X	X	X	X	The technology is currently not economically used for Hg stabilization
CBPS	X	15450	X	X	X	X	The technology is currently not economically used for Hg stabilization
Encapsulation without stabilization	X	-	X	X	X	X	The technology is currently not economically used for Hg stabilization
Sulphurisation /with **Encapsulation**	MERSADE	21600-25000	2 kg	100 kg/day	✓	30 wt%	Needed time period for a large scale application: 3-5 years

3.3 Options for Mercury Storage and Disposal

This chapter presents the concepts for the storage of mercury with options for above-ground and underground storage, with state-of-the art examples of implementation in the developing countries and associated costs in these countries.

3.3.1 Above-ground specially engineered warehouses

In this chapter, as a first approach, an overview of the state of the art of above ground facilities is presented. Above ground facilities are defined here as specially engineered warehouses, such as buildings and special landfills, designed for elemental mercury storage.

3.3.1.1 Concept and requirements

Above ground facilities are defined here as engineered warehouses specially designed and well equipped to store mercury for a long time, avoiding emissions to the environment. They must have artificial and engineered protection barriers against the release of metallic mercury as leachate, vapor, or contaminated solids. The selection of an area for the implementation of an above-ground engineered warehouse, take into account the large experience and normative framework of the EU (Regulation (EC) N° 1102/2008, metallic mercury as a liquid waste), North America and other normative and legal framework in place in LAC countries. The basic requirements are as follows:

- The location must not be susceptible to earthquake, hurricanes and flooding;
- More than one area must be considered, mainly in dry climate places;
- Appropriate distance from any water basin;
- Appropriate distance from populated areas, considering the wind direction.
- Appropriate distance from National Parks, conservation areas and fragile environmental systems;
- Good soil stability;
- Protection of mercury containers against meteoric water;
- Proximity of roads or transportation structure.

In addition the facility must to comply with the following construction and operation requirements:

- Buildings, special Hg-resistant sealing for the floor and in particular the packaging system of the waste and installation of a slope towards a collection sump.
- Adequate security measures (e.g. fencing, guards, restricted access, emergency plans)
- Prevention of vapor emissions produced during packaging, handling, internal transportation, and temperature control;

- Protection of groundwater and superficial water contamination;
- Impermeability towards the soil;
- Monitoring systems (air, containment, blood and urine of workers, others); regular emission control of the facility surroundings; permanent mercury vapor monitoring with a sensitivity ensuring at least that the recommended indicative limit value of 0.02 mg mercury/m^3 is not exceeded;
- Monitoring system equipped with a visual and acoustic alert system in case the limit values are exceeded;
- Maintenance and calibration of monitoring system checked at least yearly;
- Vapor emission detection **near to the ground floor** as mercury vapor is heavier than air;
- Reversibility of storage;
- Spills prevention and control;
- Packing and over packing standards;
- **No storage together with other waste**;
- Risks and accident prevention system ;
- Independent auditing regularly.

The following subchapters present some examples of warehouses considered state of the art of above ground facilities. The most relevant experience of the engineered warehouse concept is installed in the USA.

3.3.1.2 State of Art in Above-ground facilities

Below some examples of implemented above ground facilities.

A. The Defense National Stockpile Center (DNSC) - USA

The Defense National Stockpile Center program was established by Congress of USA to minimize the American dependence on foreign sources of essential materials in times of national emergency. Since 1988, the Defense Logistics Agency (DLA) has been responsible for the program and established the Defense National Stockpile Center (DNSC) to manage the program and operate storage depots nationwide.

DNSC is responsible for providing safe, secure, and environmentally sound stewardship of all commodities in the inventory. The stockpile includes approximately 65 commodities, including aluminum oxide, cobalt, ferrochrome, lead, rubber, tin, zinc, in addition to mercury.

DNSC currently has 4,890 tons (4,436 metric tons) of mercury stored in enclosed warehouses at three DNSC sites: Somerville, New Jersey; New Haven, Indiana; and Warren, Ohio; and at the U.S. Department of Energy (DOE) Y-12 National Security Complex at Oak Ridge, Tennessee.

This inventory has been stored for over 40 years and consists of elemental mercury that ranges in purity from 99.5 to 99.9 percent. Congress has declared most of the DNSC materials, including mercury, to be in excess of national defense needs and has authorized their disposition, generally by sale until 1994. After the environmental and health risks related to mercury became more and more obvious, the DOD halted the selling of elemental mercury.

In 2003/2004 a Mercury Management Environmental Impact Assessment (MM EIS) was carried out to find the most appropriate way of dealing with the stored mercury in the future for a period of 40 years. As a result of the MM EIS, the DNSC is currently in the process of consolidating and concentrating its mercury holdings from facilities in New Jersey, Indiana, and Ohio at one site, the Hawthorne Army Depot in Nevada. This depot was selected as a future storage site for liquid mercury currently stockpiled.

The selected warehouse (Hawthorne Army Depot) was not one of the existing mercury storage sites. This decision to use it was based on a combination of environmental, economic and technical factors, policy considerations and public and stakeholder comments [DNSC 2004].

A considered option at the Hawthorne Army Depot is the use of earth-mounded storage buildings (igloos).The site has 393 empty, usable igloos. The igloos are made of steel-reinforced concrete and covered with about 2ft (1m) of soil. The mercury could be stored in about 125 igloos.

Below-ground facilities such as bunkers and mines were considered but not evaluated, as bunkers would be similar to the evaluated igloos at Hawthorn. Due to the limited availability of existing mines, inspection considerations, additional material handling, and regulatory issues regarding the storage in mines, the underground storage was not considered to be a reasonable alternative.

The MM EIS also took into consideration underground storage as well as pre-treatment options. A pre-treatment of the metallic mercury to a stabilized, less toxic form before storage was eliminated from a detailed analysis. According to the DNSC EIS, treatment and storage would result in additional environmental impact and costs, without significant benefits. In their opinion, metallic mercury can be safely stored as it is for example in most industrial processes requiring mercury.

Based on the immaturity of the bulk mercury treatment technologies and the lack of a way forward approved by the EPA for treatment and disposal of elemental mercury, the disposal in a qualified landfill after pre-treatment was not evaluated in detail in the MM EIS.

The selected mercury storage warehouse at Hawthorne Army depot must to be upgraded to fulfill the required safety standards for long-term storage of the metallic mercury. In general, the following safety requirements and level of protection have to be fulfilled by the warehouse [DNSC 2004]:

- Sealed warehouse floors (without drains) with epoxy mercury-resistant sealer (Intrusion protection);
- Intrusion detection;
- Adequate lighting for inspection;
- Static ventilation;
- All doors fitted with 3 inch containment dikes that are incorporated into floor sealant systems;
- Heat, smoke and fire detection system – monitored continuously;
- Fire protection system (active fire suppression system, fire extinguisher and alarm system);
- Closely controlled access (Security systems);
- Regular monitoring (routine monitoring and inspections of mercury);
- Protective equipment and supplies;
- Emergency procedures (spill prevention control and response procedures);
- Positive contact intrusion detection on all doors, windows and vents – monitored continuously;
- Ramped containment dikes.

The DOD safely stored for over 50 years, 4, 436 metric tons of commodity grade elemental mercury in the units (Figure 3.7) below:

- Somerville, New Jersey: 2, 617 MT;
- Warren, Ohio: 1, 262 MT;
- New Haven, Indiana: 557 MT.

In 2002, 108,386 flasks were re- packed and 20,276 in 2005.

Figure 3.7 – Previous storage methods (flasks directly stored into pallets) (SOURCE: DNSC, 2007)

New Facility

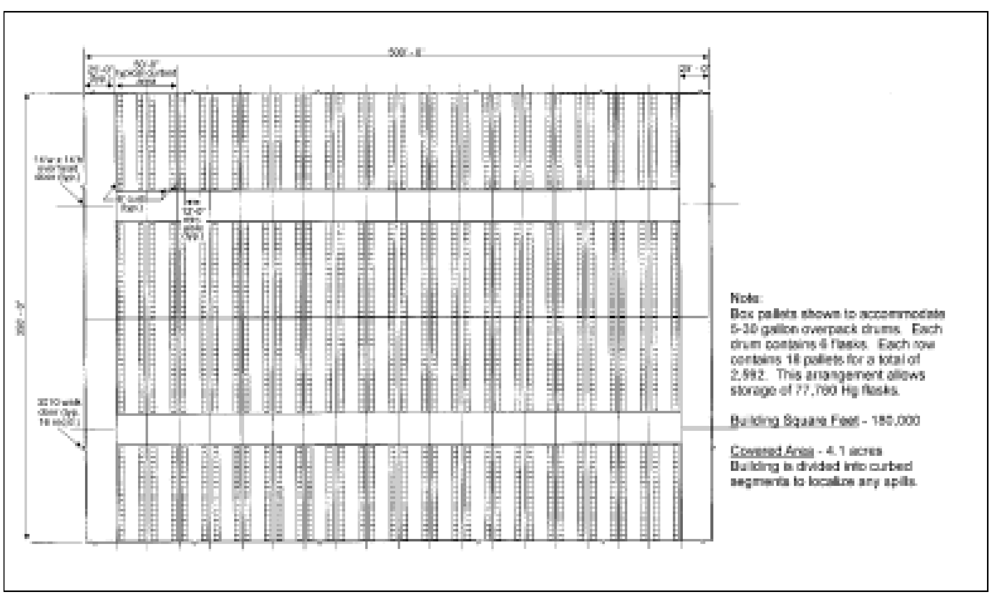
The warehouses at the Hawthorne Army Depot are constructed with concrete support columns, steel roof trusses, and transited roofing.

The additional stockpile in mention requires approximately 200,000 ft^2 (18,581 m^2) of storage space. It is likely that a new mercury storage building will be constructed using concrete floors and walls, a steel support structure, and an aggregate roofing system. Multiple large roll up doors will be used to enhance access. Lighting, ventilation, fire suppression (sprinkler system), and a security system will be included. No floor drains are contemplated and the concrete floor will be sealed and curbed to reduce the chance that mercury could be released to the environment. It is estimated that 14 acres (5.7 ha) of land will be affected during construction; of the storage building which will occupy 4.6 acres (1.9 ha).

The storage area

The new storage facility has a new lay-out and drums are stored on pallets in lines. Figure 3.8 provides a diagram of the layout of the mercury storage building.

Figure 3.8 – Diagram of the layout in the mercury storage building (Source: DNSC- 2004).



The warehouses have concrete floors and walls (resistant to fire). Along the line of the existing warehouses, the new site will have approved spill prevention control and countermeasures and installation spill contingency plans to ensure that the appropriate response to a spill is made. State and local emergency response teams participate in the emergency measures of the mercury storage. In case of a mercury spill, an appropriate response would occur and the spill would be cleaned up to applicable standards.

Public access to the storage site is restricted by a security system, including the guards. Warehouses are kept locked except for inspections and other periodic maintenance work. In addition to security, perimeter fencing, and closely controlled access comparable to the levels of protection at the current mercury storage sites, DNSC will work with local authorities to ensure that even the most unlikely scenarios would be handled properly.

Maintenance and Inspection

Apart from the technical safety measures, periodic maintenance activities and inspections of the stored mercury by appropriately trained DNSC or contract personnel are essential to ensure that it is safe and secure. Inspections have to be conducted by trained personnel and include methods for visual examinations and mercury vapor monitoring using state-of-the-art equipment.

In 2002, the DNSC issued the Environmental Inspection Plan for Mercury in Storage (Appendix 4–A in the Defense National Stockpile Operations and Logistics Storage Manual). The main purpose of this manual is to improve the inspection and reporting process for mercury storage. The plan also documents the correct storage and control measures that are required for the protection, safety, and health of workers and the public, and protection of the environment. The manual provides procedures for the frequency of inspections; temperature, barometric pressure, and humidity measurements; vapor monitoring; visual inspection; documentation records and corrective action.

In case the DNSC action level of 0.025 mg Hg/m^3 is exceeded or if metallic mercury is found during a visual inspection, an investigation has to be initiated to determine the cause. Any defects in the packaging have to be quickly corrected.

Costs

The facility at Hawthorne will be operated by a contractor. DNSC estimates that storage of mercury at Hawthorne will cost US$0.22-0,299 per pound per year, for a total of a US$ 1,9 – 2,7million per year for the military's entire stockpile of mercury (US-EPA, 2007b).

Aside from the state facilities, the safe management of excess non-federal mercury supply has to be addressed. Cost estimates are also available for the private sector storage of elemental mercury. The US EPA study (US EPA 2007b) examined the costs of private sector storage under two storage scenarios: a storage facility that uses rented warehouses and a storage facility that includes construction of warehouses specifically for mercury storage. Estimates of total storage costs assume that over a 40-year period, either 7,500 or 10,000 metric tons of excess mercury supply will require storage.

Table 3.2 - Summary of Estimates of Total Storage Costs (US Dollars) for 40 Years [US EPA 2007b]

Storage Capacity	Total Cost Estimates	Rent Scenario	Construction Scenario
7,500 ton	Total Project Costs (undiscounted)	59.5 - 144.2 million	50.0 - 137.7 million
	Net Present Value of Total Project Costs	18.5 - 39.9 million	17.8 - 41.0 million
	Annualized Costs	1.4 - 3.0 million	1.3 - 3.1 million
	Annualized Costs per Pound	0.084 - 0.181	0.081 - 0.186
10,000 ton	Total Project Costs (undiscounted)	69.8 - 183.9 million	57.3 - 174.9 million
	Net Present Value of Total Project Costs	21.3 - 50.9 million	20.0 - 51.9 million
	Annualized Costs	1.6 - 3.8 million	1.5 - 3.9 million
	Annualized Costs per Pound	0.072 - 0.173	0.068 - 0.177

Note: present value calculation assumes a seven percent discount rate.

B. USA Department of Energy – DOE

Elemental mercury has long been used in manufacturing processes, because it is a good conductor of electricity and it alloys (mixes) readily with other metals. Currently elemental mercury in the United States comes from several sources, including mercury used in the chlorine and caustic soda manufacturing process, mercury reclaimed from recycling and waste recovery activities, and mercury generated as a byproduct of the gold mining process.

Comment [VC1]: Referencia **Federal Register** / Vol. 74, No. 53 / Friday, March 20, 2009 / Notices

The 'Mercury Export Ban Act of 2008' (MEBA) bans the export of elemental mercury from the United States as of January 1, 2013. It prohibits the sale, distribution, or transfer of mercury by Federal agencies to other government agencies and private entities as of October 14, 2008.

The bill also requires the Department of Energy to identify a safe, long-term storage site for up to 17,000 tons of mercury that includes stockpiles held by the federal government, as well as commercial supplies.

DOE must designate one or more facilities for long-term management and storage of mercury generated in the United States and has it operational by January 1, 2013. Any facility must comply with applicable requirements of the Solid Waste Disposal Act, as amended by the

Resource Conservation and Recovery Act. MEBA does not specify how long mercury may require storage. DOE is required to charge a fee to cover the cost of mercury storage.

The Act requires the US Environmental Protection Agency (USEPA) to report to Congress on whether to expand the export ban to cover one or more mercury compounds. This report was issued in October 2009.

USEPA must report to Congress by January 1, 2017, on the global supply and trade of elemental mercury, including whether additional primary mercury mining has occurred as a consequence of the Act.

DOE estimates that approximately 10,000 metric tons (11,000 tons) of excess mercury will need to be managed and stored in a facility designed to last at least 40 years.

Potential sources of elemental mercury in the United States include mercury that is used in chlor-alkali industry, reclaimed from recycling and waste recovery activities, and generated as a byproduct of gold mining. In addition, DOE currently stores approximately 1,200 metric tons (1,300 tons) of mercury at its Y–12 National Security Complex in Oak Ridge, Tennessee. At Y-12 National Security Complex in the Oak Ridge Reservation the 3-L containers are stored in box pallets with spill trays on seismically rated racks or on a sloped floor. This site was not considered for mercury long term storage because MEBA specifies that the DOE-designated mercury storage facilities shall not include Y-12 National Security Complex or any other portion or facility at the Oak Ridge Reservation in Oak Ridge.

On July 2, 2009, DOE issued a Notice of Intent in the Federal Register soliciting public input on development an Environmental Impact Statement (EIS). DOE considered all comments received during the scoping period (July 2 through August 24, 2009) in preparing a first draft of an EIS, published in January, 2010. The first draft EIS evaluates the potential impacts of the establishment of a facility (ies) for the long-term management and storage of mercury. After public comments, it is expected that by fall 2010 the final version of the EIS will be released.

In November 2009 the DOE published the “Interim Guidance on Packaging, Transport, Receipt, Management, and Long-Term Storage of Elemental Mercury” [DOE 2009]. These interim guidelines are a framework for the standards and procedures associated with a DOE-designated elemental mercury storage facility with a focus on the RCRA permitting of such a facility and planning for that storage facility’s needs.

USA DOE considered alternatives

As required by NEPA, the DOE EIS evaluates a No Action Alternative to serve as a basis for comparison with the action or site alternatives. Ten potential sites as mercury storage site were considered: 5 owned by DOE, 1 by DNSC (Hawthorne Army Depot in Nevada) and 4 by private sector. Applying the DOE screening criteria, the institution confirmed that seven of the ten storage sites appeared to be reasonable alternatives.

Areas analyzed for each alternative site include: land use and visual resources; geology, soils, and geologic hazards; water resources; meteorology, air quality, and noise; ecological resources; cultural and paleontological resources; site infrastructure; waste management;

occupational and public health and safety; ecological risk; socioeconomics; and environmental justice.

The main criteria defined by DOE to be attained are:

- The facility (ies) will not create significant conflict with any existing DOE site mission and will not interfere with future mission compatibility;

- The candidate location has an existing facility (ies) suitable for mercury storage with the capability and flexibility for operational expansion, if necessary;

- As required by the Act, the facility (ies) is, or potentially will be, capable of complying with the Resource Conservation and Recovery Act (RCRA) permitting requirements, including sitting requirements.

- The facility (ies) has supporting infrastructure and a capability or potential capability for flooring that would support mercury loadings;

- Storage of mercury at the facility (ies) is compatible with local and regional land use plans, and new construction would be feasible, as may be required;

- The facility (ies) is accessible to major transportation routes;

- The candidate location has sufficient information on hand to adequately characterize the site.

The DOE mercury storage facilities would include the following characteristics:

- RCRA-regulated/permitted design with proper spill containment features and emergency response procedures
- Security and access control
- Fire suppression systems
- Ventilated storage area(s)
- Fully enclosed weather-protected building(s)
- Reinforced-concrete floors able to accommodate mercury storage

The mercury storage facility would have areas for administration, receiving and shipping, storage, and handling. The storage area would constitute approximately 90 percent of the floor space. The storage area would generally be a large open space similar to a warehouse, where storage, inspection, and monitoring could be effectively performed.

The mercury storage facility(ies) would accept two types of mercury containers: 3-liter (34.6-kilogram [76-pound]) flasks and 1-metric-ton (1.1-ton) containers. Other containers could be approved and accepted on a case-by-case basis.

The racks should have a 3° slope towards the aisle to cause leaked mercury to flow towards the edge of the spill tray in order to quickly identify spills. The spill tray on the pallet should have retaining walls with sufficient height to contain at least 10% of the mercury contents on the pallet at the indicated angle.

Figure 3.9 illustrates what the exterior of a new mercury storage facility(ies) might look like, and Figure 3.10 provides a potential conceptual layout of the interior and how the mercury containers might be stored.

Figure 3.9 - Building Exterior (**SOURCE: DOD, 2009)**

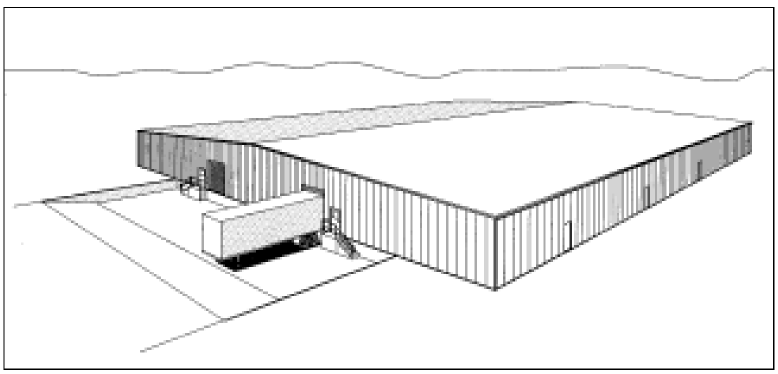
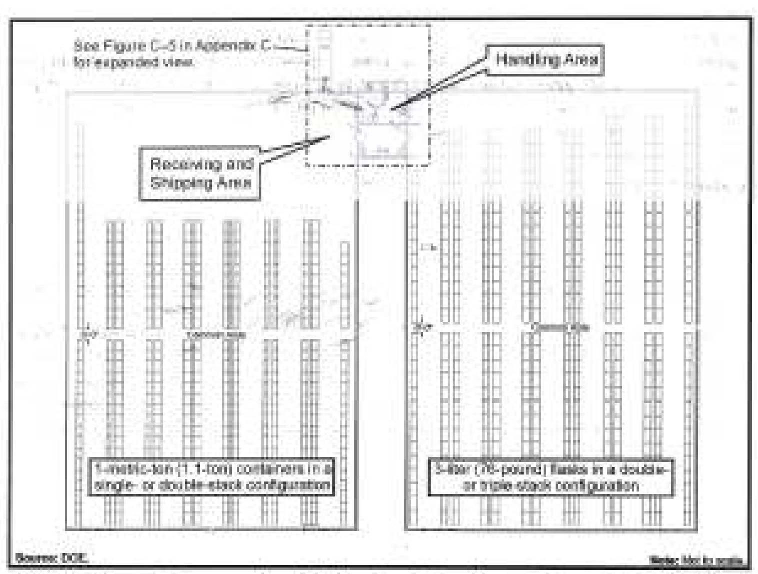


Figure 3.10 - Potential conceptual layout of the interior (**SOURCE: DOD, 2009)**



DOE has identified Waste Control Specialists, LLC, near Andrews, Texas, as the Preferred Alternative location for long-term storage of U.S. mercury, based on the following factors:

- Compatibility with existing waste management activities, land use plans, and regulatory agreements
- Remote location
- Low population density in surrounding area
- No nearby major bodies of surface water
- Existing rail line
- Environmental impacts similar to those at other candidate sites

No final decision will be made until this draft EIS has been subject to public review and comment, and an EIS has been published, and a Record of Decision (ROD) has been issued.

C. Minas de Almadén - Mayasa - SPAIN - EU

The European Mercury Strategy promoted by the European Parliament sets the standard for appropriate installations to store mercury metal derived from the European Union territories after the export ban to third countries enters into force.

Currently, the EU financed Project MERSADE entitled "Mercury Safety Deposit" (Acronym: MERSADE, project reference: MERSADE LIFE06 ENV/ES/PREP/03) is being carried out by Minas de Almadén y Arrayanes, S.A. (Mayasa) together with its partners CENIM (Centro Nacional de Investigaciones Metalúrgicas) and the University of Castilla la Mancha.

Minas de Almadén (MAYASA) in Spain is the largest company treating liquid mercury apart from other sources it receives from decommissioned chlor-alkali plants. The company uses an auxiliary above-ground building as a warehouse for the storage of the mercury. The installation is located above a former mercury mine.

The MERSADE project aims to design and construct a safe storage installation prototype for mercury metal, based on the experience in handling, and storage of the current installations at the Las Cuevas mercury warehouse, in Almaden (Ciudad Real – Spain). http://www.mayasa.es/ing/mersade.asp

This project develops technical support for a long term storage plan (for the next 50 years) which will define the packaging to be used during the transport from plants to the site where it will be deposited, the procedure for handling the metal and the construction of a prototype facility for depositing surplus mercury coming from EU countries. The mercury supply is expected to be mainly derived from the termination of chlor-alkali production, voluntary agreed to by industry and endorsed by the European Commission. The quantity of mercury metal currently in use in the European Union's of 27 member states is not known and efforts are made to obtain concrete data from the 1st of July 2011 onward in order to provide exact figures for storage and disposal.

The project is expected to develop a model for a bulk mercury deposit that meets strict safety requirements and prevents mercury emissions after closure.

Operation

Metallic mercury is stored in flasks (34.5kg net), containers (1 ton) or bulk tanks. The flasks and containers are also used for the transport of liquid mercury and thus fulfill the requirements of transport regulations. The filling and re-filling of tanks with mercury takes place via pipes and valves. Displaced air during filling activities is extracted and cleaned via special filters with activated carbon.

The purity of the stored mercury is 99.9%. In case the delivered mercury does not fulfill this criterion, a cleaning of the mercury takes place before storage.

Floor

The bulk tanks are placed in a collecting basin made of concrete which is capable of receiving all mercury included in the bulk tanks in case of an accident. All the areas where mercury is handled, stored or packaged are especially treated with waterproof protective epoxy based paint on walls and flooring.).

In addition, the floors have a slight slope directed to a central collecting basin.

Vapor control

Gas displacement systems and activated carbon filters are installed. Mercury emissions from operational processes (e.g. filling of tanks) are monitored by Hg-emission monitoring systems. The measurement results are regularly evaluated. Accompanying studies related to possible impacts of mercury emissions have been carried out under the Mersade project. According to these studies, direct impacts of the emissions on environmental surroundings are expected up to a maximum distance (along the direction of the prevailing wind) of 300m from the central point of the installation.

The Hg-emissions from the storage site are estimated (by modeling) to be around 15kg per year [personal communication Mr. Ramos, Mayasa to BiPRO representatives].

The project also includes investigations on existing storage containers, in order to identify the most appropriate material for long-term storage.

MAYASA and the Spanish national and regional authorities reached also an agreement to create the national technological center on mercury decontamination. This center will undertake research activities on mercury storage, but also on mercury monitoring, decontamination techniques, etc. The center will also promote the technology transfer and capacity building to third countries.

The following statements by EU consultants BiPRO regarding above ground facilities reflect the current debate on the issue:

- Mercury still remains in the biosphere;
- The safety of this option is dependent on political and economic constraints (we added political and economic stability);

- It may not be a permanent solution and in a next future this mercury will need to be treated and send to a long term storage facility.

3.3.2 Below-ground storage in geological formation

The chapter on storage of waste in geological formations is a general overview on the issue based on technical and economic information available in UNEP's webpage and the opinions of specialists from Germany and Sweden, since there are no important experiences and studies so far undertaken in the LAC region. Regionally, only Mexico has a specific technical standard for the storage of drilling residue and other hydrocarbon waste in geological cavities of salt domes, which are considered geologically stable.

Because it is a new subject for most of LAC countries, the following chapter gives a summary of the main technical requirements and restrictions for underground storage, and shows some examples.

3.3.2.1 The concept of underground storage and requirements

The concept of underground disposal is based on the consideration to isolate waste from the biosphere in geological formations, where it is expected to remain stable over a very long time.

Isolation of mercury is considered to be best achieved through its emplacement at significant depths underground. Containment and isolation of the mercury is provided both by its containers, into which the waste is put before being emplaced in the repository and by various additional engineered barriers, additionally to the natural barrier provided by the host rock, far from the biosphere. The essence of this form of disposal is that the best protection for present and future generations and for the environment is provided by a passive system made up of engineered and natural barriers.

Geological disposal can be undertaken in a number of geological formations, the most commonly studied rock types being clay, salt, and hard magmatic, metamorphic or volcanic rock such as granite, gneiss, and basalt.

The depth at which the disposed material would be emplaced depends to a large extent on the type of formation used and the isolation capacity of the overlying formations. Suitable clay formations, for example, tend to occur in layers of a few hundred meters thickness at a depth of a few hundred meters. Salt deposits occur as bedded layers or salt domes at shallow or greater depths. For disposal in hard rocks, the usual design depth is between 500 and 1000 m, and the aim is to use parts of the rock formation that contain very few large fracture zones or faults in order to control formation water and intruding humidity.

Information on experience from current underground storage of liquid mercury is not available. The below cited review on the state-of-the-art of disposal operations for hazardous waste, in salt mines or deep underground hard rock formations, based on the experience with the underground disposal of hazardous waste and radioactive waste in Germany and other European countries (BiPRO, 2010c).

In Germany, the experience with the disposal of **mercury-containing waste** and **other hazardous waste** has been available for several decades (e.g. underground waste disposal since 1972 in a German salt mine).

Valuable information can also be drawn from experiences in the underground disposal of radioactive waste in Japan, Canada, Sweden, Germany, and other countries.

BiPRO (2010) reports that for the German environmental authorities, the disposal of liquid mercury in salt mines is seen as a long term safe solution as long as all legal requirements are fulfilled and the long-term assessment of the underground facility allows the storage of liquid mercury. However, until now only very limited information is available related to the behavior of liquid mercury in salt rock. First research results relating to the solubility of metallic mercury and mercury compounds in saline solutions are available, but have to be further investigated. These results show that the solubility of mercury in salt solutions is lower compared to pure water but is nevertheless significantly higher compared to mercury sulphide. Tests are planned for 2010.

Germany has years of experience with the final disposal of radioactive waste in salt mines. In order to ensure an appropriate level of safety via the geological barrier, underground disposal of radioactive waste is usually carried out in depths ranging from several hundred to about one thousand meters.

Although the properties of radioactive waste are somewhat different to liquid mercury, experiences from research, in particular related to geological requirements of host rock such as its stability, hardness and plasticity are also valid for the permanent storage of liquid mercury.

According BRASSER (2009b), the main requirements for underground waste storage are:

- A disused, excavated area of a mine, remote from the mineral extraction part and able to be sealed off from the area where extraction is taking place is available.
- The cavities resulting from mineral extraction have to remain open. There must be no backfill obligation.
- The mined cavities have to be stable and accessible even after a prolonged time.
- The mine must to be dry and free of water.
- The cavities, in which the waste is stored, have to be sealed off from water-bearing layers.

Concerning mercury storage together with other types of waste in underground facilities, additional requirements have to be taken into consideration (GRS, 2009):

- Hg impurities must be avoided because they can lead to highly increased mercury solubility (Hg purity must be higher than 99.9%)
- Oxidizing agents in the vicinity of Hg should be avoided (i.e. chromate containing wastes)
- The high vapor pressure of metallic Hg poses high demands on the handling and ventilation
- To improve the safety and to simplify the Hg handling, Hg must be stabilized as Hg-sulfide
- Specific waste acceptance criteria, dependent on local legal framework is required.

3.3.2.2 Potential host rocks

Many deep mines of different types of rock are generally suitable for the storage of hazardous waste. Depending on their geological formation, mines which are currently still in use may be used as hazardous waste disposal sites in the future (BiPRO, 2010c).

Appropriate host rocks for disposal of metallic mercury are salt and hard rock, according to Council Decision 2003/33/EC.

In a geological sense, the term hard rock includes igneous rocks (e.g. granite or basalt) and metamorphic rocks (e.g. slate, gneiss, schist).

Sedimentary rocks (e.g. clay, shale) are of lately considered a good option for storage on grounds of their high impermeability. Salt is a specific type of sedimentary rock derived from the evaporation of salt brines and has sealing properties.

Many types of consolidated hard rock and some types of sedimentary rock are theoretically feasible options, and serve for underground disposal sites for mercury (BiPRO, 2010c).

This generally corresponds to experiences from disposal options for radioactive waste according to which the preferred host rock could be hard rock (i.e. crystalline igneous rock), or sedimentary rock (e.g. clay or salt). Laboratories for testing and building confidence in disposal technologies for the underground storage of radioactive waste have been established in all types of potential host rocks [IAEA 2009, by BiPRO, 2010c].

A. Storage in Salt Rock

Salt rock serves in Germany and UK as underground storage facilities. The following subchapter is an overview of the main rock proprieties and the experience of these countries with salt related storage issues.

Geological salt formations occur either as layered salt or as salt domes, usually of a sodium or potassium type. Both formations can principally be used for disposal purposes. A salt formation to be used as storage or disposal site must have the following properties:

- Permeability: Very low (practically impermeable)
- Mechanical Strength: Medium
- Deformation behavior: Viscous-plastic (creep)
- Stability of cavities: Self-supporting
- In situ stresses: Isotropic
- Dissolution behavior: High
- Sorption behavior: Very low

Salt rock is very dry; it contains no free water and offers very good isolation of the waste.

Together with an overlying and underlying impermeable rock strata (e.g. clay or shale), it acts as a geological barrier and prevents groundwater entering the storage facility and, where necessary, effectively stops liquids or gases escaping from the disposal area.

On the other hand, salt rock is highly soluble, thus any infiltration of water would cause severe damage to the confinement. Salt rock is perfectly impermeable with respect to gas [Popov 2006, by BiPRO-2010c], **as a consequence no gas producing materials should be stored to avoid an increase of pressure in the rock formation**. Recent research give has shown that in case of gas generation there will be no "explosion". The gas will rather escape via cracks and fissures – as assumed so far – to the effect that the impermeability of the surrounding salt rock will decrease gradually. The loss in permeability occurs in a defined area around the stored material and stops as soon as the pressure decreases due to the possibility of the gas to expand. [Brückner 2003, Popp 2007, By BiPRO 2010c]

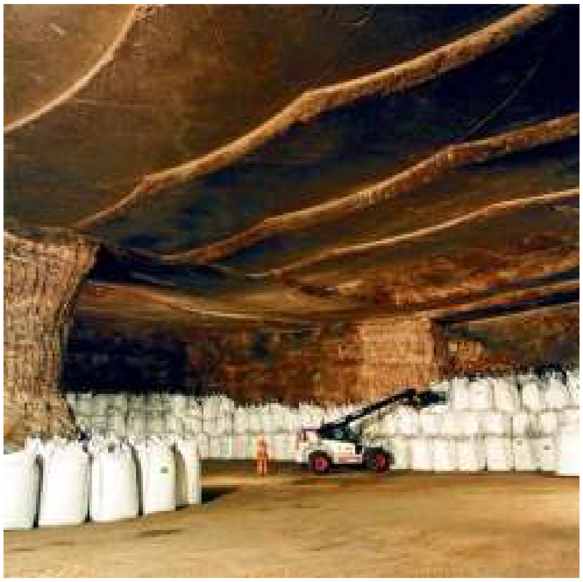
Salt rock generally has a low sorption capability. The hydraulic conductivity of rock salt is very low. A liner is usually not required in salt formations. Here, rock creep is a continuous process leading to deformation in response to lithostatic pressure. Salt creep will close the void space around waste packages in the emplacement cells, leading to complete encapsulation. The creep rate depends on in situ stress (increasing with depth) and temperature (BiPRO, 2010c).

The investigation of the structure of layered salt mines is easier – compared to salt domes, and well established investigation methods are available [GSR 2008]. In particular, the presence of brine in local lenses or irregular structures or fissures may cause difficulties for a safe storage. Therefore, the presence of such structures has to be excluded via a site-specific safety assessment [Popov 2006, by BiPRO, 2010c].

At the German underground Herfa-Neurode waste disposal site, salt dams are constructed or stone walls are built in order to separate the storage cells and to facilitate the ventilation of the disposal site.

In Europe, salt mines are currently authorized for the underground disposal of hazardous waste only in Germany -5 sites, and the UK - 1 site (BiPRO, 2010c).

Figure 3.10 – Salt mine at Winsford, Cheshire, England (DEFRA, 2009)



In Germany, 3 companies are authorized to permanently store mercury containing waste in 5 salt mines whereof one of the sites is not currently in operation:

- Germany, Herfa-Neurode (Hesse) underground waste disposal
- Germany, Zielitz (Saxony-Anhalt) underground waste disposal
- Germany, Heilbronn (Kochendorf, Baden-Württemberg) underground waste disposal
- Germany, Sondershausen underground waste disposal
- Germany, Borth (North Rhine-Westphalia) underground waste disposal (valid permit but not in operation)

All in all, approximately three million tons of hazardous waste have been disposed of in the two disposal sites Herfa-Neurode (since 1972) and Zielitz (since 1995). Herfa-Neurode was the first facility worldwide, and is still the biggest hazardous waste underground disposal salt mine.

Operation of the underground disposals

Main steps:

1. Generator/owner of the waste must obtain the facilities' approval before transporting the waste to the facility by sending a description and analysis of the composition of the waste to the regulation authorities.

2. After a first check at the disposal site, the documents have to be sent to the relevant authorities (normally environmental) and the acceptance of the waste has to be approved by the authority.

3. At reception, the waste documents, the delivered amounts and the packaging are checked and random samples of the waste are analyzed (degassing, visual inspection, chemical composition). - Waste is only unloaded if it is identified as indicated in the waste documents and fulfils specific waste acceptance criteria. Otherwise the disposal of the waste is rejected.

4. Accepted waste is unloaded and transported to the shaft where it is then transported underground.

Storage facility operation

Erected walls of salt separate the single material groups from each other. As soon as a field is filled, it is closed off with up to 15-metre-wide dams.

The underground disposal sites are organized like warehouses. A sample of each waste is stored in a sample room underground. Storage place and storage time is documented and waste can be removed from the mine if required.

For underground storage of elemental mercury, specific technical standards are required, including packaging, analysis and documentation.

Environment and safety

Due to its plastic deformation behavior, salt rock may completely enclose metallic mercury in a gas-tight and impermeable geological barrier. Under natural disposal conditions, rock salt is practically impermeable to gases and liquids [BGR 2007, by BiPRO 2010c].

In long term storage, the only effective barrier to safely contain hazardous waste is salt rock and its specific isolation criteria. However, a minimum thickness of the salt layer is needed around the waste to ensure a safe encapsulation of it. For short-term storage, additional engineered measures, such as containment structures or constructed barriers can be applied.

Nevertheless, there are also concerns related to a permanent storage of liquid mercury in rock salt. A Swedish report [SOU 2008, by BiPRO 2010c] states that salt mines have properties which enable the waste to be completely enclosed. But for this to occur it is important that "the deformations occur without cracks and the shafts, inspection drill-holes and the like that link the terminal storage facility to flowing groundwater are properly sealed. If the waste body produces leaks, it is crucial that the surrounding rock has a natural ability to immobilize it and to ameliorate the effects of a leak."

In the report entitled "Safety analysis and scenarios for salt mine storage", possible scenarios for the permanent underground storage of liquid mercury in salt mines and the associated possible environmental risks (see [SOU 2008, by BiPRO 2010c]) are described.

The main concerns are:

- Possible sinking of the "heavy" mercury (which is seen as a long process that can take place over hundreds or thousands of years) and thus increased risk of liquid mercury to come in contact with open fissures

- Salt rock formations are affected by stress and strain, thus the waste is subject to pressure over time which might result in it being squeezed out into the access shaft for example.

- Fissures in the salt rock could trigger a release of the liquid mercury or mercury vapor into the biosphere

- Chemical reaction in the storage site (e.g. reaction between mercury and containment) may result in gas formation and a corresponding pressurization with risks that the contaminants could be pressed out through sealing plugs, fissures or pores of the rock. Corrective measures and retrieval of waste is therefore more difficult in cases where liquid mercury is stored without containers. In addition, mercury may very efficiently leach through existing pores and fissures.

- Possible plug leaks can occur due to very high petrostatic pressure at greater depths. As a consequence an effective enclosure of the mercury at a depth of 500 m would require enforced and strengthened plugs. (max. pore radius: 68-80 nm).

Experts suggest that the post-closure models developed for the disposal of radioactive waste could be adapted to the specific characteristics of mercury.

Economical Aspects

The final costs for disposal of 1 ton of hazardous waste is between US$ 340 to US$1200 in Europe, irrespective of the hazardousness of the disposed waste (e.g. metallic mercury or pre-treated mercury), if the site-specific waste acceptance criteria are fulfilled. The upper end of the price already includes additional costs, which might result from specific storage requirements for a special type of hazardous waste (e.g. separate chamber, isolated area). According to the necessity of additional requirements to be fulfilled the price will be higher.

For a cost estimate the following has to be taken into consideration: volume of mercury to be stored, technology acquirement, permits and documentation, packaging and over packing, project costs, pre-treatment, site assignment, building work, public consulting and publication, workers, machinery, monitoring, operation and maintenance, insurance.

B. Storage in hard rock formations

Properties of crystalline rock to be considered a storage option are:

- Permeability: Very low (unfractured) to high (fractured)

- Hydraulic conductivity: Very low to high

- Mechanical Strength: High

- Deformation behavior: Brittle
- Stability of cavities: High (unfractured) to low (strongly fractured)
- In situ stresses: Anisotropic
- Dissolution behavior: Very low
- Sorption behavior: Medium to high

The hydraulic conductivity of crystalline rock depends to a great extent on its physical state, whether fractured or not.

The permeability of the rock is highly dependent on whether it is fractured or not. In situ stress (anisotropic) in hard rock formations and the typical deformation behavior (brittle) may lead to fractures in the host rock (see [GRS 2009, by BiPRO 2010c]).

Hard rocks are effectively self-supporting and minimal engineered support and maintenance is required to prevent failure of the rock walls in the emplacement cells and access drifts. Crystalline rock has excellent stability of the drifts and room even at large depths but it has a relatively high permeability [Popov 2006, by BiPRO 2010c].

In the case of hard-rock, total containment is not possible. Due to its brittle deformation behavior, cracks and faults in the host rock may occur and liquids and gases could escape from a hard rock depository. In such cases, an underground storage needs to be constructed in a way that natural attenuation of the surrounding strata mediates the effect of pollutants to the extent that they have no irreversible negative effects on the environment. This means that engineered barriers are needed to attenuate and degrade pollutants as well as the state of the waste (**e.g. solid waste with a low solubility and volatility**) will determine the acceptability of a release from such a facility (Council Decision 2003/33/EC).

Hydraulic conductivity [GSR 2008, by BiPRO 2010c] and homogeneity of crystalline rock (granite) is strongly site-related and examination of a homogenous rock structure is very complex [GRS 2008]. High permeability properties are only guaranteed in unfractured rocks. In the case of fractured rocks, engineered barriers, appropriate containers or backfilling are required to avoid contamination of the environment.

For the backfilling of rooms and drifts, dense clay material rich in the mineral smectite seems to be the most appropriate material for crystalline rock. Various techniques for preparation and application of the clay-based materials have been tested and found to be very effective as "near-field" isolation of solid waste represented by mercury batteries. The best isolating medium turned out to be dense clay material applied in the form of pre-compacted blocks of clay powder or as on-site compacted clay layers.

Dense clay (bentonite) is also recommended [BGR 2007, by BiPRO 2010c] as appropriate backfilling material for crystalline rock.

Experiences related to the storage of waste in crystalline rock are available but only for stabilized waste.

Experience of underground disposal of mercury in hard rock formations

Although there are many hard rock mines (both active and inactive) in Europe, **experience with the** disposal of mercury in hard rock formations is very limited. Deep underground hard rock formations are typically used for storage of solid industrial waste such as fly-ash from incineration plants [Popov 2006, by BiPRO 2010c]. These waste types might contain small amounts of Hg but only in a solid matrix.

In 2005 the Swedish government commissioned an inquiry into permanent deep bedrock storage of mercury-containing waste. The inquiry concluded that the technical conditions required to build secure underground depositories in stable geological formations are very good. This report further states that all waste, including metallic mercury, must be appropriately stabilized prior to deposition , as the direct deposition of metallic mercury (for example in steel containers) poses safety issues, and raises new problems for which there is currently no adequate knowledge.

In Norway mercury-residue from zinc-production is cemented into sarcophagi and placed in a bedrock hall at the production site. Other disposal facilities in rock caverns are used mostly for industrial waste. Disposal of mercury waste in Norway (the maximum contents allowed in waste is 10% Hg) will need stabilization (with gypsum, cement, sulphur and sulphides as binders) prior to disposal. A national study recommends a temporary storage until immobilization technologies are developed. **Temporary storage could typically be in salt mines (which are already available), rock caverns, or preferably in deep bedrock permanent depositories, seeking non-oxidative conditions** [Kystverket 2008, by BiPRO 2010c].

Economic Aspects

There are no assumptions to costs relating to the storage of elemental mercury. In 2001, a report published by the Swedish EPA estimated the cost of a deep bedrock repository with a capacity of about 1,000-20,000 tons of high-level mercury waste to be about US$ 26 to 40 million (US$ 25 to 85,000/TM). The highest figure refers to storage of mixed waste, such as process waste containing 1-10% mercury.

Environmental and safety aspects

Total enclosure of the waste is technically not feasible in hard rock depositories. Due to its brittle deformation behavior, hard rock cannot encapsulate and fully enclose metallic mercury or mercury compounds.

Additional artificial or engineered barriers are needed to achieve better enclosure results and to ensure a safe encapsulation of the hazardous waste over a very long time.

Although hard rock has a very low hydraulic conductivity and gas permeability – under the condition of unfractured rock – the investigation on the homogeneity of this type of specimen is very complex [GRS 2008, by BiPRO 2010c]. It is difficult to exclude the occurrence of fractures or faults for a relevant variety of host rock [GRS 2008, by BiPRO 2010c].

Containers, which for instance may provide an important additional safety factor for the storage of metallic mercury, cannot be considered for long-term storage (see Decision 2003/33/EC, Appendix A, point 1.2.7). Therefore considerations for long-term safety are based solely on engineered barriers.

The presence of ground water flow in hard rock formations cannot be excluded, but the exchange rate of deep groundwater in hard rock is expected to be very low [Höglund 2009]. The effect of chemical stabilization of metallic mercury will further reduce the release rates to the environment by a factor of 100 in all alternatives [Höglund 2009].

The mentioned studies here (Environment Canada, 2001) and (US-EPA, 2003) justify the permanent storage of pre-treated (stabilized) mercury. It is assessed as an appropriate solution for the storage of excess mercury. In (US EPA 2002b) the temporary storage of liquid (bulk) mercury in existing mine cavities has been identified as a possible option.

In the report [SOU 2008, by BiPRO 2010c], the storage of liquid mercury in deep underground hard rock formations is not recommended.

Conclusions

In hard rock formations a total enclosure of the waste by the host rock is not possible. Standard procedure is the encapsulation of the waste cells with clay or other impermeable material. It is anticipated that the attenuation and degradation capacity of these artificially constructed barriers assist and prolong the long term safety of deep underground storage in hard rock formations.

Possible fractures in hard crystalline rock and the resulting higher permeability and higher hydraulic conductivity of hard rock formations may cause releases of liquid mercury or mercury vapor into the biosphere [GRS 2008, by BiPRO, 2010c].

The presumed groundwater flow in hard rock formations is considered a handicap, therefore the storage of liquid mercury is seen as critical due to the higher solubility in comparison to storage of solidified mercury with its lower solubility ([GRS 2008], [Höglund 2009], by BiPRO, 2010c). Where storage of stabilized mercury is concerned (e.g. in form of mercury sulphide), the hydraulic situation has to be very carefully taken into consideration to avoid non-acceptable emissions from the storage site into the biosphere via groundwater flows.

Experience with regard to the storage of metallic mercury as well as stabilized mercury (e.g. mercury sulphide) in hard rock formations is not yet available. In deep underground hard rock formations typically solid industrial waste such as fly ash from incineration plants containing small amount of mercury is stored, but only in a solid matrix [Popov 2006]. In Norway two underground facilities have a permit for the storage of stabilized *mercury containing waste* with a maximum mercury content of 10% [Kystverket 2008, by BiPRO, 2010c].

In addition, a Swedish study assessed Swedish bedrock to be able to meet specific requirements for the storage of stabilized mercury [SOU 2008, by BiPRO, 2010c].

Hard rock formations are seen particularly suitable for the storage of stabilized mercury [SOU 2008], [Höglund 2009], by BiPRO, 2010c.

C. Storage in Sedimentary rock

Argillaceous rock covers a wide range of rock types from plastic clays, with transitional types, to strongly consolidated and partially fractured claystones. Argillaceous rock formations in France (Callovo-Oxfordian), Canada (Ordovician argillites) and Switzerland (Opalinus Clay) are highly consolidated sediments.

The following are the most important properties of argillaceous rock:

- Permeability: Very low to low
- Hydraulic conductivity: Very low
- Mechanical strength: Low to medium
- Deformation behavior: Plastic to brittle
- Stability of cavities: Artificial reinforcement required
- Estrés in situ: Anisótropo
- Dissolution behavior: Very low
- Sorption behavior: Very high

Argillaceous rock has a very low hydraulic conductivity but poor stability and the vicinity of the drifts may be very conductive.

Argillaceous rock formations possess relatively high mechanical strength, depending on the particular structure (fracturing) and mineralogy of the rock. However, these may exhibit some plastic behavior, which progressively reduces fracturing but they may also lead to excavation damage zones around the repository due to excavation are a problem, depending on the rock characteristics. Appropriate support would be required for operational safety, although it is considered that excavations could be kept open with suitable maintenance over extended periods. In argillaceous rock, short term support (from a few months to some years) is often provided by means of rock bolts with metallic arches, metallic meshes and/or shotcrete. Concrete linings can subsequently be deployed to provide mechanical stability for a longer period.

Regular maintenance of the excavation lining may be necessary should the access remain open to enable getting easily to the waste emplacement cell. The frequency and scale of any maintenance work will depend on the deformation rate of the rock at the proposed depth and on the design and properties of the lining.

According to [GRS 2008, by BiPRO 2010c] argillaceous rock is generally assumed to have adequate strength for the construction and maintenance of underground drifts, but the stability of the drifts can only be guaranteed by additional reinforcement and supporting measures. These measures are particularly complex and expensive in unconsolidated clay, therefore storage in consolidated clay is more appropriate.

As in the case of crystalline rock, clay material rich in smectites is particularly required as backfilling material due to its high isolating potential [Popov 2006, by BiPRO, 2010c]. Argillaceous rocks have proven their long-term effectiveness as geological barriers, where they form tight seals, for example above hydrocarbon reservoirs**. Mineralogical, geochemical and geotechnical investigations of argillaceous rocks are currently being conducted in international rock laboratories. Little information is available due to a lack of mining experience with these rocks** [GRS 2008, by BiPRO, 2010c].

3.3.2.4 Potential host rock formations for underground storage in LAC

A suitable geologic formation for the disposal of mercury in the subsurface must meet certain characteristics such as a low permeability and preferably a low sorption capacity (geochemical immobilization). A tectonically stable region is preferred, which is not subject to earthquakes.

Rocks of low or no permeability are mainly those of an igneous intrusive nature, such as granite and gneiss in general, and dense sedimentary rocks like clays or salt formations (domes or salt beds).

All these rock types have a low primary permeability. However, with the exception of salt, they may show under certain circumstances elevated secondary permeability, as a consequence of fracturing or shearing generated by the tectonic deformation. The intrusive igneous and metamorphic rocks are the types more affected by ruptil tectonism. Most of these rocks, depending on their age, are intensely fractured.

A review of underground storage possibilities in the western hemisphere implies in a short review of South American geology and its potential for such purposes.

South America can be divided into three major geological provinces. The oldest rocks occur in the east of the continent, in the plateaus of the Guyana and Brazilian Shields, separated by the Amazon basin. To the West and north is a Paleozoic area of broad plains, underlain by Paleozoic rocks, and to the west again is the Andean mobile belt, lying along the length of the Pacific coast and extending along the northern Caribbean coast. This belt is of Mesozoic to Tertiary age. The most promising rock types are the granites and gneisses of the Precambrian Guyana and Brazilian Shields and to a lesser extent the relatively young granite intrusions of the Andean belt.

The Guyana shield occupies: Guyana, Suriname, French Guiana, and parts of Venezuela, Colombia, and the northern part of Brazil. The oldest rocks are highly metamorphosed plutonic rock complexes mixed with a variety of less highly metamorphosed sedimentary and volcanic successions which are older than 2,000 million years. These old assemblages are overlain by a flat-lying sedimentary formation known as the Roraima Formation which comprises several thousand meters of sandstones, conglomerates, and shales, whereby the shale formations are of interest for the review here undertaken.

Rocks of Paleozoic age cover a large area between the old shield areas and the Andean belt to the west. They consist mainly of shallow-water sediments. At the end of Paleozoic times glacial deposit are generated, which include impermeable clays and siltstones.

The Andean mobile belt at the western margin of the continent is characterized by widespread volcanic activity and uplift of the mountain chain of the Andes. The continued westward movement of South America is evident from the deep-seated earthquakes occurring below the Andes, Large intrusions of granite occurred in this region.

Gneiss and granitic rocks have a wide distribution on the entire South American continent, being registered practically in all pre-Cambrian and also in younger terrains along the Andean Mountains. In general they are fractured, but there are also occurrences of low fracture incidence. Each typology of rock requires local studies, case by case, to evaluate their tectonic and permeability condition.

Due to their tectonic instability and great probability of earth movements the Andean range is not very suitable for underground storage, even though there are adequate rock types identified, for instance large granite intrusions. Unfavorable conditions also are encountered in the Caribbean region due to the high seismicity which is present it these areas. In addition they are susceptible to hurricanes and tropical storms. In the ***Annex 6*** a table summarizes the main regional specifics for storage sites in the LAC region including seismic maps.

Clay, argillite, and siltstones occur in sedimentary basins and are abundant on the South American Continent. They are registered at variable depths, from superficial to more than 5,000 m. Generally they show little fracturing.

Salt rock, also present in sedimentary basins, have restricted occurrence in Brazil, with only one potassium mine in Sergipe State and known underground reserves in the states of Amazonas, Minas and Tocantins. Salt mines are known from Colombia and México. In *Annex 7*, a map is attached with the outcrops of suitable geological formations for underground storage in the region. For a more detailed selection of sites a pre-feasibility study considering geological, technical and legal aspects has to be undertaken.

Mercury storage in abandoned mines, especially salt mines or in granitic rock requires more detailed studies in order to select an appropriate site. In Latin America and Caribbean this would imply higher costs for planning and investment since this kind of work has not been done so far, as compared to various European countries , where a variety of options do exist and are exploited.

LEGAL AND SOCIAL AND CULTURAL ASPECTS

The only practical reference in the LAC region regarding underground storage is the technical standard for the confinement of liquid oil wastes in salt domes in Mexico. The facilities are not in use yet.

Even showing its environmental benefits, an underground deposit, requires a complex process of environmental licensing, that includes other institutions such as those that regulate the use of underground resources, mining, the municipalities, and the army (which authorizes the use of explosives), among others. In addition, the environmental impact assessment would also require a study of alternative areas, pre-feasibility assessment, public consultations, inventories, among other legal requirements.

The selection of an underground site requires a pre-feasibility study, including detailed information on geological, environmental, social and legal aspects, infrastructure facilities and other. In some countries the use of underground bedrocks can be limited by other uses, for instance the strategic storage of oil and gas in cavities and salt domes.

In most countries, environmental licensing processes involve the active participation and/or dissemination of the project outline to the community. Government entities have to be prepared to confront local and nation-wide protests because of the high potential of environmental impact which could affect natural resources or resources important to other sectors, such as tourism.

Based on the experience of large infrastructure projects, such as highways, hydroelectric, and others, the time frame of a complete environmental licensing process can take more than 5 years, involving all stakeholders.

The storage alternatives in hard rocks in Sweden are mentioned as an example. They have been investigated since 2005 (BiPRO, 2010) and are still awaiting the final approval by Swedish EPA.

A realistic picture for the development of a concept and the preliminary administrative and licensing steps is calculated in the realm of the next 5 years. Perhaps in Mexico, where the normative regulation is more developed, salt domes and old mining sites can be used earlier.

Other aspects to be considered are related to the legal, political, economical and institutional stability of the countries, as long term storage will prevail and remain active as governments and project managers. The facilities will need resources; monitoring and public awareness about the long term risks for many years after these installations are approved and have started working.

In summary, the long term environmental liabilities have to be taken into consideration before a facility can be approved for permanent storage.

ECONOMIC ASPECTS

There are no precise cost estimates for mercury disposal in underground facilities, because this option has never been implemented yet. The estimates are based on the prices charged for hazardous waste in Europe.

BiPRO (2010) reports the cost for disposal of 1 ton of hazardous waste to be between US$370 and US$1,260 in salt rocks, irrespective of the quality of the disposed waste (e.g. metallic mercury or pre-treated mercury).

For hard rock, BiPRO reports that figures can vary according to the actual prices estimated by the companies that will manage the facilities and to the depth at which the facility will be installed. The investments for a deep bedrock storage implanted adjacent to an old mining site is approximately US$1300 -2,160/$m^3$ for a developed space of 10,000 m^3 o US$220 – 275 per m^3 at 100,000 m^3 of storing volume. Additional excavation costs are calculated at US$70 per excavated m^3 of volume. The construction of an entrance ramp is estimated at costs of approximately US$ 7200 /m.

Further costs for equipment such as pumps, cables, ventilation, lights etc are estimated at 20-25 percent of the construction cost, plus pumping and ventilation. Approximately US$ 175,000 – 288,000/year are estimated for staff and transportation. The overall estimated operative expenses range around US$360, 000-700,000/year.

The costs of pre-treatment must be added as well. These depend on an official approval by the environmental authorities and others like insurances, auditing, contingencies, closing the storage, monitoring.

The specific requirements for underground disposal facilities and the acceptance criteria are not yet agreed; therefore, their economical significance remains unclear for the moment and theses costs have to be considered with some care.

Another uncertainty is the potential future role of chemical stabilization.

Despite the lack of underground facilities for waste disposal in the LAC countries, European costs estimates should not be extrapolated to the region. Instead, the regional or local costs must be assessed in a study that includes technical, environmental, social, legal and economic feasibility issues.

In the cost structure the studies must consider various aspects like location, disposal concept, annual throughput, investments, required in infrastructure, distances, country specific requirements, pre-treatment requirements, and national costs.

Nevertheless these prices may be considered when estimating the costs of future mercury exportation to Europe for final disposal.

3.4 Other options & relevant experiences

Landfills and monofills are mentioned in the literature as an option for stabilized mercury final disposal. However, several countries worldwide do not consider landfills as an option. Above ground warehouses and other hard structures such as igloos and bunkers have also been considered as a feasible option. Costs can be calculated using the matrix shown at the end of this chapter. The most realistic and viable options, however remain the temporary storage and export to safe storage facilities.

3.4.1 Export option for mercury waste storage

For countries that produce a small mercury surplus or where the construction and operation of a storage facility is not feasible economically, the export of the generated mercury waste must be considered. Adequate storage facilities are commercially available worldwide, for instance in the USA, Mayasa in Spain, the salt mines in Germany or England. However, this implies political negotiations and the willingness of the above-mentioned countries to accept mercury contaminated hazardous waste from smaller countries or individual generators. In fact, this practice is already ongoing with the Peruvian and Chilean exports of mercury as a by-product to the USA and the mercury resulting from decommissioned Brazilian chlor-alkali facilities sent to Spain last year.

The waste export may be kept in the catalogue of alternatives, in case this option is offered to Latin American countries and the costs are competitive.

Mayasa, in Spain, paid US$5.30/kg for the mercury from the Brazilian company Solvay. Last year, Newmont Mining Corporation exported mercury to USA with the characteristics presented in Annex 8. Costs are presented in Tables 3.3 and 3.4, not including mine inspections (bottles certification by SGS, filled bottles inspection by Bureau Veritas, Loading, others). **(Reference:** Personal Information from. Morales Valencia).

Table 3.3 – Costs of mercury exporting (SOURCE: Marco Morales Valencia – Newmont Mining Company)

MERCURY EXPORT EXPENSES	
EXPENSES	
	Cost per kg U$
Inland freight mine site - Callao port	$0,74
Customs agent fee	$0,08
Freight forwarder fee	$0,01
Ocean shipment	$0,31
TOTAL	**$1,14**
SALE TO BETHLEHEM	
Invoiced per kg	**$0,35**
SUMMARY	
Sale to Bethlehem	$0,35
Export expenses	-$1,14
TOTAL	**-$0,79**

Table 3.4 – Costs of mercury exporting (SOURCE: **Personal information of** Katia Castillo Legal Departament of Barrick Mining).)

Item	Amount (USD)	Cost/kg (USD/kg)	Comment
1. Maritime freight charge (from port in Peru to port in USA)	2500	0,28	Per each 9TM container of 20'
2. Local terrestrial transportation (port- minesite- port)	3500	0,39	Custody, terrestrial transportation insurance
3. Maritime transportation insurance	146	0,02	Fixed cost
4. Other costs (loading, unloading, storage, safety seal, others)	600	0,07	Per each 9TM container of 20'
5. Certificate of packing by Ports´ authority	900	0,10	Yearly
		0,85	**Total**
Estimated total Hg exporting costs	**US$ 7646**		

Exportation is expected to become more expensive, since companies will be charged higher fees for treatment and disposal services provided at storage facilities.

A future threat identified for this option is Directive (CE) No 1102/2008 OF THE EUROPEAN PARLIAMENT AND COUNCIL, of October 22, 2008, regarding the prohibition of metal mercury exports and certain compounds and mixes of mercury. Article 8 establishes that the Commission will organize an exchange of initial information among the member States and the corresponding interested parties, no later than January 1, 2010. This exchange of information will focus especially on the need to:

a) Enlarge the export ban to other mercury compounds, to include mixes with a smaller mercury content and products containing mercury, particularly thermometers, barometers and sphygmomanometers;

b) Ban the imports of metal mercury, mercury compounds and products containing mercury;

c) Enlarge the compulsory storage of metal mercury coming from other sources; and

d) Establish deadlines for the temporary storage of metal mercury.

Considering this statement, it is important to follow up the periodic reviews of the EU Mercury Export Ban and create mechanisms to authorize the import of mercury waste for storage purposes permanently.

3.4.2 Temporary storage

Temporary storage facilities, above or underground, are an intermediate option until the mercury stabilization and immobilization technologies, and the final disposal criteria are well consolidated, which was estimated by BiPRO (2010) to be until 5 years.

BiPRO (2010) estimates a timeframe for temporary storage of 5 years due to the fact that "currently no permanent solution is available. Although the European Community States are engaged to find a permanent solution for mercury storage, all potential permanent solutions still have a certain level of uncertainty related to their availability by March 2011. Temporary storage solutions are required to bridge the gap until final solutions are available as a best alternative" (see Chapter 11 Conclusions and Recommendations –page 280-281 - "*Requirements for facilities and acceptance criteria for the disposal of metallic mercury"*- Final Report - BiPRO, 2010 *).*

For the LAC region, this solution can fill the gap in the creation of the necessary legal framework, training, and research programs, as well as the transportation infrastructure and the construction of a permanent storage facility.

A rented warehouse or above-ground facilities especially built for this purpose would serve as a temporary storage, and they are more feasible as short- or medium-term solutions because of their reversibility and reasonable costs, added to the fact that the process to get the environmental permit is easier than an underground facility.

3.5 Analysis of existing facilities

The main current technical options to manage mercury waste were presented in previous chapters, as well as the state of the art of any alternative in the world. LAC can consider the following options in the next five years:

a. Above ground warehouses as temporary facility

b. Exportation for mercury storage

Table 3.4 summarizes all the options for mercury storage.

Warehouses are the most consolidated option and at present they are the easiest structure to implement because they does not require the use of natural resources and the environmental permit procedures are less complex. Nevertheless, as it is considered by EU, this option cannot be considered a long-term storage option. Management of a warehouse requires strict control. Political and institutional stability are mandatory, to keep and insure the mercury stock under an efficient operational and maintenance control. These risks must be considered in a risk assessment and the necessary preventive strategies have to be taken into account in the design and in the environmental permit procedures for the facility.

The construction of underground facilities requires very high investments either in the research based in the national geological inventory and studies made in the field, special construction structure, costs of a social awareness, infrastructure for transporting, and training programs. Countries need time to create in their legal framework this kind of final disposal, trough regulations and technical standards.

Economical aspects must be considered. Similar structures in Europe share the costs and space with other wastes streams, using the area prepared before due mining activities. For most countries of LAC, the first structure would be build just for elemental mercury final disposal.

For most countries of LA&C, the hard rock formations are the most current alternative as an underground option. In this case, it is required a pre-treatment (stabilization/solidification) which is considered not mature enough to guarantee its efficiency in industrial scale for most environmental authorities in developed countries and scientists. As consequence, the concept of an underground disposal requires more time to be an option in the region.

Exports can be a good short term solution, especially for countries with a very small mercury surplus, where a special construction is not an economical solution. Export also is the best solution for countries where risks due to natural phenomena are important aspects to be considered. Anyway, the export solution to a safe mercury storage is a definitive solution for any country. Besides, the mercury export requires a careful analysis regarding technical, political and legal aspects related to the hazard substance exportation for a longterm storage purpose. Both countries (the exporter and the importer) must establish common rules regarding mercury export, like quality control, packing, amounts to be stored, period of time in which mercury exports will be accepted, and others.

This option can be combined with an interim storage in above ground facilities, near a harbor or airport. Cooperation agreements similar to the one that Canada has signed with the Caribbean region for hazard waste are examples of mechanisms to ensure a permanent mercury sequestration in these countries. These agreements help to reduce the high costs of elemental mercury final disposal, which are not affordable for most of developing countries.

It is recommended that even a short time storage in above ground facilities follow the example and complain with the whole technical requirements of a longterm storage, but in a smaller scale. The constant movements of the heavy pallets and the variety of sources from where the elemental mercury comes are risks to be considered in the design and operation of the facility.

Landfills and monofills are not an available option for elemental mercury storage as it is a liquid and it is difficult to stabilize. The literature mentions the construction of an exclusive bunker with configuration and monitoring system similar to a warehouse. We consider the operation of these structures as more complicated than the warehouse facility.

Table 3.4 outlines a comparative matrix of the mentioned options for mercury sequestration.

TABLE 3.4 – Comparison of mercury sequestration options.

OPTION	PRE-TREATMENT	PACKAGING	MATURITY	DIFFICULTY	LIFE OF INSTALLATION (years)
Aboveground warehouse	Not needed	Flask - over pack, containers, pallets	good	Medium	50 or more
Underground rock salt*	Needed or not	Sacks or drums	no	High	>100
Underground hard rock	Needed	Sacks or drums	no	High	>100
Underground clay	Needed	Sacks or drums	no	High	>100
Exports	No. But can be a requirement of the facility manager	Flasks or container	good	Low	>50 or >100
Temporary storage underground	No	Flasks or container	no	Medium	>1 year (5 years EU)
Temporary storage above ground	No	Flasks or container	good	Low	>1 year (5 years EU)
Landfill	yes	Drums or sacks	Not feasible today	High	>100

*The storage without a pre-treatment is still not agreed.

ECONOMIC ASPECTS

According to the volume of mercury to be stored and considering local conditions, LAC countries may select one or more of three options: (a) above-ground specially engineered warehouse, (b) underground storage within geological formation; and (c) export to EU, USA or a regional facility, approved under cooperation agreements.

In addition to the legal and international commitments, the decision will be influenced mainly by economic aspects, i.e., the capital investment, the operation, maintenance and post closing costs.

Option (b) still is unavailable and actually its costs are considered just for exports of mercury waste.

Exports of Mercury Waste

Option (c) involves the following additional costs: permit and acceptance by the importer facility, plus costs of transport, packing, documentation, customs according to the weight to be exported and the required pre-treatment (stabilization/immobilization).

Until March of 2011, the costs of exportation of elemental mercury, mostly provided by chlor alkali plants, mercury contaminated wastes or mercury contaminated mining tails are related only with operational costs (auditing, transport, packing, documentation, customs, permits) because they are exported to be sold in the world market. This is the reason because the prices paid today by companies are lower when compared with those to be applied in the future.

When Europe and USA start to ban mercury exports, two situations can happen:

1. Mercury will be export to be used in processes where there is not an economical alternative free of mercury; then, mercury still will be in the market;
2. Mercury will be stored in an approved facility; in this case, facilities fees must be considered. It is not clear if it will be paid in one payment or if there is a periodic fee for costs of maintenance.

At present, a preliminary estimate must consider:

a. Customs, freight and shipment fees; Example -US$ 1140/t – Mining tails from Peru to USA

b. Permits and insurance – vary from country to country

c. Internal costs - auditing, internal control, etc – vary from country to country

d. Packaging – US$ 500-900/t

e. Transport – according oil costs in each country.

These costs represents approximately USD 0.8 to 0.85/kg of wastes poorly containing mercury (considering mining tail as a mining waste). These costs must be different of those to export elemental mercury (99 to 99,5% of purity), which volume must be lower and specific weight higher. Packing must also be different.

Since 2013 the costs of storage fees must be considered. According the first approach given by BiPRO costs for storage are:

a. Above ground facility - USD 5,7 to 18,4/kg (considering USA costs)

b. Underground facilities – USD 0,34 to 1,2/kg in Germany salt mines Underground facilities – USD 25 to 85/kg according estimated cost in Swedish hard rock formations.

These are estimated costs and not necessarily they represent the fees to be applied for facility clients.

Storage in above-ground warehouses

A case study is proposed for a storage facility in a 10 to 50 years period of time (until 2020 and 2060, respectively).

In the economic analysis of option (a), legal and economic aspects, as well prices were estimated on the basis of projects for hazardous and non hazardous waste in Brazil and Mexico, countries where costs were fastened obtained and were a facility probably will be built. The costs framework can be adapted for any country, with local prices.

Three scenarios were proposed:

(A) Small amount of mercury to be stored: weight of mercury to be stored < 100 ton; this solution is appropriate for local facilities as hazard wastes managers, public or private; countries with low mercury excess can use this scenario;

(B) First scenario proposed by Peter Maxson in 2020, assuming one storage facility in one country: weight of mercury to be stored < 1,500 t;

(C) An extrapolation of the amounts of mercury to be disposed of, because of the improvements in mining tails and other usage restrictions: weight of mercury to be stored > 8500 t initially estimated for the whole region, it will be considered just in one country.

Packaging is an important aspect to be considered for longterm storage, The costs of packaging can be absorbed by mercury generators, like chlor-alkali companies, mining enterprises, or mercury recyclers. In Brazil, some recyclers use the same flask in which mercury is imported. We have reported that in places where there are gaps in mercury control, flasks used in mercury imports are discarded and reused for other purposes. We considered packaging as a fixed cost for some facility clients, like municipalities or hospitals, in order to have an appropriate mercury disposal. In LAC region elemental mercury extracted or separated from equipments and devices is still stored in glasses, plastic or any other available recipient. Places of short term storage are full of these containers. We have reported some accidents because of these practices. Probably the first action for appropriate mercury longterm storage will be an appropriate handle and packaging.

Costs of transportation must be considered in the site selection, in order to reduce costs of the main users of the storage. These costs depend on gas prices which are different for each country. Diesel prices vary from USD 1.2/L in Brazil to USD 0.30/L in Ecuador or lower in Venezuela. Other aspects which influence transportation costs are road tolls. In Mexico, these prices can represent an extra tank of diesel, depending of the distance.

STORAGE ARRANGEMENT:

The facility will store mercury in one-metric-ton containers on pallets, with three containers fitting on each 1.2 m by 1.2 m pallet. This arrangement allows approximately 2 ton per m^2 of storage space. However, each storage building will need to set aside at least 20 percent of total storage space as clearance to facilitate inspection of stored mercury. .

SECURITY:

Security will consist of a fence that will enclose the entire facility, forming a perimeter 100 m from the storage buildings. This fence will have one security post with 24-hour surveillance by camera and on-site personnel.

SOURCES OF MERCURY:

Although mercury is expected to come from mercury recyclers and retorters (who treat mercury containing products), and closed mercury cell chlor-alkali facilities, this report assumes that all mercury to be stored will pass through mercury recyclers and retorters for packaging before being transported. The same treatment is expected to be done to mining tails, by-product, foundries, and oil and gas air emissions treatment sludge to be accepted in the facility. Costs of treatment and packaging for big companies and waste generator are not included in this report.

The following costs were considered for this case study:

STUDIES, PERMITS, INSURANCE AND PUBLIC AWARENESS

- Development of environmental impact assessment and facility design: costs related with the environmental impact assessment, building and ancillary facilities design, according to the national legislation and local requirements;
- Environmental permits and others: estimated cost of licensing and permits which include environmental, health, municipal, and other permits required in Brazil and Mexico.
- Public awareness: the unit costs related to programs and public audiences for social awareness.

- Insurance: the unit cost includes taxes and insurance paid for loadings, working insurances, and others set forth in national legislations (environmental insurance in Ecuador, and other countries);

CONSTRUCTION:

- Land Purchase: The land purchase unit cost applies the typical land costs for industrial use in areas not excessively over-evaluated like São Paulo, Rio de Janeiro, Mexico City and Guadalajara. The area must have the necessary infrastructure available, like roads, energy, and communications.

- Construction: the unit cost reflects typical core/shell construction costs for industrial buildings, including taxes, permits and labor insurances. The square meter for industrial construction must be adapted because of mercury specifications (density, volatility, and specificity). The prices are estimated for floor strengtheners and coating, room temperature control and monitoring systems. Learning the construction specifications can increase the prices, due the limited market for experienced constructors;
- Machinery: estimated initially as 20% of the whole construction investment by BiPRO (2010); theses costs can be higher depending on the prices of technology in each country. Equipment and machinery considered are: computer-controlled air monitoring systems, lab equipment, computers and heavy machinery, loading and unloading vehicles. We will assume the costs of 20% as proposed by BiPRO;

Financial costs - the unit cost for annual taxes payments due to loads and costs of investments – estimated as 12% per year in Brasil (BNDES – 0,97% /month - http://www.nossacaixadesenvolvimento.com.br/portal.php/linhas-financiamento) and 14% in Mexico (http://www.banamex.com/image_bin/indicadores_economicos/1052.png) .
PERSONNEL:

- Labor: labor costs related to the permanent employees as secretary, plant and offices workers, gardeners, and guards
- Professional team: labor costs of professional team as engineers, lab professionals, lawyers, managers.
- Training: unit costs related to training programs, technical trips and attendance to conferences

OPERATIONAL COSTS

- Operational costs – unit costs of communications, electricity, water, facilities maintenance, annual taxes and permits, security and insurances, participation in events like meetings and negotiations with clients; these costs vary from one country to another and can be estimated as a fixed annual cost.
-

- Transportation: Transportation unit costs represent the cost to transport one ton of mercury from its point of origin to the storage facility site by truck. The values can vary from one country to the other depending on fuel, vehicle prices and road systems;

- Maintenance and monitoring costs: unit costs related to monitoring, maintenance and reposition of flasks, containers, pallets, equipment; costs of sampling and laboratories, research; these costs are estimated in accordance with the amount of mercury stored and the number of workers; In this model, it is estimated at least 30% flasks changing during the 50 years and 6% in 10 years.

- Offices and kitchen: unit costs related to office material, cleaning, and kitchen materials.

- Certification and inspections: unit costs related to quality, environmental and health certification, internal and external auditing; annual environmental permit costs;

- Communication programs: unit costs related to marketing and information regarding the facility.

OTHER COSTS:

- Unforeseen events: unit costs resulting from labor lawsuits, accidents and other unforeseen situations; estimated as 5% of project;

- Shut-down costs: are the costs related to the cleaning and sale of the site, payment of social insurance, communications and the implementation of an annual monitoring program for 10 years surrounding the facility. It is estimated as 50% of total investment.

Table 3.5 outlines a simplified example of the capital investment for the installation for 10 and 50 years of a warehouse facility in Brazil and México. Brazilian costs were research on the newspaper, Engineer Council Magazine. Mexican costs were provided by personal communication of Mr. Jorge Jimenez Perez from SEMARNAT and economical indicators. In these estimates, costs of pre-treatment and mercury purification are not considered. We considered these aspects in the chapter 4, where mercury wastes are discussed.

Table 3.6 outlines a proposal structure for annualized costs for a warehouse operation. The prices or costs estimate are merely a reference, because there is no practical example of mercury storage in the region. Based on the experience of the USA buildings, local costs and a security margin of space, we considered the following values:

a. One ton of Hg by every 0.8 m^2, handling, management and security external areas included;

b. Currency exchange – R$ 1,70/1US$ and PM$ 12/1 US$;

c. US$ 450/m^2 of construction (special flooring, electrical and emergency facilities) in Brazil =- USD 200/m^2 - México;

d. Purchase of land in industrial areas (with road system available): US$ 25000/ha - Brasil 80000/ha

e. Minimum wage – US$ 300 in Brazil, USD 110 in Mexico – We considered an –average of 4 times the minimum wage/worker/ month and 6 times the minimum wage/professional/month plus 1.8% of social costs in Brazil; average of 8 times the minimum wage/worker/ month and 15 times the minimum wage/professional/month plus 1.8% of social costs in México;

f. Formal training programs - US$1,500/20h*20 students; US$ 5000-10000/year attendance to conferences and technical visits in both countries

g. Monitoring – US$ 1,000/month -; US$ 6000/year after closing for both countries;

h. Flasks prices – US$ 30/flask for both countries – 10-20% exchanged during the whole operational time;

i. ;

Costs used for environmental permits considered Brazilian values given by environmental authorities of State of Rio Grande do Sul and other local permits (health, municipalities, army, IBAMA, etc.). Mexican costs must be better evaluated.

Comment [VC2]: referencia http://www.fepam.rs.gov.br/licenciamento/Area1/default.asp\

Studies and design costs considered an average price practiced in Latin America.

For interim storage in harbor and airport areas, this same matrix can be applied to smaller amount of mercury to be stored until export. Land and/or building can be rented instead of having the obligation of property maintenance. Anyway the rented building will need some adaptations for mercury storage. In this case, costs of area devaluation must be considered due its use for mercury storage. Owners can ask for compensation.

Comment [VC3]: REVISAR COM TRINI: QUIERO DECIR QUE AL DISPONER MERCURIO EM UMA ÁREA, ESTA AUTOMATICAMENTE DEBE PERDER VALOR, DE MERCADO, PUES PASA A SER UM ÁREA DE SACRIFICIO. MISMO CON TODOS LOS CUIDADOS, SIEMPRE TENDRÁ EL ESTIGMA DE ALMACENAMIENTO DE MERCURIO.

It is recommended that even when total costs reflect an overall facility-operating period of 50 years, facility operators estimate costs in five separate ten-years planning cycles. As it was proposed in the second scenario, operators must design facilities and make capital investments to meet projected mercury storage requirements for each ten-year period, when new improvements and information are available.

Table 3.5 – Estimated Capital Investment for Above-ground Warehouse Facility Construction

Investment details		Costs Brazil (US$ *1,000)			Costs México (US$ *1,000)		
		A - < 100 t	**B - < 1,500 t**	**C - < 8,500 t**	**A - < 100 t**	**B - < 1,500 t**	**C - < 8,500 t**
Studies, permits, insurance and public awareness	Environmental impact studies and facility design	200	600	1500	200	600	1500
	Environmental and other permits	16,8	45,9	160	16,8	45,9	160
	Public awareness	5	50	100	5	50	100
	Insurance	30	150	600	40	120	450
Land and Construction costs	Industrial plot of land	30 (>1 ha)	30 (>1 ha)	80 (2ha)	88 (>1 ha)	88 (>1 ha)	160 (2ha)
	Construction costs	50	600	3400	24	360	2040
	Machinery and equipments – 25% whole construction cost	12,5	150	850	6	90	510
Financial Costs	*Loans amortization (considering 70% financed and rates of interest around 0,97%/month, 10 years for repayment)*	153,29	719,86	2970,33	165,34	601,47	2179,80
Net Investment Costs		**314,3**	**1475,9**	**6090**	**339,8**	**1233,9**	**4470**
Present Cost/ton		**3,14**	**0,98**	**0,72**	**3,40**	**0,82**	**0,53**
Total Investment costs (financial costs included)		**467,59**	**2195,76**	**9060,33**	**505,14**	**1835,37**	**6649,80**
Total costs/ton		**4,68**	**1,46**	**1,07**	**5,05**	**1,22**	**0,78**

Table 3.6 – Estimated Annualized Cost for Above-ground Warehouse Facility Operation

Operational Costs		**Costs Brazil (US$ *1,000)**			**Costs México (US$ *1,000)**		
		A - < 100 t	**B - < 1,500 t**	**C - < 8,500 t**	**A - < 100 t**	**B - < 1,500 t**	**C - < 8,500 t**
Personnel	Labor (6;10;15 workers)	168	281	421	124	225	309
	Professional team (2; 4; 6 professionals)	84	168	253	77	154	232
	Training	4	8	10	4	8	10
Operation start-up	Operation (energy, communications, taxes)	7	14	21	6	10	12
	Maintenance and monitoring (air, soil, ground water, blood and urine)	36	48	50	36	48	50
	Offices and kitchen	2	5	7	2	5	7
	Communication and Marketing Programs	12	12	12	12	12	12
	Unforeseen events and shut down costs	10	20	50	10	20	50
Others (permits renew; auditings)		8	12	20	8	12	20
ANNUAL OPERATIONAL COSTS		**332**	**568**	**844**	**279**	**494**	**702**
OPERATIONAL COSTS/t		**17**	**4**	**5**	**14**	**3**	**4**

4 Technological options for mercury-containing wastes and end-of-life product management

The main objective of this chapter is to present actions to complement the initiatives implemented by the countries to phase-out the use of mercury in products and processes, generating a surplus of mercury-containing materials to be disposed of.

This chapter will not discuss in depth all the mercury-containing wastes and processes based on mercury. Instead, it will outline some alternatives to create awareness regarding the need for an appropriate destination for mercury-containing products and the measures that should be implemented for the safely handling of mercury in the processes.

Most options are already mentioned in the technical literature and in the UNEP and Basel Convention Guidelines. The US legislation is mentioned as an example of the handling, treatment and final disposal of mercury wastes. Some examples in LAC region are also presented to illustrate the existing local alternatives.

Before determining the appropriate final disposal for mercury wastes, it is important to consider some preliminary steps to develop a strategy that may reach most mercury wastes and prevent any releases to the environment during their collection, transportation and disposal.

According to the Basel Convention (1 – Basel ConventionTechnical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Mercury – 5th Draft (**14 May 2010)** all mercury wastes are considered as hazardous wastes. Any programs designed for their management should include the key elements below:

- Establishment of a baseline as a basis for evaluating and quantifying program improvements;

Stakeholder participation in the development of plans and strategies for implementing BEP and BAT

- Development of model areas to demonstrate the application of Best Available Technologies and Practices;
- A systematic approach to mercury waste management and storage;
- Capacity building;
- Awareness-raising, training and education;
- Periodic monitoring and evaluation, and continuous improvement of the program;
- Dissemination of information regarding successful models of mercury reduction; and

- Replication of successful models to other areas.

Other recommended complementary activities are:

- Documentation of existing mercury waste management practices and policies;
- Review and ammendment, where appropriate, of national policies, laws and regulations, in order to define hazardous wastes, including mercury wastes, Environmental Sound Management (ESM) of mercury wastes, to ensure they meet the requirements of the Basel and Stockholm conventions;
- Establishment of mercury waste minimization in cleaner production programs;
- Creation of institutional capability to carry out the new policies and practices;

It is recommended to register large scale mercury waste generators, such as hospitals, medical clinics, dentists, research institutes, collectors of mercury waste, etc. The registration of mercury waste generators provides clear information on the origins of mercury waste stream, as well as kinds and volume of mercury waste (or a number of used mercury-containing products).

Mercury waste should be dealt with on following ESM practices, i.e.,taking all practicable steps to ensure that mercury waste is managed in a manner that will protect human health and the environment from any adverse effects that may result from mercury waste. Otherwise, if mercury in waste leaks out and re-enters the global mercury cycle, mercury will be present not only in the environment, but also in the food chain.

When awarding authorization for operation of treatment and disposal facilities for mercury waste, it is important to enforce the ESM of mercury waste, and to ensure the institutional capacity is available to guarantee the mercury control strategy.

Facilities must be inspected for compliance; at those inspections, samples must be collected for laboratory testing, to determine the level of exposure to human health (using human samples) and the environment (using environmental samples) by analyzing total and/or methylmercury concentrations.

4.1 Legal framework in LAC related with mercury-containing wastes

The environmental regulation in LAC is generally fragmented. Liquids, solids, and vapors are standardized separately, applying limits for them to be discarded into the environment and some prohibitions such as incineration and uses.

The solid waste management is limited by some requests for transport, incineration, final disposal into the legal framework. Almost nothing is established for mercury-containing wastes.

In most countries of the region, sludge dewatering is considered the end of the treatment process before the final disposal in special landfills. Just in big centers, and for remediation of contaminated sites, stabilization and solidification of mercury wastes are requirements to be admitted in a landfill. In some cases, contaminated materials are so inappropriately handled during the interim storage, transportation and disposal that vapors and leaches can be released to the environment.

A compilation of the existing legislation in the region regarding the management of hazardous residues that includes mercury was carried out, and it is summarized in the table of ***Annex 9***. The objective was to identify the region's strengths and needs in order to control new sources of elemental mercury or prevent its release to the environment.

Making an allowance for the waste management in the entire LAC, mercury-containing wastes and mercury-containing products in their end of life are of special concern to governments and representatives of civil society, especially those that are discarded daily into the environment.

Several countries have legislation on hazardous waste management, but it is poorly implemented. Few cities in the region report a segregated collection and appropriate destination of mercury and other hazardous wastes. In 2002, the World Health Organization carried out research about the sanitary services in Latin America and found out that only 23% of the urban centers have an appropriate urban solid waste final disposal. (http://www.cepis.ops-oms.org/bvsacg/guialcalde/1salud/1-4salud.htm#Reto_Residuos_Solidos).

Products containing mercury would eventually be transformed into hazardous waste when they are discarded and there are risks of releasing mercury into the environment. Mercury content in products varies considerably from one product to another, ranging from only a few milligrams for some kinds of lamps to 1.5 g for a medical thermometer, or up to 100 g for an industrial thermometer. But large amounts of several of these products are used annually, resulting eventually in a large quantity of mercury contaminated wastes that should be disposed of, in general in unsound conditions.

In Brazil, Resolution 401/2008 of CONAMA not only restricts mercury content, as it was shown in Section 1.1.3.1, but it also establishes the obligation for manufacturers and importers to have management plans for batteries at the end of their lifespan and to implement systems for their collection and disposal. In this country, some States or Municipalities developed specific legislation banning the disposal of batteries on disposal sites for municipal waste. These laws require manufacturers, importers and traders to implement systems to collect used batteries and provide environmentally sound management.

Similarly, no specific legislation has been found for the disposal of mercury-containing wastes. Mercury-containing wastes are disposed of in safety landfills when the country in question has them or in hazardous waste landfills or urban solid waste landfills. Legislation for hazardous waste management is in force in: Argentine, Brazil, Chile, Colombia, Ecuador, Peru, Venezuela, Costa Rica, El Salvador, Mexico and Nicaragua, while Panama has a National Policy for Integral

Wastes Management. In general, the regulations of hazardous wastes have adopted the annexes of the Basel Convention for the classification of hazardous waste, among which are found those containing mercury or its compounds.

On the other hand, most of the countries use the Environmental Impact Assessment (EIA) tool for the evaluation of projects to establish final disposal sites for solid waste, both for domestic as well as for hazardous wastes. The EIA is the instrument that ensures the necessary conditions to minimize environmental impacts. Up to the present, none of the countries have any specific regulation for the storage of mercury as waste. Some countries have specific regulations or technical standards for the selection of an appropriate site and to build and operate a confinement for hazardous wastes; such is the case of Brazil, Chile and Mexico. Other countries contemplate some of these requirements within their legislation on hazardous waste; e.g., Argentina and Ecuador. Mexico is the only country that also has a technical standard for the confinement of waste in cavities built by dissolution of salt domes with the main objective of storing oil wastes.

Finally, no regulations or technical Standards specific to the management of mercury wastes have been detected. The aim of these standards would be to improve the management of mercury, by preventing liberation of mercury vapors into the environment, as well as the protection of workers and the control of risks during the phases of storage, packaging, transport and manipulation of waste.

4.2 Transboundary Movement Restrictions

Considering the text of the Basel Convention, wastes that are subject to transboundary movement shall be considered "hazardous wastes" if they belong to any category contained in Annex I, as is the case with item Y29- (Mercury; mercury compounds), and others that can be mercury-containing wastes (Y1, Y2, Y3, Y4, Y15, Y18), except if they lack any of the characteristic listed in Annex III.

At present, most of the countries have restrictions on transboundary movements of hazardous waste. Some of them absolutely prohibit the introduction of hazardous wastes into the countries, while others prohibit their importation for storage or final disposal. Under the framework of the Central American Integration System (SICA), Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama subscribed a Regional Agreement on Transboundary Movements of Hazardous Waste on December 11 1992. This agreement prohibits the import and transit of hazardous waste into these countries from countries that are not part of the agreement. It also establishes that "The Parties will not allow the export of hazardous waste to States that have banned their import… or if it is considered that such waste will not be managed in a healthy environmental manner…"

Annex 10 presents a summary of the restrictions to transboundary movements in great part of the South and Central American countries.

The GTG Basel Convention Guidelines GTG identify the following reference documents for shipment and transboundary movement of hazardous wastes (SBC, 2010):

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

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).

4.3 Mercury-containing wastes and end-of-life products management

Considering the chemical characteristics of mercury, once mercury-containing wastes are in the stream to be disposed, potential environmental impacts are expected as a result of:

- Leachate - high mercury concentration
- Vapor
- Mercury-containing solids (dust).

Mercury wastes might need special technical standards in the handling, transport, temporary storage and final disposal, in order to avoid their release as vapor or leaches.

Disposal of mercury-contaminated waste requires special control of both volatilization losses and any subsequent solubilization in leachate, because these emissions can easily cross the engineering barrier of the site.

The following information is based on the Basel Convention recommendations, through the "Technical Guidelines for the EMS of Waste consisting of Elemental Mercury and Wastes Containing or Contaminated with Mercury", 5th Edition, 13th may 2010.

4.3.1 Handling

Some recommendations for users, generators, transporters and managers, regarding the handling of mercury-containing wastes:

a. Mercury-containing products, such as fluorescent lamps, thermometers, electrical and electronic devices, must be handled so as to prevent them from breaking, getting crushed or bg pulled apart. Instead, a box or appropriate protective packing must be provided for transport and/or storage.

b. End users of mercury-containing products of liquid type, such as paints and pesticides as well as dental amalgam, should not discharge those products into sinks or toilets; otherwise they will have to treat and separate mercury from the water stream.

c. Mercury-containing products should not be mixed with any other products, broken, disposed of as other wastes nor discharged into the environment;

d. If mercury-containing products are accidentally broken or spilt, follow the cleanup procedure.

4.3.2 Interim Storage at End Users

Mercury waste should be safely stored and segregated from other wastes until final users bring them to waste collection stations or facilities.

For household mercury waste, mainly florescent lamps, other lamps and mercury-containing thermometers, it is expected that consumers use the same package to temporally store them. However, if these packages are not available, used mercury-containing products are carefully stored in long vertical boxes or containers, and other types of boxes. Some disposal facilities or commercial services provide a specific package for interim storage and transport.

Liquid type of mercury waste, such as dental amalgam, paints, pesticides, etc., should be kept in the original containers and its lids should be closed tightly. Containers and packages enclosing mercury waste should not be placed in trash for other wastes; those should be marked as “Hazardous Mercury Waste” and placed in a dry place, such as a warehouse or other sites that are usually idle.

A plan to store large numbers of mercury-containing products may be required, especially for large-scale users, such as governments, businesses, schools, etc.

If original boxes or packages fit for mercury-containing products are available, used mercury-containing products should be placed in these boxes or packages. If original boxes or packages are not available, containers especially made to store mercury-containing products (e.g. fluorescent lamp containers) should be purchased.

4.3.3 Segregation and Collection

Segregation and collection of mercury waste are the key factors to implement an ESM , because if mercury waste is simply disposed of as MSW without any segregation, mercury in waste may be released into the environment upon landfilling or incineration. Mercury waste should be separately collected from other wastes streams preventing any physical contact or contamination and stored into a recycle bin or container itended for mercury waste alone.

Mercury waste can be discharged into a special box only for mercury waste at a public waste collection station. It is very important to set colored-waste containers or to set some identification labeling for exclusive storage of mercury waste. Mercury waste boxes or containers should be set at the same places as existing waste collection stations.

Mercury waste should be collected exclusively by authorized collectors, such as municipal collectors or contractors, private companies, local collectors, etc.

Mercury waste boxes or containers should be always monitored regularly, checking that no other wastes are being disposed of together. This activity must be complemented with massive public information, to improve the public’s behavior regarding mercury management.

Public or private organizations that dispose of large amounts of mercury waste must provide their own internal collection and interim storage systems in order to facilitate the public or private transport to the final disposal facility.

Aspect Requirements for Interim Storage

- Storage sites within multi-purpose buildings should be in a locked dedicated room or partition away from very busy areas;
- Outdoor dedicated storage buildings or containers should be surrounded by a lockable fenced enclosure;
- Separate storage areas, rooms or buildings should be used for each type of waste, unless specific approval has been given for joint storage;
- Wastes should not be stored on or near “sensitive sites” (e.g. hospitals, schools, residences, food processing facilities, and other sites considered environmentally sensitive sites);
- Storage rooms, buildings and containers should be located and kept in conditions that will minimize volatilization;
- Ventilating a site with carbon filtration of exhaust gases is considered whenever exposure to vapors for those who work in the site and those living and working in the vicinity of the site is a concern;
- Sealing and venting a site so that only well-filtered exhaust gases are released to outside air is considered when environmental concerns are paramount;
- Dedicated buildings or containers should be in good condition and made of hard plastic or metal, not wood, fibreboard, drywall, plaster or insulation;
- The roof of dedicated buildings or containers and surrounding land should be sloped so as to provide drainage away from the site;
- The floors of storage sites inside buildings should be concrete or durable (e.g., 6 mm) plastic sheeting. Concrete should be coated with a durable epoxy;
- The storage area should be marked or delineated clearly by fencing, posts, or walls in order to limit access to it;
- A recording system on the condition of the storage area should be established, details of which shall include the observations, name of inspector, date inspected, etc.;
- The storage area should have adequate roof and walls to prevent rain water from reaching the mercury and mercury-containing material;
- The containment floor or walls in the storage area should be free from any cracks or openings;
- Storage area floors should be constructed of impervious material such as concrete or steel, and whenever mercury is in liquid form, a secondary containment must be provided;
- Visible warning signs and notices must be placed in conspicuous areas in the premises;

- Drainage facilities should be installed in premises where mercury and related compounds are used and handled to contain possible spillage or releases;
- The outside of the storage site should be labeled as a waste storage site; and
- The site should undergo routine inspection to check any leaks, degradation of container materials, vandalism, the integrity of fire alarms and fire suppression systems and the general status of the site.

Mercury waste collected at each organization can be sent to waste management centers or recycling facilities where mercury waste is dealt with in an environmentally sound manner.

Sewage treatment plants and incinerators are generally designed to equip with collectors appropriate for collecting sewage sludge, ash and residues which might contain trace amounts of mercury, as well as other heavy metals. Mercury in those wastes is collected at facilities. Those mercury wastes should be safely stored until further treatments become available, as presented expressed above.

4.3.4 Take-Back Program

A take-back program is a BEP, in which the manufactures have the physical responsibility for products and/or packaging at the end of their lives. A take-back program fundamentally places the responsibility of the end-of-life product back on the manufacturers. One of the outcomes of a take-back program is that it taps on the 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.

The main purposes of a take-back program for mercury-containing products are to phase out mercury-containing products and to aim at using mercury-free products or mercury-containing products whose mercury contents are as low as practically possible.

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 program, because these products are widely used and have a high recycling potential.

4.3.5 Transportation

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, labeling and manifest procedures.

Only an authorized and trained transporter can transport mercury to authorized sites. Authorized transporter must check that wastes are properly described in the labels, and packed in compliance with regulations. Authorized transporters must have approved vehicles, trained drivers, vehicles marked with the appropriate hazard symbols and emergency plans. Manifest systems should be used to:

- provide a record of the waste generated and its movement;
- provide information for the final disposal site management;
- serve as a "chain of custody" document;
- enable compliance with regulations; and,
- observe ensure duty of care.

Transporting vehicles should have first aid equipment; they must be equipped with fire extinguishers according to the substances carried and trained personnel. Authorized transporters shall manage mercury waste in a way that prevents breakage, releases of their components to the environment, and their exposure to moisture.

4.3.6 Waste management and storage

The management plan of the storage area must be in writing, and it should include:

- Statement that movement of wastes should be minimized to avoid risk to employees, spill, and injury;
- Documentation of each waste container in the storage including:
    - Chemical name of the material;
    - Chemical composition/formula;
    - Initial storage date; and
    - Warning statement; e.g., "Contains Toxic Material"
- Liquid wastes should be placed in containment trays or a curbed, leak-proof area. The liquid containment volume should be at least 125% of the liquid waste volume, taking into account the space taken up by stored items in the containment area;
- Contaminated solids should be stored in sealed containers such as barrels or pails, steel waste containers or in specially constructed trays or containers;
- Proper loading or unloading of containers should be observed;
- Segregation, adequate ventilation and ideal condition for storage of the chemical should be maintained in the area;
- A copy of the Material Safety Data Sheet should be available in the area; and
- Only trained personnel should be handling containers in storage as well as in the transport of such substances or mixtures.

4.3.6.1 Emergency Plan

Emergency showers and eyewash units with adequate water supply should be available;

Storage sites should have a fire alarm system, and inside buildings should have a fire suppression system (preferably a water-free system). If the fire suppressant is water, then the floor of the storage room should be curbed and the floor drainage system should not lead to the sewer or storm-sewer or directly to surface water, but should have its own collection system, such as a sump.

An emergency plan must be in place and implemented immediately in case of accidental spillage and other emergencies.

4.4 Treatment of Mercury Waste and Recovery of Mercury

Mercury wastes from mercury-containing products and industrial processes should be treated in an environmentally sound manner to fully avoid the adverse effects of mercury releases to the environment if improperly managed.

To be approved into a storage facility for final long-term storage, mercury is required to have a certain purity. Some options of mercury recovering processes are presented in this chapter.

Mercury recovery is done in three steps:

1) Pretreatment - when products are broken or disassembled to pieces to facilitate the separation of mercury from the matrix

2) Roasting processes – or retort; mercury is separated by heating it to its vaporization temperature

3) Purification – mercury is condensed and collected apart from other contaminants.

These processes must be done in a closed-system and under reduced pressure to prevent release of mercury vapor into the processing area. The exhausted air must to be treated in filters and activated carbon beds. Workers should wear and protective gears, such as helmet, goggles, masks (particulate respirator), gloves, protective clothing, boots, etc.

4.4.1 Pretreatment

Some pre-treatments are presented for different products or wastes; many of them have patents and are used over wide areas of the region:

a. Fluorescent Lamps – parts can be separated by mechanical crushing or air separation . <u>Mechanical Crushing -</u> 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, where the end products are eliminated 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.

Air Separation - Aluminum end caps of fluorescent lamps (straight, circular and compact tubes) are cut by hydrogen burners. Air blowing flows into the cut fluorescent lamps from the bottom to remove mercury-phosphor powder. Mercury-phosphor powder is collected at a precipitator; glass parts are crushed and acid-washed, and mercury-phosphor powder adsorbed on glass is completely removed. In addition, end-caps are crushed and magnetically separated to aluminum, iron and plastics for recycling.

b. Mercury Batteries - mercury batteries should be separately collected or segregated before recycling. Before roasting treatment, impurities mixed with and adsorbed onto mercury batteries should be removed preferably by mechanical process.

c. Sewage Sludge: Sewage sludge needs to be dewatered to about 20 to 35 percent solids before any thermal treatments. After dewatering, sewage sludge can be processed in roasting process.

d. Liquid mercury (elemental mercury)- containing products, such as thermometers, barometers, can be collected without any breakage. After collection of liquid mercury-containing products, liquid mercury inside of the products is extracted, and extracted liquid mercury directly goes to distillation for purification under reduced pressure.

4.4.2 Roasting Process

The pretreated mercury waste, such as mercury/phosphor powder, cleaned mercury-batteries, dewatered sewage sludge, screened soil, etc., can be treated by roasting/retorting treatments including rotary kiln and multiple hearth process equipped with a mercury vapor 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. Therefore, exhaust gas treatment devices should be provided.

Main roasting processes:

a. Vacuum-sealed Roasting Technology - 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 Subsequently mercury is re-condensed and recovered as elemental mercury.

b. Rotary Kiln - incinerates the combustible pre-treated mercury waste as well as industrial wastes, particularly wastes containing a high percentage of plastic. 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 decomposed by heat radiation (600-800ºC) 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 turns into mercury vapor during heat radiation processing at 600-800^{o}C. A vacuum carries the vapor 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.

c. Multiple Hearth Roaster - vertical cylindrical refractory steel-lined 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 central hearths, producing 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^{o}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^{o}C. In the drying zone, some volatiles (including mercury vapor) are released from the mercury waste and exit the furnace without being exposed to the full combustion temperatures.

d. Flue Gas Treatment - during the roasting process, mercury and other air pollutants are released into flue gas. Basic flue gas treatment consists of the 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.

4.4.3 Recovery of Mercury – Purification

Mercury vapor emitted from mercury waste during heat treatment goes directly to condenser (s) and condensed by heat exchanger cold water (preferably ≤10^{o}C) supplied from a chiller. Roasting mercury waste involves introducing air to the hot waste; the air oxidizes the mercury compounds and helps carrying them to a condenser. Collected mercury is subsequently purified by successive distillation for resale or reuse. Purified mercury can be traded as a commodity and utilized generally for mercury-containing products.

4.4.4 Other Process

Other processes are used mainly for separate mercury from a liquid or air emission matrix.

1. Chemical Leaching/Acid Leaching - is an aqueous process that depends on the ability of a leaching solution to solubilize mercury and remove it from the waste matrix. The solubilized mercury ideally partitions to the liquid phase, which is filtered off for further treatment (e.g. precipitation, ion exchange, carbon adsorption). A chemical leaching process brings mercury-contaminated materials into contact with a leaching solution that generates an ionic soluble form of mercury. This process can remove inorganic forms of mercury from inorganic waste matrices, but it is less effective for removing non-reactive elemental mercury unless the leaching formula is capable of ionizing mercury to an extractable form. The mercury-containing leaching is typically removed from the contaminated materials for further treatment (e.g. precipitation).

2. Chemical oxidation of elemental mercury and organomercury compounds - is a process developed to destroy the organics, to convert mercury into a soluble form and to form mercury halide compounds. It is effective in treating mercury-containing waste. Chemical oxidation processes are useful for aqueous wastes containing mercury, slurry and tailings. Oxidizing reagents used in these processes include sodium

hypochlorite, ozone, hydrogen peroxide, chlorine dioxide, free chlorine (gas), etc. 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 2007f).

3. Chemical Precipitation - are typically the final step in the mercury treatment process after all organic content has been destroyed. Precipitation reagents include lime ($Ca(OH)_2$), caustic (NaOH), sodium sulphide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulphide (FeS). Sulphide is preferred because it forms the most stable complex. It is important, however, that alkali constituents, such as sodium, do not precipitate in the mercury-sulphide matrix because they contaminate the matrix, making it more susceptible to the effects of acid-oxidative leaching. Sulphide precipitation is preferable to hydroxide precipitation using hydrazine because mercury hydroxide is susceptible to matrix dissolution over a wide range of pH under oxidizing conditions.

4. Ion Exchange Resin – method used for removing mercury from aqueous streams, particularly at concentrations on the order of 1 to 10 parts per billion. 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 of. In addition, organic mercury compounds do not ionize, so they are not easily removed by using conventional ion exchange. If a selective resin is used, the adsorption process is usually irreversible and the resin must be disposed of in a hazardous waste unit.

5. Chelating Resin - is an ion-exchange resin that has been developed as a functional polymer, which selectively catches ions from solutions that contain various metal ions and separates them. It is made of a polymer base with a 3-D 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.

6. Activated Carbon - 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 adsorbs mercury and other heavy metals as well as organic substances.

4.4.5 Treatment to prepare mercury wastes for final disposal

The main treatments for final disposal of mercury containing wastes, when the amount of mercury in the matrix allows the waste to be accepted in a landfill are: amalgamation, stabilization and solidification. These treatments were presented in Chapter 3.

4.5 Experiences of mercury wastes final disposal in developed countries

EU and USA regulations have improved the standards by individualizing the wastes and approved treatments for final disposal for each one.

For above-ground facilities, waste acceptance criteria are established in Decision 2003/33/EC in Europe, for pollutant concentrations, etc.

Decision 2000/532/EC defines stabilization as the process of changing the dangerousness of the constituents in the waste and thus transforming hazardous wastes into non-hazardous. The solidification process is described as the only process that changes the physical state of the waste by using additives, (e.g. liquid into solid) without changing the chemical properties of the waste.

In USA, the Resource Conservation and Recovery Act (RCRA) section, an amendment to the Solid Waste Disposal Act, enacted in 1976 by the US Congress, as well as the EPA Land Disposal Restrictions (LDR) program establishes the conditions for mercury-containing waste to be disposed of.

The concept of Land Disposal Units (LDUs) for hazardous waste disposal includes landfill, surface impoundment, waste pile, land treatment unit, injection well, salt dome formation, salt bed formation, underground mine, underground cave. In 1984, the US Congress created EPA's Land Disposal Restrictions (LDR) program. This programs aims to ensure that toxic constituents present in hazardous waste are properly treated before hazardous waste is land disposed. Since then, the LDR team has developed mandatory technology-based treatment standards that must be met before hazardous waste is placed in a landfill. These standards help minimize short and long-term threats to human health and the environment, which directly benefits local communities where hazardous waste landfills are located. The Table in ***Annex 11*** presents the land disposal restrictions regulations for mercury-containing non-wastewaters.

The LDR regulations contain treatment standards for the RCRA hazardous waste codes, including those identified as hazardous because of mercury. EPA has designated some widely generated hazardous wastes, including certain spent batteries, pesticides, mercury-containing equipment and light bulbs, as "universal wastes". The regulations that govern universal wastes include special management provisions intended to facilitate the recycling of such materials. The states and municipalities can elect legislations more stringent than the federal hazardous waste regulations. For example, Vermont bans all mercury-containing waste from landfills, including mercury-containing waste generated by households.

The LDR regulations categorize mercury wastes as low mercury wastes, high mercury wastes, or elemental mercury wastes.

Low Mercury Waste: Low mercury wastes are those hazardous wastes containing less than 260 mg/kg of total mercury. Current regulations require that these wastes be treated to a certain numerical level, i.e., 0.20 mg/L, measured using the Toxicity Characteristic Leaching Procedure (TCLP) for **mercury waste from retorting**, and 0.025 mg/L TCLP for all other low mercury wastes. These concentrations are generally **met by stabilization/solidification treatment**.

High Mercury Waste: High mercury wastes are those that are characteristically hazardous and that contain greater than 260 mg/kg total mercury. Because of this high concentration of mercury, they are generally required to **undergo roasting or retorting.** This is defined, in part, as: "Retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery." The residuals from the roasting or retorting process are then subjected to a numerical treatment standard (if the waste meets the definition of "low mercury subcategory").

Elemental Mercury: Characteristic hazardous elemental mercury wastes (RCRA hazardous waste code D009) **are required to be roasted or retorted**, if they contain greater than or equal to 260 mg/kg total mercury. Because the uses for elemental mercury in products are declining, stockpiles of excess commodity (bulk) mercury currently exist. If these stockpiles are deemed to be wastes, then they are subject to the retorting or roasting standard. Waste streams of **elemental mercury contaminated with radioactive materials** are **required to be treated by amalgamation**, defined as: "Amalgamation of liquid, elemental mercury contaminated with radioactive materials utilizing inorganic agents such as copper, zinc, nickel, gold, and sulfur that results in a non-liquid, semisolid amalgam and thereby reducing potential emissions of elemental mercury vapors to the air."

At the time of promulgation, the assumed approach for compliance with these regulations was separation of the mercury from the wastes and recycling of the pure elemental mercury back into commerce. However, this assumed compliance scenario was invalid for mixed wastes containing mercury, especially wastes that are radioactively contaminated, because there is no use for this recovered mercury.

For each mercury waste or discarded mercury compost, USEPA defines the acceptable treatment to reduce toxicity and risks. In ***Annex 12***, there is a catalogue with the approved treatment for mercury-containing wastes.

The Sustainable Hospitals Project from Massachussets (http://www.sustainablehospitals.org/HTMLSrc/IP_Mercury.html) made an extensive list of products and alternatives to phase-out mercury from health care. Some are summarized here:

- Thermostat probes may be found in several types of gas-fired appliances that have pilot lights, such as ranges, ovens, clothes dryers, water heaters, furnaces or space heaters;

- Electrical material: Tilt switch, Thermostat, reed relay, and others. Manufacturers have not eliminated mercury in all electrical equipment due to cost considerations. However, because of an awareness of mercury problems, manufacturers are increasingly making alternatives available. Ask your vendor to assist the hospital in selecting mercury-free products.

- Mercuric oxide (mercury zinc) batteries and button batteries that may contain added mercury if newly purchased. Mercuric oxide batteries offer a reliable and constant rate of discharge and can be made in a wide variety of sizes intended for use in medical devices. Since 1990s, new models generally require zinc air batteries. However, mercuric oxide batteries may remain in hospital stock for many years for use in older equipment. The shelf life of mercuric oxide batteries is up to ten years. Some of the medical devices that may still require mercuric oxide batteries include cardiac monitors, pH meters, oxygen analyzers and monitors, and telemetry instruments. For medical devices, there are Food and Drug Administration and Underwriters Laboratory certification concerns with replacing a battery. It is important to contact the equipment manufacturer before replacing a mercuric oxide battery with a substitute to ensure that the device has been approved for use with the alternative battery. Rechargeable (nickel-cadmium) batteries cannot be used as an alternative to mercuric oxide batteries.

The project keeps in its webpage a complete list of mercury free products providers.

Some electrical manufacters already use the label of mercury free products, indicating a change of behavior (http://home-and-garden.become.com/robertshaw-400421-24v-mercuryfree-mechanical-thermostats--compare-prices--sc914063261

4.6 Experiences in LAC with mercury wastes and mercury-containing products in their end-of-life

The countries of the LAC region have experienced innumerable accidents or intentional releases, with their consequent environmental liabilities resulting from mercury released in the process of mercury wastes management.

In this context, important aspects related with mercury wastes management must be taken into account in order to prevent the release of the pollutant into the environment and to control the main risks it poses to humans and to natural resources.

Mercury-containing products are largely spread into the society, in household materials and equipments, offices and medical care. Some products are incentivized by government programs, as are the economic lamps, largely used or freely distributed in houses. Electrical material with high mercury concentration is continually released by the fast changes in the technologies of equipments.

Some products are in the focus of the society and some services providers are improving the collection and recycling system. Examples are lamps, thermometers, and others. Some examples will be shown below for part of these products.

4.6.1 LAMPS, THERMOMETERS AND OTHERS

The recent climate change policies in LAC are giving incentives to change incandescent lamps by fluorescent bulbs, in which mercury is an essential component. The most common types of energy-efficient lighting that contain mercury are: fluorescent bulbs, including compact fluorescent light bulbs (CFLs) and high intensity discharge (HID) bulbs.

Although lighting manufacturers have greatly reduced the amount of mercury used in lighting over the past 20 years, they are not yet able to completely eliminate the need for mercury. While the new mercury-containing bulbs contain small amounts of mercury (an average of 5 milligrams or about 1/100th of the amount of mercury found in a mercury fever thermometer), the high mercury-containing lamps are still in the market and they are one of numerous sources that collectively impact the environment during disposal.

Metallic vapor, Mercury vapor, and Sodium vapor lamps are largely used in industries and offices facilities. In a recent report, a lamp recycler responsible for retort mentioned that for every 100,000 lamps recycled that are collected in the Brazilian market, 1 kg of mercury is recovered. If we consider that in Brazil for instance 200 million lamps are sold yearly, it is expected that 2 ton of mercury is released per year coming from bulbs. A flow sheet of the complete process of mercury recovery from lamps is presented in Figure 4.1

The electric policy and urban solid waste services in LAC could not find a universal collection of these and other mercury-containing products. In some cities there are some facilities to receive these wastes, but without a massive education program, they are sub utilized.

Collection and treatment are a paid service (US$0.56/LAMP), mainly done by industries and institutions within an environmental permit process or by voluntary initiatives. As a result, less than 3% is treated. Services are not regulated and monitoring and wastes control are not well done.

As an example, research about services in Brazil was carried out by the consultants, and the service providers and technologies are shown in table 4.1

Table 4.1 – List of lamps recyclers in Brazil

Country	Company	Technology	Wastes recycled	Final mercury product
Brazil	• Brasil Recicle/ Apliquim	Bulb mill and retort	Lamps, thermometers, amalgams, electrical material	Elemental mercury 99.9%
	Trampo Recicla Lamps	Bulb mill using vacuum and high temperature with activated carbon filter	Lamps	Dust and activated carbon with mercury
	Bulbox	Bulb eater – lamps Mill	Lamps	Dust and activated carbon with mercury
	Naturalis Brasil	Bulb eater – lamps Mill	Lamps	Dust and activated carbon with mercury

There are different technologies and different Policies in the states, none officially approved by any professional council, technical standards or regulation.

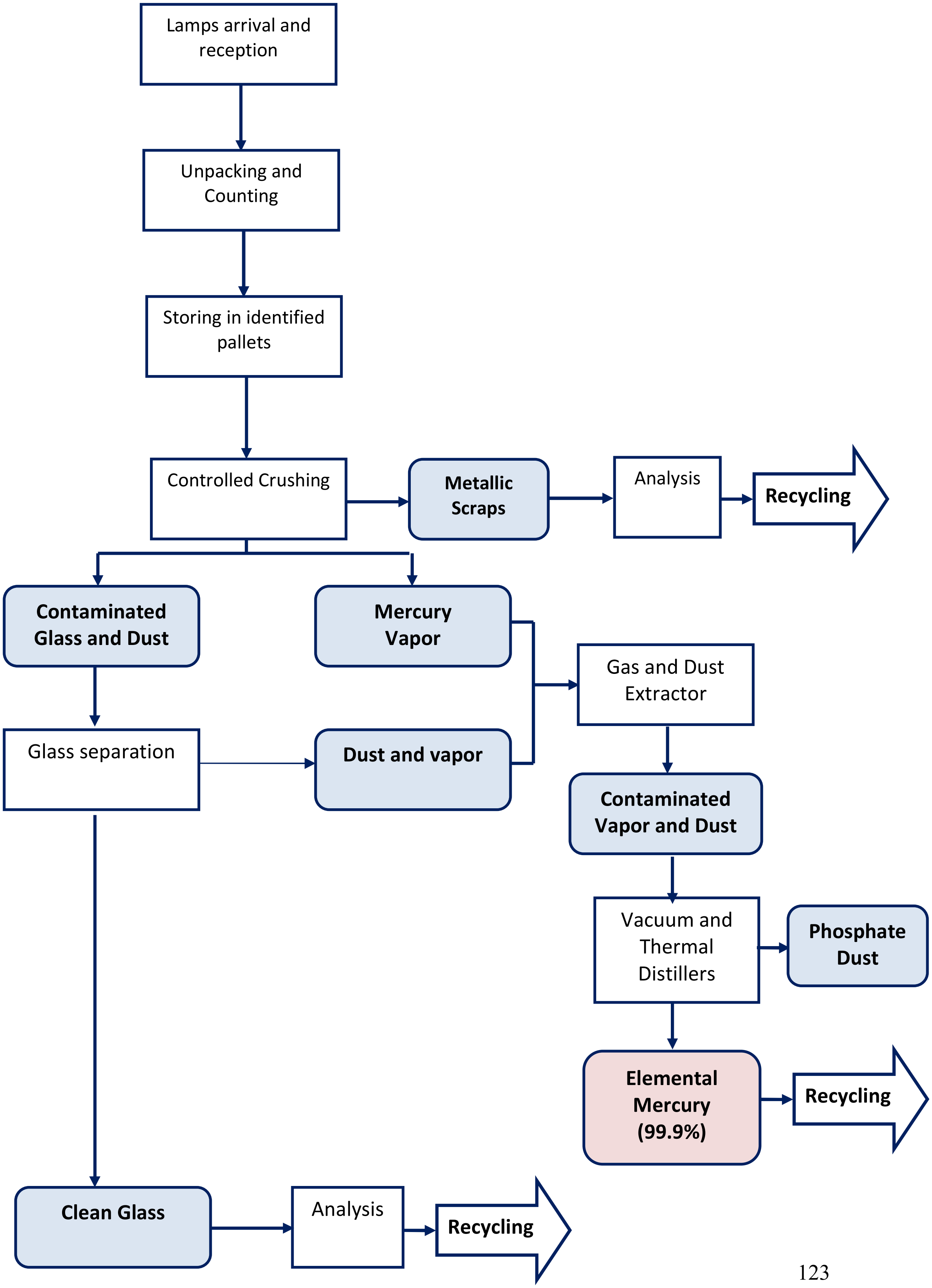
In fact there are fails in the policies for the whole chain, from production:

- Restriction on the use of metallic gas;
- Packaging design to better protect the product;
- Labeling advising regarding mercury, and to induce to keep package to discard, and inform about collection and services;
- Collection services
- Technical Standards for treatment, recycling and disposal.
- Monitoring and control.

In many countries the main initiative with respect to bulbs managements are WebPages and flyers of Ministries of Energy, lamps manufacturers and environmental authorities with instructions such as:

- Never crush lamps in the storing or using area ;
- Keep the original package to store used lamps and deliver them to store facilities or collect services;
- Broken lamps must be packed in a sealed steel or plastic drum, internally coated with plain and transparent plastic with double weld in the bottom; and others.

Figure 4.1 - Flow sheet of mercury recovery from lamps



4.6.2 Other Products

Many other products with higher mercury content are used, but they are not spread in the trash as lamps and batteries are. Electrical and electronic devices are collected or stored in workshops and scrap dealers.

The use of mercury in dental care ranks third in terms of quantity in the region, and it is spread uncontrolled in most countries.

Since a few years ago, liquid mercury has been increasingly substituted by encapsulated mercury, where mercury comes in a capsule separated by a membrane of silver chain. This kind of material demands less mercury and reduces the liberation of metal to the air.

This change significantly reduced the use of mercury in medical offices, but it increased the price of fillings, to the point they could become higher than those of resin.

The consumption, prices and quality of products vary from a region to another in Latin America. Only in Brazil, the north and north-east region present greater amalgam consumption than the south and south-east, which have greater income.

The investment required for the change of elemental mercury to encapsulated amalgam is the acquisition of the mixing equipment, which approximately costs US$300. This equipment can be used for other materials, so the investment can be recovered quickly.

Gradually the quality of alternative materials becomes more similar to amalgam in terms of impermeability and durability requirements. Dental products traders report that the main clients for amalgam are governmental institutions. They believe that a definitive move for mercury options requires a cultural change and training of professionals. Peter Maxson assumed a 15% reduction by 2015, and a gradual reduction thereafter to 50% of present consumption by 2050. These values could be conservative, if a work with health professionals and Ministries of Health in the region integrates a system that normalizes the quality of fillings.

On the other hand, a policy for medical offices and equipment in this period is required, since a large part of the contamination comes from the removal of the old fillings more than from the new to be put into the client.

4.6.3 Wastes destination

Collected mercury-containing products and materials might be a problem if there is not any posterior treatment or destination.

Some small businesses have developed small retorting equipment, especially in mining areas, but any mercury monitoring system was reported. In Mexico, many recyclers retort mining tailings and mercury compounds, especially in mining regions. Some of them export mercury to South America.

In LAC some equipment manufacturers advertise their technologies. Table **4.2** shows the main providers of technologies for mercury recovery in products and wastes in LAC. Some offer kits with sealed packaging for the transport of mercury wastes (lamps, sludge, batteries) to the retort facilities in the market of USA.

Table 4.2 – Suppliers of main technologies for mercury recovery in products and wastes in LAC

Company	Origin	Technology	Wastes treated	Presence in LAC
Air Cycle Corporation	USA	Lamps mill with carbon activate filter (Bulb eater) Easy Pack containers	Lamps	Brazil
MRT System International AB	Sweden	Batch Distillers	Fluorescent powder Crushed lamps Batteries Dental amalgam Military waste	Argentina, Bolivia, Brazil, Colombia, Ecuador, Paraguay, Uruguay, Venezuela
		Continuous Process Distiller	Fluorescent powder Crushed lamps Sludges Backlights Exhaust pipes	
BALCAN ENGINEERING LIMITED	UK	• Lamps mill with activated carbon • Mercury dust cleaner (still developing)	Mostly lamps	They have web page in Portuguese but we did not find representatives in LAC
Summit Valley Equipment & Engineering	USA	Hg retorts and vacuum distillation ovens (0.5 – 40 ft^3 material capacity	Mining waste and tails	**Chile -** Minera Meridian – El Penon Project; COMPANIA MINERA MANTOS DE ORO Mina La Coipa, Chile **Peru-** Minera Yanacocha SRL; Goldez Minera Yanacocha **Mexico –** MEXTICA DE MEXICO Minera San Xavier San Luis, Hg RETORTS; M3 ENGINEERING - Minera Penasquito 2 40MR1E Hg Retorts; MINERA PENMONT Mina La Herradura, 15 cu.ft. Mercury Retort. **Venezuela -** BOLIVAR

Company	Origin	Technology	Wastes treated	Presence in LAC
				GOLDFIELDS Retort - Minera Bonanza, MINERA HECLA de VENEZOLANA, C.A., Mina La Camorra, 2cu.ft. Mercury Retort with Refrigerated Condenser; HECLA LA CAMORRA-RETORT/KILN/RECTIFIE; **Costa Rica -** CORPORACION de MINERALES MALLON S.A. - 2 cu.ft. Mercury Retort**.**

Basically mercury-containing products and wastes can be:

- **Stored –** if mercury is not easily released: it is in an amalgam, or encapsulated in glass or metal (thermometers, manometers, relay)
- **Treated** (stabilized and solidified) to be disposed off – sludges, salts, contaminated material;
- **Retort or kiln** to recover mercury for recycling - lamps, chlor-alkali
- **Retort** to recover mercury to be stored – any source
- **Export –** when countries have bilateral agreements or companies are interested to recover mercury from the exported wastes.

5 REGIONAL NETWORK FOR MERCURY MANAGEMENT

This consulting work tries to provide UNEP and ExeCom a list of people or institutions relevant to the issue of mercury, be them government agencies such as the environmental agencies in the country, or private companies linked to the management of mercury. The list included in ***Annex 13*** is not intended to be a "closed" list, but the starting point to create a large Network for the management of mercury in LAC.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The main conclusions are:

- At present, with the exception of Mexico and Chile, the LAC region is characterized more as importer of mercury than as exporter, especially due to the chlor—alkali plants and informal mining; but this situation can change in the near future, in particular with the improvement of regional trade of mercury;

- With the ban on mercury exports from Europe and USA, some plants might be encouraged to change the process; some industries in Brazil, Mexico, Cuba and Uruguay have already started the process of changing of technology;

- Legislation for mercury use control is improving in various countries of LAC as well the wastes management and initiatives to phase out the use of mercury; this new scenario will be decisive in accelerating the increase of mercury surplus and the necessity to implement a storage facility to sequester the mercury used in mining.

- Once the mercury surplus is increasing, most countries don't have an accurate inventory of sources, uses and quantities of mercury produced in the region in order to prepare a balance and determine if the excess is used in small-scale gold minig; the lack of confident information is a gap for the storage planning;

- Other gap is the environmental legislation and technical standards for mercury and mercury containing wastes management in most countries in the LAC region. There is a lack of legislated technical criteria for handling, packing, transporting, treating mercury and mercury wastes. The consequence is that mercury containing wastes and elemental mercury are disposed in landfills, or inappropriated stored with risks to the environment and human being.

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- Underground facilities are an unlikely solution in the short term for most countries in the LAC region, owing to the lack of reliable information on the potential geological and environmental resources that could host a storage facility. Some countries might not fit the necessary conditions to host an underground facility, because of geographic, legal and cultural conditions. Economic factors can influence the decision, given that the infrastructure required in underground storage facilities may demand very high investments. In Europe, the costs and space of these facilities are shared by several waste streams, which leads to a reduction of operational costs.

- The need for mature pre-treatment technologies to stabilize and solidify mercury constitutes an additional limiting factor in the implementation of long-term storage facilities.

- Actually, above-ground engineered warehouses are the most consolidated and feasible facilities for the long-term storage of mercury for the region. Nevertheless, mercury stays in the biosphere. Political and institutional stability are mandatory conditions to keep and insure mercury sequestration.

- Exports can be a good short term solution, especially for countries with a very small mercury surplus, where a special construction is not an economical solution. Export also is the best solution for countries where risks due natural phenomena are important aspects to be considered. Anyway, the export solution to a safe mercury storage is a definitive solution for any country.This option can be combined with interim storage in above-ground facilities located near harbors or airports. This solution requires bilateral cooperation agreements for the approval of exports and reduction of the costs entailed by the final disposal.

- An above-ground engineered warehouse can be also a short-term solution for mercury storage in the LAC region

6.2 RECOMMENDATIONS

6.2.1 LEGISLATION

Under the current scenario for the permanent sequestration of mercury it is recommended to:

- Countries must develop an specific legislation in order to create in the national legal framework the concept of mercury longterm storage as the more appropriate final disposal for elemental mercury

Comment [VC4]: Quiero decir que todavia no hay legislación específica para el almancenamiento de mercurio.

- To develop technical standards for mercury handling, treatment, packaging and transport for storage purposes;

- To improve the technical standards for the management of mercury waste and mercury-added products in their end of life: treatment, packing, domestic storage, transport, quality for disposal, final disposal.

- To develop and harmonize the regional legislation for mercury limits in emissions and air monitoring, mainly in non ferrous metals mining and coal burning.

- To negotiate a gradual elimination of mercury in products and processes and to adopt BAT's; while cleaner production programs are implemented to minimize releases of mercury to the environment;

- Harmonize the trade of elemental mercury, mercury-containing products and salts in the region, prohibiting imports of goods for which regionally mercury free options are available;

- To improve educational programs for national and local authorities, as well as stakeholders.

- To improve institutional capacity and networks to implement appropriate management of mercury until its sequestration.
- To implement an integrated program involving national and regional authorities, NGOs, private sector, health care professionals, universities and research centers seeking to improve the technical standards in mercury management and monitoring, and to raise awareness regarding mercury-free processes and products;
-

6.2.2 TRANSBOUNDARY MOVEMENTS

Regarding transboundary movements of mercury and products with mercury, the actions to be taken on the part of the States require, necessarily, of reliable official information about mercury movements across borders. It is understood that said information may only come from the statistics developed by the respective national customs or governmental environmental control agencies.

In this sense a series of suggestions are made with the purpose of undertaking modifications, in appropriate cases, that would allow for a greater ease of understanding of the information and the monitoring of the destinations of mercury in the region.

- Adequacy of the nomenclature – as was mentioned, from 2007 in the Harmonized System, there is a specific position reserved exclusively for mercury compounds according to the prompt request of the Rotterdam Convention. It suggests to those States who not yet use this version to implement it at the earliest possible time. Similarly it suggests to those States whose customs still accept mercury compounds declarations from other positions, to not authorize any shipment of mercury compounds in positions other than position 2852.00. It suggests that this position be used exclusively and as the Harmonized Systems states for the mentioned compounds and to not admit the shipment of other kinds of substances under it.
- Opening of position 2852.00 – The example of MERCOSUR where the opportunity is given to add up to four more digits to position 2852.00 to allow the discrimination among the diverse chemical forms in which mercury is presented (oxides, salts: chlorides, sulfates, nitrates and organic- mercurial compounds etc.) is a way to know not only the real amount of transboundary mercury, but also the applications in products or processes. It is suggested to carry out a negotiation among the countries to establish the opening of the position above according to common technical criteria agreed in order to facilitate the actions of mercury control in the region.
- Disclosure of importers and exporters - It is suggested that the information of exporters and importers for those foreign trade operations that involve elemental mercury as well as its compounds, alloys or wastes that contain it, be easily accessible as well as customs statistics.
- Disclosure of the information – The information provided by national customs is very heterogeneous regarding the fields available in the databases. The customs of Peru and

Colombia are the ones that provide greater detail of the operations including in addition to the importer, the gross and net amounts, the prices CIF and FOB, the origin and provenance. Other relevant data such as supplier, brand and detail of the merchandise. For the reasons exposed in the previous point it is suggested that customs require that importers disclose the supplier, the brand and the final application of the mercury or its compounds, as well as the prices, as a form of evaluating how this affects the market of the product in the region.

- Traceability – As was mentioned, several of the main importers of mercury are distributing companies that sell it to the final users or to other minority distributors. The same happens with recycling companies. To establish a more rigorous control regarding the final destinations of the metal, it is recommended to the States that the respective environmental authorities request from the distributors a detailed report on sales that include customers, quantities traded and transporters, as does IBAMA. This could be done under the form of an affidavit or in formats standardized for the region.
- Custody chain - improve a custody chain of mercury that ensures the tracking of the whole production chain from its sources until its final sequestration;

6.2.3 MERCURY FINAL DISPOSAL

It is recommended:

- National governments must urgently develop mercury national inventory, in order to determine realistic estimates about the need and sizes of storage facilities;
- As an emergency action, temporary storage needs to be planned in regions where elemental mercury is already accumulated and need to be appropriated stored; aboveground warehouses are the faster solution for temporary storage; investigations regarding appropriated areas near to the big generators or negotiation with hazard waste managers must be started in order to accelerate the storage construction;
- Exports can be an alternative to reduce the national mercury surplus, although before 2013, this solution does not guarantee that exported mercury will not be available in the international market; with this respect, governments and the private sector should start negotiations with storage facilities in other countries as an alternative to sequester mercury;
- National governments should initiate and promote pre-feasibility studies about geologic national resources as an alternative to be used in the future for mercury final disposal, when treatment technologies are mature enough;
- To develop a mercury website hosted by governments linked to the mercury pages of UNEP, and to mercury pages of other countries and institutions. These sites must provide all the necessary information on sequestration of mercury to citizens, professionals and authorities.

- To work jointly with cooperation agencies (World Bank, IDB, etc.) promoting the development of financial mechanisms aimed at raising awareness, fostering research, partnerships and capacity building, and to start designing a pilot project for the storage of mercury in LAC.
- To create a mercury website in government pages linked to the mercury pages of UNEP, and to mercury pages of other countries and institutions. These sites must provide the whole necessary information to citizens, professionals and authorities to sequester mercury.

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ANNEXS

Annex 1	Legal framework in LAC related to mercury trade, storage and control of use or phase-out
Annex 2	Latin America and Caribbean elemental mercury excess, 2010-2050 (tonnes) - Base Case Scenario - from Peter Maxson, 2009
Annex 3	Active Chlor-alkali plants in LAC
Annex 4	Major Gold and Zinc mines in operation in LAC
Annex 5	Part 2 and 3 – Mercury Compunds- PIC CIRCULAR – December 2009 – Rotterdam Convention
Annex 6	Summary on Regional Specifics towards Mercury Storage facilities and Seismicity maps of the region
Annex 7	Outcropping geological formations in the Region
Annex 8	Characteristics of Mercury Exported by Newmont Mining Corporation – Yanacocha-Peru
Annex 9	Legal framework in LAC related to hazardous waste
Annex 10	Legal restrictions on transboundary movement of hazardous wastes
Annex 11	Land disposal restrictions regulations for mercury-containing non-wastewaters
Annex 12	Approved treatment for mercury containing wastes
Annex 13	Regional network for mercury

LIST OF TABLES

Table 1.1	Physical and chemical properties of main mercury salts	10
Table 1.2	Mercury consumption in South America and the Caribbean, 2005 (tons)	18
Table 1.3	Maximum Mercury content allowed in lamps Annex Directive 2002/95/EC	23
Table 1.4	Basic assumptions regarding LAC mercury consumption 2010-2050	22
Table 2.1	Membership of the countries of the LAC region	31
Table 2.2	Codes adopted by the countries of MERCOSUR	32
Table 2.3	Imports of elemental mercury (CODE: 280540 of HS2007)	35
Table 2.4	Exports of elemental mercury (CODE: 280540 de HS2007)	36
Table 2.5	Mercury traded intra and extra Region	40
Table 2.6	Mercury compounds imports	43
Table 3.1	Overview on existing pre-treatment technologies for liquid mercury	57
Table 3.2	Summary of Estimates of Total Storage Costs (US Dollars) for 40 Years [US EPA 2007a]	65
Table 3.3	Costs of mercury exporting	84
Table 3.4	Comparisons between mercury sequestration options	87
Table 3.5	Estimated Capital Investment for Above-ground Warehouse Facility Construction and 10 years operating cost	92
Table 4.1	List of lamps recyclers in Brazil	110
Table 4.2	Suppliers of main technologies for mercury recovery in products and wastes in LAC	113-114

LIST OF FIGURES

Figure 1.1a	Secondary container for broken mercury thermometers	25
Figure 1.1b	Terciary container for broken mercury thermometers	25
Figure 3.1	Sequence of actions to be adopted for the storage of mercury	42
Figure 3.2	Design of 3L flask - 76 lb or 34.5 kg	44
Figure 3.3	1-Metric Ton Container	45
Figure 3.4	10-Metric Ton Container	45
Figure 3.5	Standard mercury steel containers used by Mayasa- Almadén	46
Figure 3.6	Previous storage methods	61
Figure 3.7	Building Exterior	62
Figure 3.8	Diagram of the layout in the mercury storage building.	62
Figure 3.9	Storage area and packing	63
Figure 3.10	Salt Mines at Winsford, Cheshire, England	73
Figure 4.1	Flow sheet of mercury recovery from lamps	111

LIST OF GRAPHS

Graph 2.1	Mercury total imports &exports	40
Graph 2.2	Mercury imports & exports outside LAC	41
Graph 2.3	Balance = imports - exports	41
Graph 2.4	Mercury excess excluding ASGM	42