Final Report

Assessment of Options for
Assessment of Options for Managing the Excess Mercury Supply
and
Costing Components of Mercury Storage in Indonesia

As part of

Development of National and Regional Approaches to
Environmentally Sound Management of Mercury in Southeast Asia

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EXECUTIVE SUMMARY

Mercury is a harmful neurotoxin that circulates on local, regional, and global scales, due to its persistent and bio-accumulating properties. Mercury tends to globally spread from one location to another through the atmosphere and biosphere. National and global policies intended to decrease the production, use, import, and export of mercury will increase the need for access to viable and secure interim storage for mercury stockpiles. In the 25th Governing Council of UNEP (GC 25/2009), the participating governments agreed to move forward with developing a legally binding treaty on mercury, and directing the Executive Director of UNEP to organize an international negotiating committee (INC) to continue enhancing capacity for mercury storage and providing information on the environmentally sound management of mercury.

Sources and Quantity of Mercury Releases

For the Asia Pacific region, it has been indicated that the quantity of excess mercury would be over 5,500 tons, which would mostly be accumulated between 2030 and 2050. According to the alternative scenario, the excess mercury could be as high as 7,500 tons, if the authorities decide to accelerate the storage the excess mercury. The report also highlighted the need to address the issues on potential excess mercury resulted from non-ferrous metal production such as zinc and gold and management of mercury waste resulted from the end-of-life products.

For Indonesia, currently there is no published data available on this inventory result that can be used for the estimation of the excess mercury and the assessment of storage options. Nevertheless, inventory result based on “Level-1 UNEP Toolkit for Identification and Quantification of Mercury Releases in Indonesia” can be used as indicators of order of magnitude for assessing main sources of mercury release as summarized below.

Source Category	Mercury Releases (kg/year)
Gold extraction with mercury amalgamation	195,000
Informal dumping of general waste	66,065
Waste incineration and open waste burning	53,234
Oil and gas production	43,605
Use and disposal of other products	37,744
Coal combustion and other coal use	32,892
Total Category	390,140

Source: DR. Kania Dewi. (2012). Inventory of Mercury Releases in Indonesia. BaliFokus.

Existing Legal and Facility Infrastructures

A comprehensive regulatory infrastructure related to the industrial hazardous waste management is currently in place in Indonesia. The regulations cover for the hazardous waste temporary storage, transportation, collection, treatment, utilization and disposal. Most of these regulations may also be adopted for the management of the excess mercury in Indonesia. However, awareness and enforcement of the regulations still need further advanced. In addition, regulatory framework for the concept of excess

mercury management, including detailed technical requirement for its long term storage, shall be further developed.

The current infrastructure for the hazardous waste management is available and can be utilized to resolve issues of low mercury containing waste, as part of the solution for the excess mercury in Indonesia. An integrated hazardous waste facility in Bogor currently has a capability of stabilization/macro-encapsulation and secure landfill for environmentally sound management of the low level mercury containing waste (<260 mg Hg/kg).[1] In addition, the facility also exports the waste that containing high level of mercury (≥260 mg Hg/kg) to Europe for recovery and disposal.

Considering this condition, establishment of mercury recovery facility in Indonesia is very important factor for the total management of mercury, in order to anticipate future change in export policy as well as minimize cost for the transportation and disposal of high level mercury containing waste regulated further under the mercury convention.

Assessment for the Mercury Storage Options

The assessments of options for the mercury storage specific to the regions have been conducted by previous studies. The summary of the studies is as following:

United States of America (USA)

USA is the country with the longest and most consolidated experience in storing elemental mercury, where the federal government is currently running two mercury storages under the responsibility of Defense National Stockpile Center (DNSC) and Department of Energy (DOE). The US approach relating to excess elemental mercury, is long-term storage in appropriate above ground facilities. Studies carried out in the USA concluded that the available stabilization technologies are considered immature and un-safe enough for large amounts of elemental mercury.

European Community (EC)

As a consequence to the Regulation (EC) No 1102/2008, large amounts of metallic mercury – which were initially considered as raw material – become waste, and adequate safe storage or disposal options have to be identified. In anticipating this, the European Commission assigned BiPRO GmbH to identify feasible storage options and to define acceptance criteria and minimum requirements for the safe disposal of metallic mercury. Based on this report, possible options for the long term solution for mercury are:

- Permanent storage of metallic mercury in salt mines
- Pre-treatment of metallic mercury with a subsequent permanent storage in salt mines
- Pre-treatment of metallic mercury with a subsequent permanent storage in deep underground hard rock formations
- Pre-treatment of metallic mercury with a subsequent permanent storage in above ground facilities

[1] PT. PPLi. Stabilization and solidification processes. http://www.wastemanagementindonesia.com/web/index.php?option=com_content&view=article&id=63&Itemid=72

Latin America and Caribbean (LAC)

Laboratorio Tecnológicodel Uruguay (LATU) and UNEP Chemicals released the study report on the feasibility of long-term storage for excess mercury in LAC. The study proposed three options for the long-term storage of mercury, that are:

- Above-ground specially engineered warehouses
- Below-ground storage in geological formation (e.g., mines, special rock formations)
- Export to a foreign country/facility, as a short term solution
- Pre-Stabilization and landfill for the final disposal of mercury containing waste

Asia-Pacific

Study conducted by S. Hagemann recommended the options for mercury storage for the Asia Pacific region are as the following:

- US concept of storing elemental Hg in aboveground warehouses for up to 40 years or more
- Storage of mercury (waste or non-waste) in aboveground warehouses
- Final disposal (permanent storage) of mercury waste in underground mines.

In addition to mercury storage options, Hagemann also recomended that the management of mercury and mercury containing waste be implemented. This management concept involves:

- Preliminary storage at the mercury containing waste generators (before collection)
- Storage of waste before treatment/ final disposal/ recycling
- Final disposal, e.g. in underground mines.

Indonesia

The viability of underground storage option for Indonesia is a rather questioning, and needs further extensive technical and legal evaluations. These are due to:

- Availability of abandoned salt mining or suitable and safe underground deep rock mines

- Geological condition and the present of potential natural disasters, which could lead to safety issues as well as high engineering and construction costs.

- Authorities and public acceptance for underground disposal of wastes have become historically complicated issues.

Establishing an aboveground warehouse for long term period (30 to 40 years) using the US concept is the most feasible option in Indonesia for the storage of excess mercury. The grounds for the selection of this option are:

- geological condition

- susceptibility to natural disasters

- un-availability of appropriate salt mines or deep rock underground mines

- proven approach of the concept

- authority and public acceptability

Other advantage of having an aboveground warehouse is that it provides a 'mercury bank', which could be required during transition period, allowing appropriate control to the mercury trade in Indonesia.

Criteria for Aboveground Storage

Site sitting for the long term storage of excess mercury shall consider the following factors:

- Public involvement and acceptance
- Technical requirements:
  - Geological/hydro-geological condition
  - Natural disasters
  - Proximity to the sources

Further regulatory framework for the site sitting of long term storage for the excess mercury shall be further developed. Current regulations pertaining to the technical requirements for hazardous waste storage, treatment and disposal (TSD) can be used as a basis for filling this gap.

The design of mercury storage building shall have minimum requirements as stipulated in the Head of BAPEDAL's Decree No. Kep-01/BAPEDAL/09/1995 regarding the Procedures & Technical Requirements for Hazardous Waste Collection & Storage, including:

- Building Layout/Design
- Roof and Walls
- Floor
- Ventilation
- Secondary Containment System
- Name Board and Signs
- Lighting
- Leak Detection
- Fire Detection and Suppression System

Cost Estimation for the Aboveground Storage

Establishment of the aboveground storage requires capital/investment cost as well as operating cost for running the storage facility. Due to no data available for the possible quantity of excess mercury in Indonesia, the cost estimation is made based on 1,000 tons of elemental mercury to be stored.

Capital cost	
Pre-construction studies/permitting	USD 425,000
Facility construction	USD 2,267,740
Facility Closure	USD 200,000
Operating Cost/year	USD 370,000

1. INTRODUCTION

1.1 Background

Mercury is a harmful neurotoxin that circulates on local, regional, and global scales, due to its persistent and bio-accumulating properties. Mercury tends to globally spread from one location to another through the atmosphere and biosphere.

The Assessment Report for Excess Mercury Supply in Asia 2010–50 (Maxson, 2010), indicated two scenarios of mercury supply-demand in Asia. The first scenario indicates an approximate of supply-demand equilibrium in 2017, with a need to store 5,500 tons of mercury (mostly accumulated between 2030 and 2050). The second indicates that excess Asian mercury appeared from around 2027, with a need to store 7,500 tons of mercury. Specifically in Asia, the estimates included Southeast Asia (Brunei Darussalam, Cambodia, China, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Democratic People's Republic of Korea, Singapore, Thailand, Vietnam) and East Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka).

Assessment reports of mercury supply in several regions also indicate that the quantities of elemental mercury that will likely to be available for use in products and processes will soon exceed demand. In the Latin American and Caribbean (LAC), the supply of mercury is likely to exceed its demand in 2017 (UNEP, 2012). Therefore, it is obvious that there is a need to prepare technical and policy measures for the mercury excess supply from the global marketplace and secure it in environmentally sound storage, as to prevent its misuse and release to the environment.

National and global policies intended to decrease the production, use, import, and export of mercury will increase the need for access to viable and secure interim storage for mercury stockpiles. Plans to store mercury require valid projections of the amount of excess mercury, necessitating an inventory of current mercury supplies and ability to project future supplies based on a thorough understanding of the uses of mercury in the country and region.

In the 25th Governing Council of UNEP (GC 25/2009), the participating governments agreed to move forward with developing a legally binding treaty on mercury, and directing the Executive Director of UNEP to organize an international negotiating committee (INC) to continue developing the following areas:

- Enhancing capacity for mercury storage;
- Reducing the supply of mercury from, for example, primary mercury mining;
- Conducting awareness-raising and pilot projects in key countries to reduce mercury use in artisanal and small-scale gold mining;
- Reducing mercury use in products and processes and raising awareness of mercury-free alternatives;

- Providing information on best available techniques and best environmental practices and on the conversion of mercury-based processes to non-mercury based processes;
- Enhancing development of national inventories on mercury;
- Raising public awareness and supporting risk communication;
- Providing information on the sound management of mercury ;

To support the above program, the US Department of State develops a foreign assistance under its Mercury Program to enhance the capacity of country to reduce the use and release of mercury in its various applications worldwide, as well as to develop strategic approaches in national and regional frames, including assessment of the requirements for the interim mercury storage. Parameters and technical specifications to include in the assessments are: site selection, site specific assessments, storage specific requirements, and cost estimate for the construction and operation of the mercury storage. Results of the study will also include recommendations and basis for country to proceed with the most feasible option on the safe long term storage of mercury.

The objective of the project is to promote the development of national strategic approaches to sequester or use of mercury in Indonesia. However, the results of the study can also be used as references for the Philippines in developing its approaches to environmentally sound management of the mercury and mercury containing waste.

1.2. Purpose of the Study

The purpose of the study is to:

- raise awareness of the storage issue among the government(s) and key stakeholders, including the mining community and NGOs;
- compile available standards and guidelines for handling, collection, packaging, labeling, safe storage, transportation, data management, and inspection and monitoring of mercury;
- create a list of recommended sites for an interim storage facility and the criteria used to make this determination;
- provide an outline of key decision-making steps in the development of a national plan that could be used by other countries and regions to develop their own plans;
- develop business models designed to encourage those who handle, recycle, or use mercury, including artisanal and small-scale gold miners to relinquish their mercury to a storage facility;
- provide a cost analysis for site preparation, facility construction, and operational budget; and
- assess barriers and innovative approaches to regional cooperation on storage.

1.3. Scope of Work

The assessment for managing the excess supply of mercury emphasizes particularly on safe and secure interim storage of mercury and mercury containing waste, including standards and guidelines for handling, collection, packaging, labeling, storage, record keeping, inspection, and monitoring of mercury in Indonesia. The scope of the assessment covers:

- Identifying sources and estimate quantity of excess mercury based on the inventory of the mercury release
- Assessing criteria for storage (temporary, local, and national).
- Assessing criteria and general standard for handling, collection, packaging, labeling, storage, transportation, data management, inspection, and monitoring of mercury.
- Developing cost estimate for the national storage, including capital investment, operation, and monitoring.

It shall be noted that the study does not cover the criteria and cost estimate for the storage located at mercury sources or generators, nor the local storage, which is intended for the transit or temporary storage.

1.4. Methodology

The methodology used in preparing this report is mainly based on literature study. Consultations with experts and authorities and field trips to existing hazardous waste facilities, were also carried out to some extents.

The first stage of the methodology is to quantify the amount of excess mercury to be stored during the defined period. Due to the lack of available data, the quantity of excess mercury for storage cost estimation, is calculated based on the available report on the inventory of mercury release performed using the UNEP Toolkit.

After the excess mercury identified, the second stage is to overview the existing legal frameworks. The objective of this approach is to review the applicability of the current legislations and estimate the gaps that shall be proposed for further follow-up in order to ensure the effectiveness of the mercury removal program within the countries.

The third stage is overview the currently available technologies and infrastructures for the management of mercury and mercury containing waste. The overview aims to determine feasible option for the ESM of mercury and mercury containing wastes, as well as the gaps, which need to be resolved as part of national action plans.

The fourth stage is reviewing the options for long-term mercury storage that have been assessed in other countries, covering: USA, Europe Community, Latin America and Caribbean. Previous assessments of the options conducted for the Asia Pacific are also evaluated. The fifth stage is screening the available options for the mercury storage, based on the actual conditions of Indonesia, and the last stage is recommendation for the most feasible option and its cost estimation.

1.5. Data Gap

In assessing options for mercury storage and estimating the storage cost, data of estimated quantity of the excess mercury to be stored is required. Unfortunately, there are no previous reports available related the mercury flows and subsequent assessment of excess mercury in Indonesia, that can be used for the basis in the mercury storage sizing and cost estimation. To fill this gap, the quantity of excess mercury is roughly estimated from the inventory result of Level-1 Mercury Release Using UNEP Toolkit (Dewi, 2012). Obviously this approach would not give an accurate estimation on the excess mercury to be stored in Indonesia.

2. SOURCE AND ESTIMATED QUANTITY OF EXCESS MERCURY

Understanding the source and distribution of the mercury are very important factors in developing national strategic plan (NSP), as well as assessing the options for the mercury storage and sizing the required storage for cost estimation. Summary of the previous studies on the assessment of excess mercury in many regions is shown in the Table 1 below.

Table 1. Summary of Estimated Excess Mercury in the Regions

Region	Est. Quantity (tons)	Remark
USA*	5,642	Current stock managed by the DNSC and DOE
European Community**	10,000	Resulted from export ban and chlor-alkali demolition
Latin America and Caribbean***	2,000 – 8,000	Excess starts in 2015 or earlier
Asia-Pasific****	5,500 – 7,500	Excess starts 2027 or earlier 2017

Source:
** US-EPA, 2007*
*** BiPRO, 2010*
**** Maxson, 2009a*
***** Maxson, 2009b*

For the Asia region, Maxson (2009) indicated that the quantity of excess mercury would be over 5,500 tons, which would mostly be accumulated between 2030 and 2050. According to the alternative scenario, the excess mercury could be as high as 7,500 tons, if the authorities decide to accelerate the storage the excess mercury. The report also highlighted the need to address the following issues:

- potential excess mercury, resulted from non-ferrous metal production such as zinc and gold
- management of mercury waste, resulted from the end-of-life products

2.1. Sources of mercury emissions

In general, source of mercury emissions to the atmosphere can classified be into three types of source, that are: natural emission ("geogenic"), human activity's emission ("anthropogenic") and re-emission (from the historically-deposited mercury). Many countries have developed inventories of mercury emission, which could better information on the sources and estimated quantity on mercury releases in specific countries and eventually in the regions and global releases. In order to standardize methodology and database of the mercury inventory, the UNEP has developed toolkit for identification and quantification of mercury releases ("the Mercury Toolkit"). The toolkit, which is a guide for the countries in developing the inventory through different stages, consists of two versions that are:

- Inventory Level 1 – simplified version of the toolkit, which is relatively easier to develop. It uses a spreadsheet with default input factors/ distribution factors, and provides a general overview of the mercury inventory
- Inventory Level 2 – comprehensive description of mercury release. It uses a spreadsheet with site specific input factors/ distribution factors.

In Indonesia, unfortunately there is no published data available on this inventory result that can be used for the estimation of the excess mercury to be stored as well as for the assessment of storage options. However, during the preparation of this report, there is a parallel project on mercury inventory conducted by BaliFokus and Ban Toxics! with the support from the US Department of State. Interim report of the mercury releases inventory indicates that the main categories of mercury release in Indonesia are: gold extraction (ASGM), waste open burning and informal dumping, oil/ gas production and coal combustion (Dewi, 2012).

The inventory result of the mercury release using UNEP Toolkit is presented in the Figure 1 below. It shall be noted that the study is based on Level-1 Toolkit for Identification and Quantification of Mercury Releases provided by UNEP, which needs further adjustments for its input factors in the Level-2 assessment.

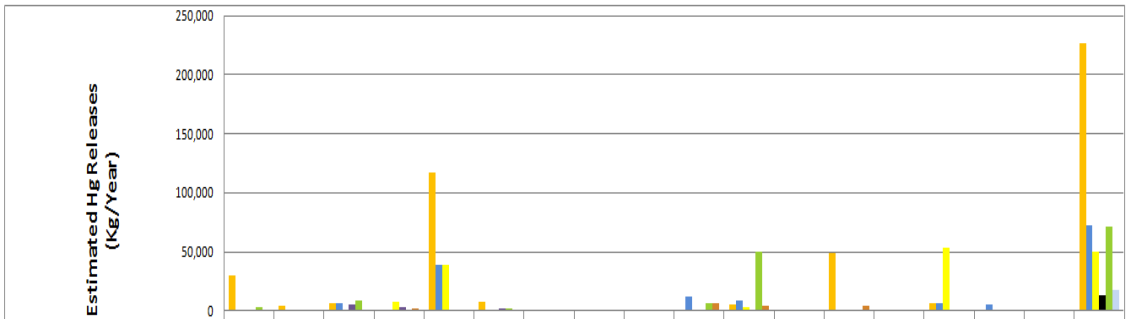
2.2 Estimated Quantity Excess Mercury in Indonesia

Based on its origin, elemental mercury may be produced from several source materials. Several terms used to classify mercury are often referred to their type of source:

- Primary mercury – unused, 'virgin' mercury that has been produced as the main product of mining activities, e.g. the processing of the mercury ore cinnabar
- Secondary mercury – mercury that is generated through recycling of mercury-containing wastes such as catalysts, products or mercury from decommissioned mercury cell chlor-alkali plants
- By-product mercury – mercury produced in the mining and processing of minerals other than mercury minerals (e.g. gold, natural gas, zinc, lead). In these processes mercury may be produced in elemental form or as mercury compounds like mercury (I) chloride (calomel).

These types of mercury contain the same elemental mercury and share the same toxic, chemical, and physical properties.

Figure 1. Inventory of Mercury Release in Indonesia Using UNEP Toolkit



	Coal combustion and other coal use	Other fossil fuel and biomass combustion	Oil and gas production	Primary metal production (excl. gold production by amalgamation)	Gold extraction with mercury amalgamation	Other materials production	Chlor-alkali production with mercury-cells	Other production of chemicals and polymers	Production of products with mercury content	Use and disposal of dental amalgam fillings	Use and disposal of other products	Production of recycled metals	Waste incineration and open waste burning*1	Waste deposition*1	Informal dumping of general waste *1*2	Waste water system/treatment *3	Crematoria and cemeteries	TOTAL
Air	29,603.0	4,281.4	5,913.9	1,307.6	117,000.0	7,185.0	0.0	0.0	24.4	712.9	5,576.0	0.0	48,822.3	0.0	6,606.5	0.0	1.9	227,030.0
Water	0.0	0.0	6,426.4	312.6	39,000.0	0.0	0.0	0.0	12.2	11,834.5	8,304.7	0.0	0.0	0.0	6,606.5	4,918.1	0.0	72,500.0
Land	0.0	0.0	0.0	7,833.3	39,000.0	0.0	0.0	0.0	244.2	0.0	3,327.0	0.0	0.0	0.0	52,852.1	0.0	35.6	50,440.0
By-products and impurities	0.0	0.0	5,789.5	3,441.5	0.0	2,200.0	0.0	0.0	0.0	1,283.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12,710.0
General waste	3,289.2	0.0	8,565.9	143.0	0.0	2,200.0	0.0	0.0	244.2	6,844.1	49,766.3	0.0	0.0	0.0	0.0	546.5	0.0	71,600.0
Sector specific waste treatment /disposal	0.0	0.0	0.0	1,940.3	0.0	0.0	0.0	0.0	24.4	6,844.1	4,039.9	0.0	4,412.2	0.0	0.0	0.0	0.0	17,260.0

Notes:

*1) To avoid double counting of mercury inputs from waste and products in the input TOTAL, only 10% of the mercury input to waste incineration, waste deposition and informal dumping is included in the total for mercury inputs. These 10% represent approximately the mercury input to waste from materials which were not quantified individually in Inventory Level 1 of this Toolkit.

*2) The estimated quantities include mercury in products which has also been accounted for under each product category. To avoid double counting, the release to land from informal dumping of general waste has been subtracted automatically in the TOTALS.

*3) The estimated input and release to water include mercury amounts which have also been accounted for under each source category. To avoid double counting, input to, and release to water from, waste water system/treatment have been subtracted automatically in the TOTALS.

Source: Kania Dewi, 2012

In Indonesia, sources of mercury mostly come from the secondary and by-product mercury, since there is no primary mercury available within the countries. In the other hand, there are also no mercury recycling facility exist within the country. This situation may lead to the conclusion that Indonesia is a net importer of the elemental mercury. The growing demands of mercury for mostly artisanal and small scale gold mining (ASGM) and in products, mercury is regularly imported as commodity from other countries to Indonesia. Lacks of implementation for Extended Producer Responsibility (EPR) and availability of mercury recovery facility, also instigate the importation of metallic mercury to fulfill the demand.

Referring to the inventory assessment using UNEP Toolkit as described in previous chapter, the main sources of mercury release in Indonesia is summarized in the Table 2 below.

Table 2. Main Sources of Mercury Release in Indonesia

Source Category	Mercury Release (kg/year)
Gold extraction with mercury amalgamation	195,000
Informal dumping of general waste	66,065
Waste incineration and open waste burning	53,234
Oil and gas production	43,605
Use and disposal of other products	37,744
Coal combustion and other coal use	32,892
Total Category	390,140

Source: Dewi (2012)

As noted above, this estimated quantity is based on interim report of Inventory Level 1, which is subject to change in Level 2 results using a site specific input factors and distribution factors. At this stage, estimating excess mercury for the assessment of storage options and capacity is a rather difficult.

3. OVERVIEW OF CURRENT MERCURY WASTE MANAGEMENT

3.1. Framework for Decision Making on the Management of Excess Mercury

The UNEP Governing Council (GC) decisions 24/3 has identified the need to develop a policy framework for addressing the global challenges posed by mercury, taking into accounts the following priorities:

- reduce atmospheric mercury emission;
- find environmentally sound solutions for the management of mercury;
- reduce global mercury demand;
- reduce the global mercury supply;
- find environmentally sound storage solutions for mercury;
- address remediation of existing contaminated sites
- increase knowledge.

For the implementation of the policy framework, there are two options can be taken, that are a new free-standing, legally binding on mercury convention, and enhance voluntary measures.

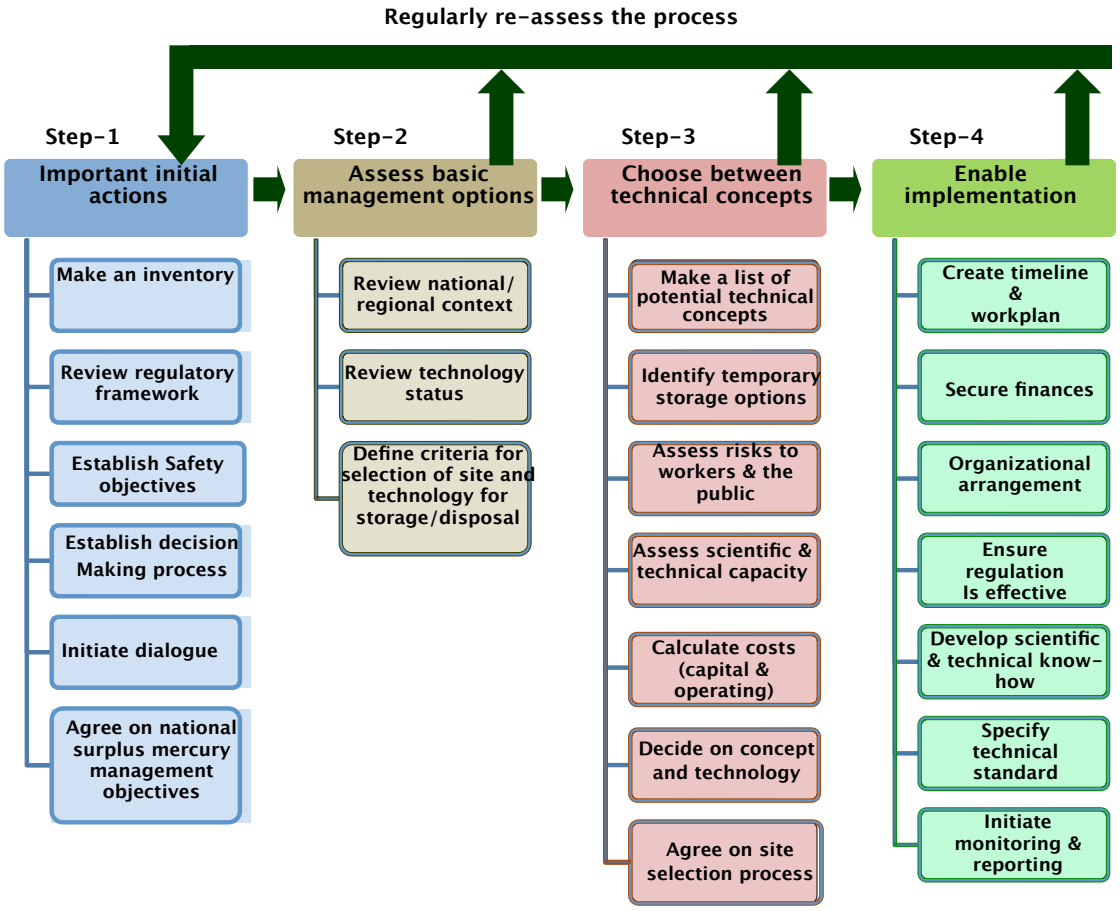
The UNEP Governing Council (GC) decisions 25/5 declared in Nairobi, Kenya on February 2009, adopted several decisions towards a mandate for preparation of a global legally binding instrument on mercury. The governments and other stakeholders are to continue and enhance existing works on the following areas:

- enhance capacity for mercury storage;
- reduce the mercury supply;
- conduct awareness-raising and pilot projects to reduce mercury use in artisanal and small-scale gold mining;
- reduce mercury use in products and processes and raise awareness of mercury-free alternatives;
- provide information on best available techniques and best environmental practices and on the conversion of mercury-based processes to non-mercury based processes;
- development of national inventories on mercury;
- raise public awareness and support risk communication;
- provide information on the sound management of mercury;

The Oxford Workshop on the Safe Storage and Disposal of Redundant Mercury was held in October 2009, supported by UK Department for Environment, Food and Rural Affairs, and involved over 40 experts from 7 countries. The event was focused on scientific and technical issues, and was followed by a sub-group discussion on considerations for the safe management of surplus mercury worldwide. The output of the workshop was further edited and published in December 2010. The following

diagram shows an outline of suggested framework for decision making for the safe management of excess mercury.

Figure 2. Suggested Framework for Decision Making for the Safe Management of Surplus Mercury – IKIMP Initiative



Source: IKIMP, 2010

The framework consists of four step of actions, covering:

- Step-1: Initial actions,
- Step-2: Assess basic management options,
- Step-3: Choose between technical concepts and
- Step-4: Enable implementation.

Each step of action above consists of several decision elements that could be taken into account when designing a national decision process. When new information obtained that could lead to the different conclusion, re-assessment of the process and/ or revision of the earlier decision may be is required.

3.2. Regulatory Overview

The following section describes overview on the current legislations both in Indonesia that can be used as a cornerstone in the establishment of the environmentally sound management of mercury. The overview is separately conducted to the mercury as "product" and mercury as a "waste".

3.2.1 Mercury as 'Product'

As a product, use-sale-distribution of metallic mercury is controlled by Government Regulation No.74 Year 2001 regarding the management of toxic and hazardous substances. However, referring to this regulation, the metallic mercury is not classified as a "prohibited substance", Instead, it is categorized as a "limited use substance", where its use-sale-distribution shall follow the following requirements:

- Producer or importer of the substance shall register to and obtain registration number from the Ministry of Environment (at the first time the substance produced or imported)
- Prior to issuing the registration number, the Ministry of Environment shall obtain the approval from the Commission of Toxic and Hazardous Substance.
- Exportation and importation of mercury shall follow notification procedures, where consents shall be given by importing/importing countries.

The regulation also stipulates requirements for general management of the toxic substances, including: MSDS, label and symbol, transportation and storage. Specific to the storage requirements, the regulation states that the storage shall meet the criteria for location and building construction, which will be further specified in the implementing regulations. Currently, the only implementing regulation available for the management of toxic substance is the Ministry of Environment Regulation No.03/2008 Regarding the Procedures for Application of Symbol and Label for Hazardous Materials

Other legislation pertaining to the use-sale-distribution of metallic mercury is West Kalimantan Province Regulation No. 4 Year 2007 pertaining to Control of Distribution and Use of Mercury and Similar Compounds. This provincial regulation is enacted by the local authority of West Kalimantan Province to anticipate the fast and un-controlled growing Artisanal and Small Scale Gold Mining (ASGM) in the region. In summary, the regulation stipulates that any importer, distributor or reseller of mercury shall have a specific permit, and only permitted entities is allowed to sale and distribute the mercury. In addition, the mercury user in West Kalimantan, either business entity or individual, shall also secure permit from the Governor, and purchase only the mercury from the permitted distributor or reseller.

3.2.2. Mercury as 'Waste'

The Government of Indonesia has released various regulations pertaining to the hazardous waste management. The recently passed Law No.32 concerning the Protection and Management of the Environment, imposes harsher penalties on improper waste management. Compared to the previous Law No.23/2004 concerning the Environmental Management, the new Law No.32 is much more comprehensive and contains significant changes in regulatory approaches. The reasons for the changes are :

- Increase in the quantity of hazardous waste generated
- Some hazardous waste is disposed by open dumping and / or open burning
- There are limited facilities for hazardous waste treatment
- Hazardous Waste Management without the permit from MOE
- Lack of stakeholder awareness and capacity related to the implementation of Hazardous Waste Management
- Illegal imports of hazardous waste

Government Regulation of the Republic of Indonesia (GR) No.18 Year 1999 pertaining to the Hazardous Waste Management, classifies the mercury and mercury containing wastes as hazardous wastes, under BAPEDAL Code D3112. As a consequence, any activities related the management of mercury and mercury containing waste shall comply with the prevailing regulations concerning hazardous waste management. These activities include:

- temporary storage by the waste generator;
- transportation;
- collection and storage and transfer station;
- treatment; and
- disposal.

Other more specific implementing legislations pertaining to the management of hazardous/toxic substance and waste, and to the mercury and mercury containing waste in particular, are:

- Government Regulation No. 85/1999 - Revision of the Hazardous Waste Management No. 18/99
- Head of BAPEDAL Decree No.: Kep-01/BAPEDAL/09/1995 - Procedures & Technical Requirements for Hazardous Waste Collection & Storage
- Head of BAPEDAL Decree No.: Kep-02/BAPEDAL/09/1995 - Hazardous Waste Documentation
- Head of BAPEDAL Decree No.: Kep-03/BAPEDAL/09/1995 - Procedures & Technical Requirements for Hazardous Waste Treatment
- Head of BAPEDAL Decree No.: Kep-04/BAPEDAL/09/1995 - Procedures & Technical requirements for disposal of treated hazardous wastes, requirements for treatment & disposal site closure and post-closure
- Head of BAPEDAL Decree No.: Kep-05/BAPEDAL/09/1995 - Hazardous Waste Symbol & Label
- Ministry of Environment's Regulation No. 18/2009 – Procedure for Permit Application for Hazardous Waste Management
- Ministry of Environment Regulation No.03/2008 - Procedures for Application of Symbol and Label for Hazardous Materials.

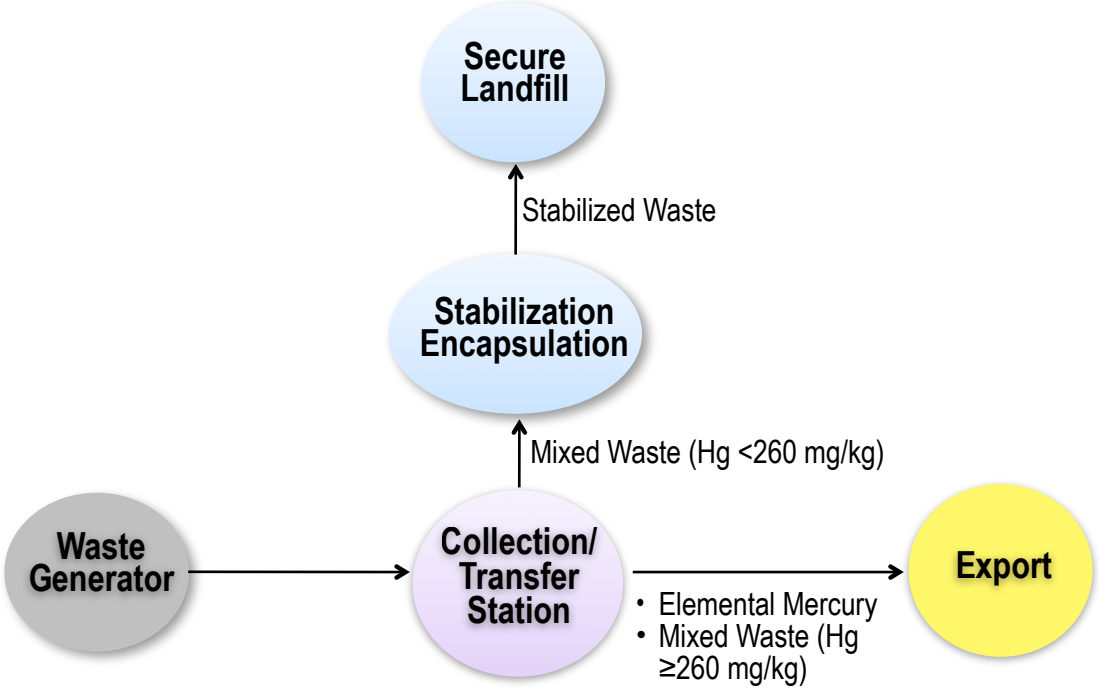
Specific requirements for the storage of hazardous and toxic waste are comprehensively stipulated in the Head of BAPEDAL Decree No.: Kep-01/BAPEDAL/09/1995 pertaining to the Procedures & Technical Requirements for Hazardous Waste Collection & Storage.

3.3. Overview of Current Infrastructure for Mercury Waste Management

As stipulated in the GR No.18/1999, hazardous waste generator has an obligation to properly manage their generated waste 'from cradle to grave'. In addition, the waste generators shall also regularly report their types of waste –including mercury and mercury containing wastes- and their quantity to the local government and the Ministry of Environment. Unfortunately the regulation is not yet been strongly enforced, that results the accurate inventory and control become more difficult. Lacks of awareness and knowledge of proper waste identification are also the other concerns, which need continuous capacity building.

Nevertheless, few of waste generators have implemented environmentally sound managements to their wastes by having cooperation with a licensed waste treatment facility to treat and dispose off their mercury containing wastes in a properly manner. Meanwhile, the wastes, which cannot be treated in the facility, are repacked and exported to the countries having a mercury recovery facility. The Figure 3 below describes a summary of environmentally sound management of mercury and mercury waste in Indonesia.

Figure 3. Flow Diagram for the Current ESM of Mercury Wastes



- **Waste Handling: Packaging, Labeling and Temporary Storage**

  Once the mercury containing wastes are generated, they are containerized in open-top drums of 200 liters for solid/semi-solid wastes, or closed-top drums for liquid/slurry wastes. In some cases, other re-usable waste containers may also be provided by the waste management service provider. Each containers shall be furnished with hazardous waste labels and symbols, conforming to the requirements as stipulated in Head of BAPEDAL's Decree No. Kep-05/BAPEDAL/09/1995.

  The waste generator is allowed to temporarily store its waste for 90 days (if the waste production is >50 kg/day) or 180 days (if the waste production is ≤50 kg/day). After this period, the waste shall be managed by the generator itself or handed over to other parties for further management.

Figure 4. Re-usable Waste Hazardous Waste Containers

1.5 m³ Closed Boxes

1.4 m³ Closed Boxes

1.5 m³ Open Top Boxes

3.2 m³ Drilling Mud / Cuttings Box

Photo: Courtesy of PT PPLI

- **Transportation to the Collection Facility/Transfer Collection**

  When the waste generator decides to conduct an off-site management, the waste is transported to the collection facility or transfer station using dedicated hazardous waste vehicles. The wastes are transported by either land and/or sea transportations from generator's site to the treatment facility. Various type vehicles are available, depending on how the waste is packaged.

  For land transportation mode, containerized wastes are carried using drum vans, or semi trailers, while bulk wastes using roll-off boxes for solid/semi-solid or tankers

for liquid/slurry. The trucks are equipped with GPS Fleet Tracking System to closely monitor the real-time position of the trucks as well key parameters of the truck conditions.

Figure 5. Hazardous Waste Transportation

10 m3 roll-off crane truck

2x20' Sea Container, semi trailer

Photo: Courtesy of PT PPLI

- **Temporary Storage and End-acceptance Laboratory Analysis**

Upon arrival at the collection/treatment facility, the waste is tested in a laboratory for its conformity to the pre-acceptance results, including assessment for its suitability for the treatment decision. The facility implements a policy that elemental mercury or waste containing mercury greater than 260 mg/kg will not accepted for the treatment and disposal at its site. If the characteristic of the waste meets the criteria for the treatment acceptance, the mercury containing waste is treated by stabilization/ encapsulation process.

- **Stabilization and Encapsulation Treatment**

The stabilization/Solidification process aims to immobilize the mercury contained in the waste, such that preventing it from being leached out. This objective is accomplished by the following stages:

(a) Stage-1: reducing the solubility of mercury contained in the waste, such as by: converting it into least soluble form, pH adjustment or sorption phenomena. Waste containing elemental mercury is reacted with elemental sulphur or sulphur salts (e.g. FeS), forming a mercury sulphide (Hagemann, 2009).

$$Hg(l) + S \rightarrow HgS$$

For the mercury in oxidized form Hg^{2+},or mercury in ionic form, a sulphide-containing agent is needed for the reaction to for an insoluble mercury sulphide:

$$Hg^{2+} + HS^{-} \rightarrow HgS + H^{+}$$

(b) Stage-2: decreasing the surface area of the waste mass across which transfer or loss contaminants can occur, such as by mixing it with Portland based cements or other pozzolanic materials.

(c) Stage-3: physical encapsulation of the stabilized/solidified waste that is intended for further containment.

In Indonesia, the criteria of stabilization treatment for hazardous waste are specified in the Head of BAPEDAL's Decree No. Kep-03/BAPEDAL/09/1995 regarding Technical Requirements for Hazardous Waste Treatment. This regulation specifies that the stabilized waste shall meet the requirements of: Toxicity Characteristic Leaching Procedure (TCLP), bearing strength, and paint filter tests. Specific to the mercury, the regulatory TCLP limit is 0.2 mg/L, prior to the disposal into the hazardous waste landfill.

At PT Prasadha Pamunah Limbah Industri (PPLI) facility, the stabilization process is performed in a steel lined pit with a capacity of approx. 100 tons. The mercury containing waste is dumped into the mixing pit from their packaging, and stabilization reagents are added into the pit. The required reagents and their composition (called 'recipe') is determined by laboratory trials prior to the full-scale process, and is a proprietary of the company. The mixture is then converted into slurry form mixed with water and homogenized.

Figure 6. Stabilization and Encapsulation of Stabilized Mercury Containing Waste

Photo: Courtesy of PT PPLI

After stabilized, solidified and encapsulated, the waste is disposed off into a secure landfill licensed for hazardous waste final disposal.

- **Final Disposal in Secure Landfill**

  The stabilized mercury containing waste shall meet the regulatory parameters prior to the final disposal in an hazardous waste landfill. These parameters are: TCLP test limits, bearing strength and paint filter test. The landfill category for final disposal of the stabilized mercury waste depends on the total concentration of the mercury in the initial waste. Category-1 Landfill, which has a double impermeable layer, shall be applied for the waste containing mercury ≥20 mg/kg, meanwhile waste containing

mercury between 2-20 mg/kg shall be disposed off in a category-II Landfill. Each landfill category has a different base lining system.

Figure 7. Category-I Landfill Schematic Diagram

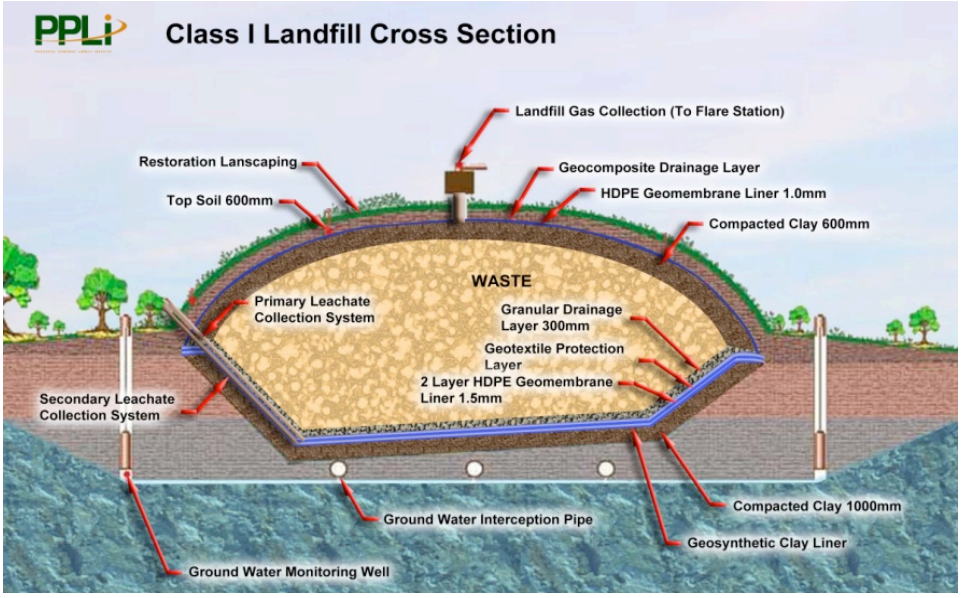


Photo: Courtesy of PT PPLI

Figure 8. Aerial View of the Hazardous Waste Landfill at PT PPLI

Photo: Courtesy of PT PPLI

- **Mercury Waste Export for Recovery**

  Mercury wastes are regulated in the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal.[2] Any export of mercury wastes to other country must comply with the Basel Convention requirements, including the prior-informed consent from the transit and receiving countries.

  Indonesia adopted the Basel Convention through a Presidential Decree No.61 Year 1993 regarding the ratification of the Basel Convention for the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal.[3] Export of the mercury containing waste to other countries for treatment and/or disposal shall follow the procedures as set in this regulation.

  For the period of 2011-2012, the Ministry of Environment has approved the application for export of mercury containing wastes, with the total exported quantity of 550 tons. The country for export destination is mainly European countries (interview). The sources of mercury containing wastes currently being exported from Indonesia are mainly from the oil and gas productions.

  Prior to shipment, the wastes are packaged in 200-liter UN-approved metal drums, with plastic inner liners. Open head drums are equipped with lids, and secured with clamps and bolts. The drums are put in wooden pallet conforming to the specification of ISPM-15.

Figure 9. Export Preparation for Mercury Containing wastes

Photo: Courtesy of PT PPLI

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[2] *Basel Convention - Controlling Transboundary Movement of Hazardous Waste and Their Disposal. http://www.basel.int/.*

[3] *Presidential Decree No.61 Year 1993 regarding the ratification of the Basel Convention for the Control of Transboundary Movements of Hazardous Wastes and their Disposal.*

4. OVERVIEW OF OPTIONS FOR MERCURY STORAGE CONCEPT

Since mercury is inorganic element that cannot be destroyed, policy frameworks designed to reduce the use of mercury must be accompanied the access to the viable, safe and secure long storage. The following section describes the progressing development of mercury storage concept in regions that can be used for reference in developing mercury management concept in Indonesia.

4.1. Mercury Storage in United States of America (USA)

USA is the country with the longest and most consolidated experience in storing elemental mercury, where the federal government is currently running two mercury storages under the responsibility of Defense National Stockpile Center (DNSC) and Department of Energy (DOE).

DNSC is a field activity of Defense Logistics Agency, operates the National Defense Stockpile Program to store sell metallurgical ores and materials. The program was established in 1940s to lessen U.S. dependence on foreign sources of supply in times of war or national emergency. DNSC has stored approximately 4,436 tons of government-owned commodity grade elemental mercury for over 50 years. The mercury stockpile has been stored in 3 (three) above ground locations, that are: Somerville, New Jersey (2,617 tons), Warren, Ohio (1,262 tons) and New Haven, Indiana (557 tons) (Lynch, 2009).

Starting 1994, due to the environmental and health risks of the mercury, the DNSC halted the selling of elemental mercury. In 2004, Mercury Management Environmental Impact Statement MM EIS) was produced to address long-term management of the elemental mercury. The MM EIS considered the following options:

- Maintaining all the sites (no-action/status quo)
- Consolidating the mercury for storage at one location for the period of 40 years (long term storage)
- Selling the elemental mercury on the market (needs 30 years to sell the whole mercury)

The result of the MM EIS concluded that the preferred alternative is the consolidation of the elemental mercury aboveground storage at one location. In 2006, it was decided that the selected warehouse was Hawthorne Army Depot, Hawthorne, Nevada. The reasons of this selection were:

- Government owned facility
- Secure storage
- Trained and experienced staff
- Emergency preparedness plans in place
- Safe long-term storage.

Currently there is still continuous dialogue between DNSC and the Nevada Division of Environmental Protection to meet Nevada requirements under that state's Chemical Accident Prevention Program.

Underground storage and pre-treatment options (stabilization of elemental mercury) were also considered in the MM EIS, but these have not been further evaluated because of the following reasons:

- limited availability of existing underground mines, inspection considerations, additional material handling, and regulatory issues.
- additional environmental impacts and costs for stabilization of elemental mercury, with less significant benefits
- possible future use of metallic mercury in industrial processes

In addition to the above described 4,436 tons of elemental mercury stockpiled by the DNSC, Department of Energy (DOE) also stored 1,206 tons of commodity-grade mercury at National Security Complex, operated by National Nuclear Security Administration (NNSA). The whole mercury was stored in approx. 35,000 76-lb flasks made of carbon steel, grouped in 45 on wooden pallets.

In 2008, the US Congress passed the 'Mercury Export Ban Act of 2008', which prohibits the sale, distribution and transfer of elemental mercury by federal agencies to any other Federal agency, any state or local government agency, or any private individual or entity, including banning for export from the United States effective1 January 2013 (14). The Act also directs the DOE to accept and store excess mercury generated from commercial mercury recyclers, by-product of gold mines, and dismantling of chlor-alkali plants.

To execute the direction, in addition to the modification of the existing facility, the DOE also has to designate more facilities for the purpose of long-term storage of elemental mercury generated in across the USA. The storage facilities shall meet the requirements as of section 5(d) of the Act, Management Standards for a Facility, including the requirements of the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act (RECRA).

To conclude, the US approach relating to excess elemental mercury, is long-term storage in appropriate above ground facilities. Studies carried out in the USA concluded that the available stabilization technologies are considered immature and un-safe enough for large amounts of elemental mercury.

4.2. Mercury Storage in European Community (EU)

In 22 October 2008, the Council and European Parliament adopted a Regulation (EC) No 1102/2008 concerning the export banning of metallic mercury and the requirement for safe storage of metallic mercury. The regulation aims to prevent the surplus mercury resulting from the closure of mercury-cell facilities in the chlor-alkali industry from re-entering the global market. The quantity of surplus mercury is estimated to be about 10.000 tons of metallic mercury. The export ban starts on 15 March 2011 and affects metallic mercury, cinnabar ore, mercury (I) chloride, mercury (II) oxide and mixtures of metallic mercury with other substances including alloys of mercury, with a concentration of at least 95 %(wt) Hg.

As a consequence to the Regulation (EC) No 1102/2008, large amounts of metallic mercury – which were initially considered as raw material – become waste, and

adequate safe storage or disposal options have to be identified. In anticipating this, the European Commission assigned BiPRO GmbH to identify feasible storage options and to define acceptance criteria and minimum requirements for the safe disposal of metallic mercury. The outcome of this study is presented below (BiPRO, 2010).

Possible Options for the Permanent Storage of Mercury

- Permanent storage of metallic mercury in salt mines
- Pre-treatment of metallic mercury with a subsequent permanent storage in salt mines
- Pre-treatment of metallic mercury with a subsequent permanent storage in deep underground hard rock formations
- Pre-treatment of metallic mercury with a subsequent permanent storage in above ground facilities

Acceptance Criteria and Facility Related Requirements

- Minimum acceptance criteria and procedure for metallic mercury (e.g. purity > 99.9%) and its containment (e.g. carbon steel container)
- Minimum acceptance criteria for stabilized mercury (e.g. leaching rate below 2 mg/kg dry mass)
- Additional facility related requirements for the permanent storage in salt rock (e.g. minimum depth of the storage area: 300 m)

EU Recommended Options

Based on an economic and environmental assessment, the following options are recommended:

- Pre-treatment (Sulphur stabilization) of metallic mercury and subsequent permanent storage in salt mines (highest level of environmental protection, acceptable costs)
- Pre-treatment (Sulphur stabilization) of metallic mercury and subsequent permanent storage in a hard rock underground formation (high level of environmental protection, acceptable costs)
- Permanent Storage of metallic mercury in salt mines (most cost effective option)

Since permanent storage solutions are currently not available, the study recommended that temporary storage solutions for the period of 5 years be implemented to bridge the gap until final solutions are available. The European Commission shall review the Regulation (EC) No. 1102/2008 by 15 March 2013, to evaluate the actual availability of permanent disposal options for pre-treated mercury and the requirement of future temporary storage.

4.3. Mercury Storage in Latin American and Caribbean (LAC)

In July 2009, UNEP Chemicals released an assessment report of Excess Mercury Supply in Latin America and the Caribbean, 2010-2050. According to Maxson (2009), for the Latin America and Caribbean (LAC) region, the Base Case Scenario indicates that the quantity of excess mercury to be stored, over the period 2015 – 2050, could be more than 8,000 tons. The scenario assessed in this report also indicates that the mercury supply in LAC may exceed demand even before 2015, which could imply a need for storage of the excess mercury in the region.

The minimum scenario of mercury accumulated could be around 2,000-3,000 tons, with the assumption that some mercury by-product continues to be exported and a slower increase of mercury by-products and waste generation. These two scenarios do not reflect the possible adoption of a near-term regional strategy of sequestering mercury that aimed to encourage reduction of mercury demand. Adoption of such a strategy would even require development of storage capacity as soon as possible.

Further in 2010, Laboratorio Tecnológicodel Uruguay (LATU) and UNEP Chemicals released the study report on the feasibility of long-term storage for excess mercury in LAC. The study proposed three options for the long-term storage of mercury, that are:

- Above-ground specially engineered warehouses
- Below-ground storage in geological formation (e.g., mines, special rock formations)
- Export to a foreign country/facility, as a short term solution

Note that LAC considers the option of export the mercury to the foreign facility. This option is feasible, when there is an in-significant amount of the excess mercury.

In 2010, Argentina and Uruguay implemented a “Mercury Two Countries Project” with the purpose to demonstrate the use of existing hazardous waste facilities as temporary storage facilities for mercury (commodity or waste) by doing a survey of such facilities and of relevant country legislation. The project results presented at the Workshop on Problems of Mercury Management in LAC Region on May 21st – 22nd, 2012[4] as follow:

- Uruguay has identified two storage/disposal sites for elemental mercury and mercury containing waste. For aboveground storage, abandoned facility of chlor-alkali plant is selected for temporary storage. For below-ground storage, CIU landfill has been put as a candidate for final disposal of mercury containing waste.
- Argentina identified 5 (five) hazardous waste landfills under Law 24.051 authorized for receiving mercury Y29 Control category subject to removal operation prior stabilization D5 hydrosulfide mercury, sulfides or poly sulphides. One facility in Buenos Aires is authorized to treat mercury-containing lamps. Two companies are doing the qualification as exporters for batteries wastes containing mercury.

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[4] *UNEP. United Nations Environment Programme. Mercury Storage Two Countries Project. [Cited: August 9, 2012.] http://www.unep.org/hazardoussubstances/Mercury/PrioritiesforAction/SupplyandStorage/Activities/LACMercuryStorageProject/MercuryStorage2CountriesProject/tabid/79070/Default.aspx.*

4.4. Mercury Storage in Asia-Pacific

The Assessment Report for Excess Mercury Supply in Asia 2010–50 (Maxson, 2009), revealed two scenarios of mercury supply-demand in Asia. The first scenario indicates an approximate of supply-demand equilibrium in 2017, with a need to store 5,500 tons of mercury. The second indicates that excess Asian mercury appeared from around 2027, with a need to store 7,500 tons of mercury. In the Asia-Pacific region, mercury demand for the production of vinyl chloride monomer (VCM) and manufacturing of fluorescent lamps is likely to increase, while demand for other products such as batteries and measuring devices will probably decline. In the long-term, it is anticipated that the mercury demand will decline faster than supply from activities such as decommissioning of chlor-alkali plants, mining, non-ferrous metal production, natural gas production and recycling of mercury containing waste.

In order to tackle the problems related to excess mercury supply in Asia-Pacific region, Hagemann (2011) proposed a three-step strategy to effectively remove mercury from the market and reduce its risk potential by permanent isolation from the biosphere. This strategy covers:

- **Effective Collection:**
  This step is intended to remove elemental mercury and mercury compounds that are no longer needed for accepted uses from the market.

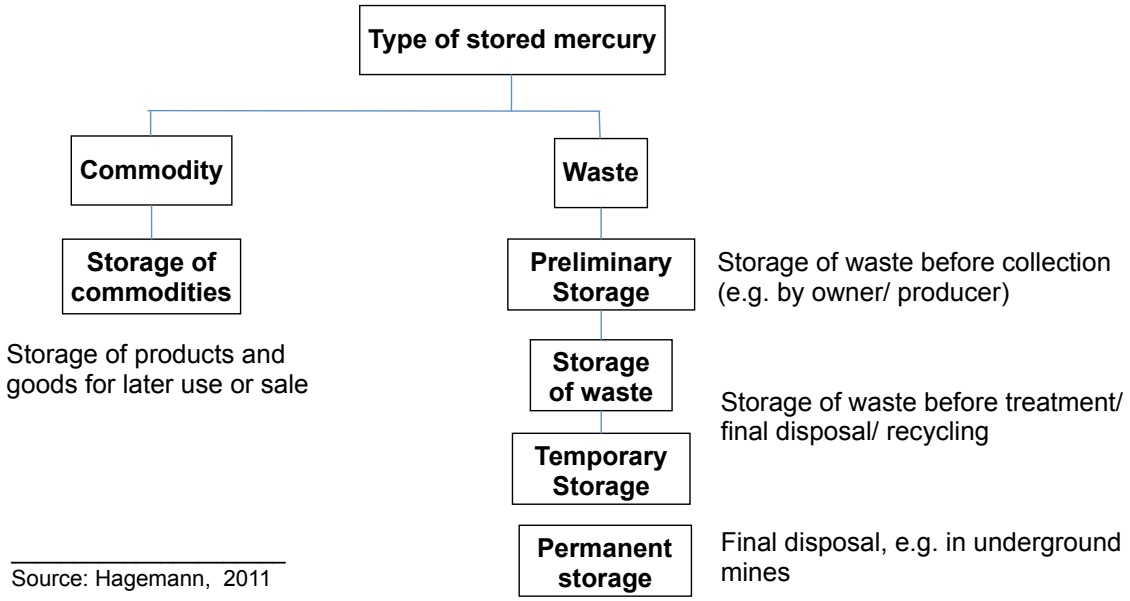
- **Early Stabilization:**
  Stabilization of mercury is a commercially available technology, that convert elemental mercury into a non-, or at least much less, soluble chemical form.

- **Safe Disposal:**
  This final step is required to achieve a final disposal for stabilized mercury in environmentally sound manner.

It shall be noted that temporary storage of elemental mercury will still be necessary in order to collect surplus mercury and prepare it for shipping. However, the duration of storing elemental mercury shall be kept as short as possible. Further, Hagemann suggested the following milestones be initiated, in order to have a successful implementation of this strategy:

- Legal framework for the obligation and requirements for collection, temporary storage, treatment, disposal.
- Improved collection systems and transport quality for elemental mercury and mercury waste.
- Availability of temporary storage facilities at end-users or waste collection facilities.
- Availability of a stabilization plant (possibly combined recovery plant to extract mercury from mercury containing waste).
- Availability of facilities for the disposal of stabilized mercury, mercury waste and possibly other hazardous wastes. For the efficiency of the transportation of the stabilized mercury and waste, these Stabilization plant and disposal facility should be in close distance.

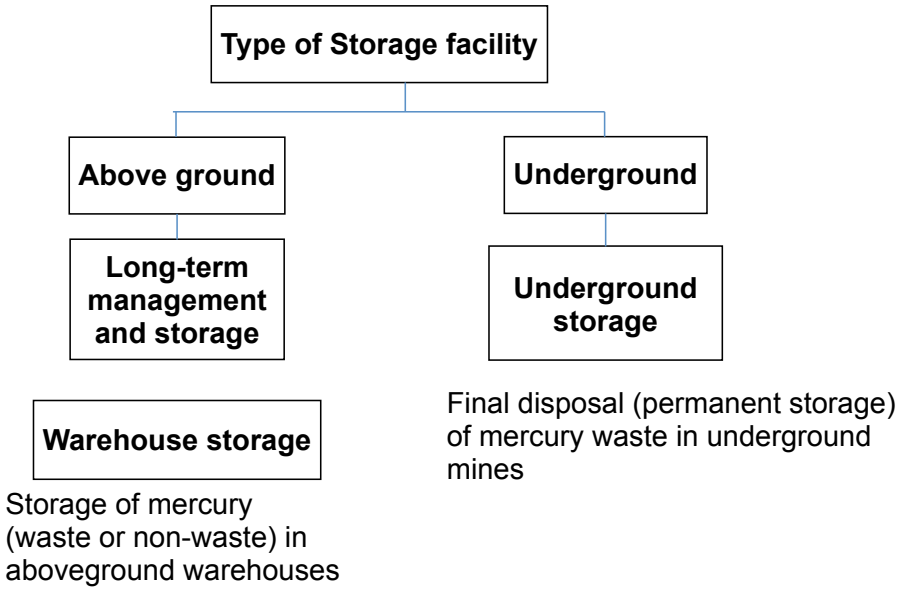
Figure 10. Type of Stored Mercury



Source: Hagemann, 2011

Further, Hagemann presented the storage options for Asia-Pacific as shown in Figure 11 below.

Figure 11. Mercury Storage Facility Options



Source: Hagemann, 2011

To conclude, the recommended options for mercury storage for the Asia Pacific region are as the following:

- US concept of storing elemental Hg in aboveground warehouses for up to 40 years or more
- Storage of mercury (waste or non-waste) in aboveground warehouses
- Final disposal (permanent storage) of mercury waste in underground mines.

In addition to mercury storage options, Hagemann also recomended that the management of mercury and mercury containing waste be implemented. This management concept involves:

- Preliminary storage at the mercury containing waste generators (before collection)
- Storage of waste before treatment/ final disposal/ recycling
- Final disposal, e.g. in underground mines

5. ASSESSMENT FOR MERCURY AND MERCURY WASTE MANAGEMENT CONCEPT

The urgency of Indonesia for mercury storage capability will depend on the rate of further demand reductions, the extent to which the countries wish to encourage these further demand reductions through supply restrictions, and the extent to which a storage solution is achieved. Even though the net supplies of excess mercury may occur in a relatively small number in these countries, the need of mercury storage still shall be assessed due to the characteristic of the mercury, which is toxic and persistent and non-degradable.

The long-term storage options for the excess mercury that have been evaluated in the various regions as described in the previous section, are summarized as a following:

- Aboveground storage without pre-stabilization (flasked elemental mercury)
- Aboveground storage with pre-stabilization process
- Underground storage in salt or hard rock formation without pre-stabilization (flasked elemental mercury)
- Underground storage in salt or hard rock formation with pre-stabilization process
- Export to other countries having a treatment and disposal facility for elemental mercury

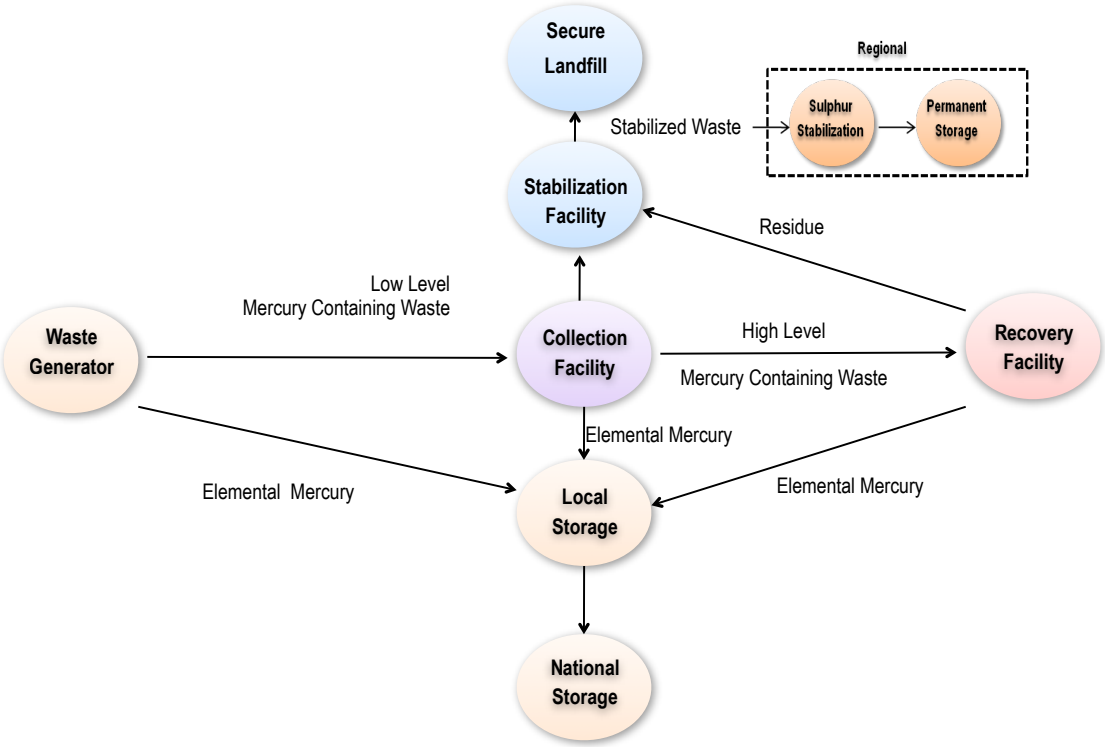
5.1. Possible Option for the Management of Mercury and Mercury Containing Wastes

The factors that influencing the selection of applicable concept for mercury and mercury containing waste management (including long-term mercury storage) in Indonesia are that the following facts:

- Legal frameworks for general hazardous waste management are already in place and relatively adequate, including obligation and requirements for collection, temporary storage, treatment, disposal –except regulations specific to the mercury management.
- Licensed stabilization plants are available for mercury containing waste in Indonesia – except for the high level mercury containing wastes (and mercury recovery plants)
- Obligation to have a proper and licensed temporary storage is implemented for every industries generating hazardous waste.
- For developing countries, cost associated with the mercury storage is a crucial factor to ensure the successful implementation of the plan.

Considering the above factors, the possible option for the management of elemental mercury and mercury containing wastes, is described in the chart as sown below.

Figure 12. Concept for Environmentally Sound Management of Mercury Waste



The recommended option for the environmentally sound management of the mercury consists of the following stages:

- Elemental mercury and/or mercury containing waste are temporarily stored at the generator's site. The temporary storage shall meet the regulatory requirements and secure a permit. At this stage, elemental mercury is already containerized in 76-lb Mercury Flasks, as to ensure the safety during storage and further transportation to the Collection Facility.
- Transportation of mercury and mercury containing waste to the existing Collection Facility within the country
- At the Collection Facility, elemental mercury in flasks are segregated from other wastes, such as low level mercury containing waste and high level mercury containing waste (including mercury containing devices, such as thermometers, switches, etc). Note that definitions of low level and high level mercury content must be established.
- Transportation of elemental mercury to the Local Mercury Temporary Storage (LMTS) located in the region within the country, transportation of low level mercury containing waste to the stabilization treatment facility, and transportation high level mercury containing waste to mercury recovery facility

- Low level mercury containing waste is stabilized in the Stabilization treatment facility and further disposed off into a secure landfill. The criteria for the stabilized mercury containing waste adopt the existing TCLP regulatory limits
- Elemental mercury recovered from high level mercury containing waste by the Recovery Facility is transported to the Local Mercury Temporary Storage (LMTS) within the country.
- Elemental mercury from various regional Temporary Storages within the country is transported to the National Mercury Storage (NMS) for long-term storage.

It shall be noted that it does not necessary each facility to be a standalone site. The facilities can be at the same vicinity, depending on several factors, such as: geographic, economic, quantity generated, and other factors. In addition, due to the small quantity of collected waste, it does not necessary that LMTS be only dedicated for elemental mercury. Instead, it can also be used to temporary stored other hazardous wastes, as long as safe and proper segregation are implemented.

While the mercury recovery facilities currently un-available in the countries, it is proposed that the high level mercury containing waste be exported to the country having such facility, to bridge the gap until recovery plants are available within the countries.

5.2. Screening Options for Long-Term Storage of Excess Mercury

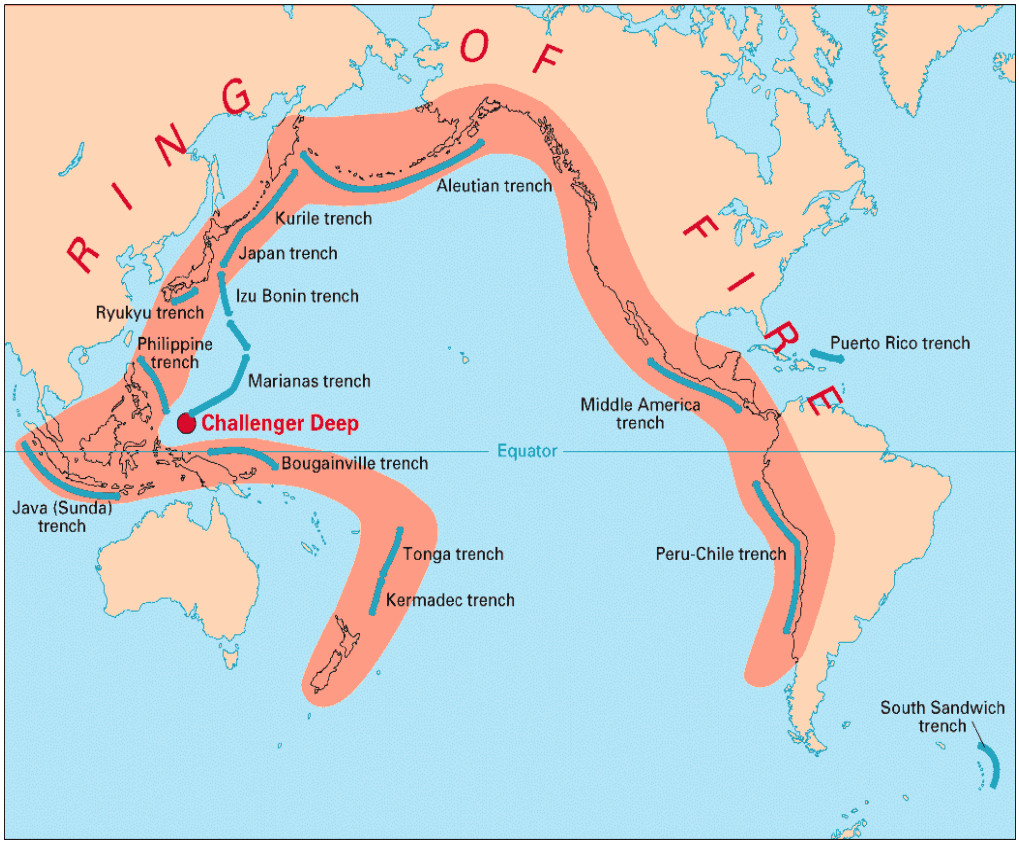
5.2.1. Evaluation of Options for Underground Storage

Indonesia lies in Pacific basin that are very susceptible to natural disasters, such as: volcanic eruptions, earthquakes, flooding and tropical storms or hurricanes. Geologically, Indonesia is located in a very unstable area known as “Pacific Ring of Fire”, where a large number of earthquakes and volcanic eruptions occur. “Ring of Fire” is a ring of volcanoes around the Pacific Ocean that result from subduction of oceanic plates lighter continental plates, as shown in the Figure 13.

In addition, the tectonic and volcanic earthquakes occurred in this region are sometime followed by major tsunamis. Due to this geological concern, design and construction of underground storage will need highly engineering standard and technology in order to tackle these natural hazards, that eventually implies to the capital cost.

Underground storage for elemental mercury is principally intended to isolate the mercury from the biosphere in geological formations, which is expected to remain stable over a very long time. For this purpose, salt mines have been extensively used for several decades in Europe, especially in Germany (BiPRO, 2010). The choice of salt rock formation is considered because it is practically impermeable and, along with overlying and underlying impermeable clay strata, provides a geological barrier. Based on the available geological information, salt rock formations are rarely available in Indonesia.

Figure 13. Pacific Ring of Fire



Source: USGS, 2012[5]

The alternative geological formation that provides equal level of safety and confinement to salt mines is an underground deep rock formation, which could reach several hundred meter depth. Hard rock formations are less impermeable against gas and liquids than salt rock, particularly due to possible fractures in the rock body. In the case of liquid mercury, the long-term safety of these barriers cannot be guaranteed and thus mercury entering the biosphere cant not be completed prevented in particular in case of liquid mercury with its higher solubility compared to stabilised waste (BiPRO, 2010).

Related to Indonesia situation, almost all mining activities are open-pit mining for several decades. Although Indonesia has enacted Law No. 41/1999, which prohibit open-pit mining, this ban is merely intended for the protected forestry. Hence, the availability of underground hard rock formations for the long-term storage in Indonesia is still perplexed and needs further evaluation. Therefore, the technical minimum requirement "equal level of safety and confinement to those of salt mines" cannot be fulfilled for this option.

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[5] *USGS. Earthquake Hazard Program. [Online] 07 18, 2012. [Cited: 08 14, 2012.] http://pubs.usgs.gov/gip/dynamic/fire.html.*

In summary, considering the above conditions, the viability of underground storage option for Indonesia is rather quizzical, and needs further extensive technical and legal evaluations. These are due to:

- Availability of abandoned salt mining or suitable and safe underground deep rock mines
- Geological condition and the present of potential natural disasters, which could lead to safety issues as well as high engineering and construction costs.

5.2.2. Evaluation of Options for the Aboveground Storage

The aboveground storage for elemental mercury is based on experience from the temporary storage of liquid mercury in the US, which stores and handles significant quantities of mercury for more than 40 years. The concept of mercury storage implemented by DNSC is:

- Safe containerizing and placement
- Technical and safety measures(flooring, containment, fire protection)
- Organizational safety measures (monitoring, inspection, security)

The containment of the elemental mercury is in particularly important for the temporary storage of liquid mercury as it has to ensure a safe storage for a certain period of time. For long-term storage, the major function of the container is to ensure a safe handling of the waste before and during storage.

Based on its long experiences and proven approach, constructing and operating an aboveground storage for excess mercury using US concept is the most feasible option for Indonesia. In addition, the basis of regularory framework and infrasturcture for hazardous waste management is in place in both countries, such that filling the gaps of these aspect will not pose significant issues. Use of existing hazardous waste storage for regional or national scopes, or selecting the suitable location for building new dedicated storage will not be crucial issue in Indonesia. The issues for the aboveground storage of mercury in elemental form, that must be taken into account during the criteria assessment are as follow:

- the excess mercury still remains in the biophere in elemental form that is susceptible for unexpected incident in the future
- un-authorized acces to the stored elememercury or theft that may lead into subsequence illegal re-use or black market.
- recurring cost for re-flasking and re-drumming

However, the aboveground storage is the most favorable option for middle term solution, at least until 2050 or longer. After this period, stabilization of elemental mercury could be implemented for further permanent storage in the country or in a centralized permanent storage in the Southeast Asian or the Asian region. Establishing proper criteria for site sitting and storage requirements are very important to tackle the above drawbacks.

6. ASSESSMENT FOR ABOVEGROUND MERCURY STORAGE

6.1. Objective and Principle of Mercury Storage

It has been identified by the recent studies that mercury supply may exceed regional demand for acceptable applications in many regions of the world, including in the countries of Indonesia. Mercury Assessment for the Philippines (DENR, 2008) reveals that the sources of mercury are mainly from: Primary Virgin Metal Production, Extraction and use of Fuel and Energy Resources, Other intentional use-thermometer etc., Wastewater, and Consumer products with intentional use of mercury. For intentional use, elemental mercury enters to the domestic market through either importation from other countries or recycled from wastes/by-products.

With the progressing implementations of cleaner technologies for industry worldwide and substitution of toxic substances in consumer products, the need for mercury will be reducing accordingly. When it becomes available but there is no use for it, elemental mercury and mercury compounds shall be removed from the market by placing them in secure storage or secure disposal, as to prevent further use of the mercury. The mercury storage and disposal shall be carried out in environmentally sound manner as to prevent the mercury from being released into the environment.

Hagemann (2011) proposed that the environmentally sound storage and disposal of excess mercury be conducted by adopting the principles as originally developed by International Atomic Energy Agency (IAEA) for nuclear waste management. These principles are:

- Protection of human health: Elemental mercury and mercury waste shall be managed in such a way as to secure an acceptable level of protection for human health.
- Protection of the environment: Elemental mercury and mercury waste shall be managed in such a way as to provide an acceptable level of protection of the environment.
- Protection beyond national borders: Elemental mercury and mercury waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.
- Protection of future generations: Elemental mercury and mercury waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.
- Burdens on future generations: Elemental mercury and mercury waste shall be managed in such a way that they will not impose undue burdens on future generations.
- National legal framework: Elemental mercury and mercury waste shall be managed within an appropriate national legal framework, including clear allocation of responsibilities and provision for independent regulatory functions.

- Control of mercury waste generation: Generation of mercury waste shall be kept to the minimum practicable.
- Mercury waste generation and management interdependencies: Interdependencies among all steps in mercury waste generation and management shall be appropriately taken into account.
- Safety of facilities: The safety of facilities for elemental mercury and mercury waste management shall be appropriately assured during their lifetime.

6.2. Public and Stakeholders Participation

Public and stakeholders participation in the decision process for site selection of the mercury storage will be required during environmental impact assessment (AMDAL) prior to building the new facility. Although all aspects of developing and operating the storage facility has been conducted in close scrutiny, nothing seems to raise as much opposition as sitting a new facility ("Not In My Back Yard"). It is not sufficient to merely have adequate measures and expect public trust. To build confidence and trust, the public and stakeholders should be involved in making decisions on issues perceived as having significant impact to their future.

Public and stakeholders involvement is a political art but considered as one of the important component of a consultation process. In some cases, technical information conveyed to the public may be confusing or even counterproductive. Conducting meaningful public and stakeholders participation involves seeking their inputs on specific issues, which have real potential to shape the final decision of site sitting. A toolkit developed by USEPA and US Department of Energy that can be used for public participation or public/stakeholders involvement reference during the environmental impact assessment process of the development of long-term management and storage of elemental mercury, includes the following:

- informing the public and stakeholders by providing information to help them understand the issues, options, and solutions
- consulting with the public to obtain their feedback on alternatives or decisions
- involving the public to ensure their concerns are considered throughout the decision process, particularly in the development of decision criteria and options
- collaborating with public to develop decision criteria and alternatives and identify the preferred solution
- empowering the public by placing final decision-making authority in their hands.

For hazardous waste treatment, storage and disposal (TSD), US-EPA issued "The Resource Conservation and Recovery Act (RCRA) Public Participation Manual", which explains how public participation works in the RCRA permitting, and how citizens, regulators, and industry can cooperate to make it work better (US EPA, 1996).

In Indonesia, requirement for having public participation is required by the Law No. 32/2009 and Government Regulation No.27/2012 as pre-requisition of the entity for getting an environmental permit.

6.3. Site Sitting

Site sitting is commonly referred to as the process of selecting site for a new facility and obtaining required permits for it. The main objective of site sitting is to assure that the mercury storage facility is located at intrinsically superior site that, by advantage of their natural features and land use setting, provides a high degree of protection to public health and the environment. The land use setting and natural features function as an additional line of defense, if the facility operation does not perform as planned (LaGrega et.al, 1994).

To start with, location for the mercury storage facility must conform to the local, regional and national spatial plans that zoning the regions based on their functions. The spatial plan classifies the land use into two main zones, that are protected zone and exploitation zone. Further, exploitation zone is sub-categorized into several zones, such as forestry, agricultural, housing, and industrial zones. In Indonesia, the facility can only be sited within the industrial zone or industrial estate.

In addition to above utmost requirement, the storage facility shall also consider other technical requirements such as geology/hydro-geology, natural hazards, soil characteristic, accessibility, climate, and other factors, which are described in the following subsections.

6.3.1. Site Location

The mercury storage location shall be away from other facilities, which susceptible to fire incident such as storage of explosive materials and fuels, and susceptible to contamination such as human or animal food, and clothing. The mercury storage shall be a standalone facility, where it is not also intended for storing other type wastes or materials.

Referring to the current regulation pertaining to the hazardous waste location (Head of BAPEDAL Decree No. Kep-01/BAPEDAL/09/1995 regarding Procedures and Technical Requirements for Hazardous Waste Storage and Collection), the location of the storage shall have sufficient distance from the public facilities and certain ecosystems. The minimum distances shall be:

- 50 meters from public facilities
- 150 meters from main roads or highways, 50 meters from other roads.
- 300 meters from public facilities such as housing areas, commercial areas, hospital medical service facilities, hotels restaurants, religious facilities, education facilities.
- 300 meters from waters such as the sea highest tide line, river, ebb fide areas, ponds, lakes, swamps, springs, resident's wells
- 300 meters from protected areas such as nature reserves protected forests.

6.3.2. Geology

Long-term Mercury storage shall be located in the area that geologically stable and capable of providing sufficient geological barriers for the protection groundwater quality. Natural geologic protection refers to the ability of geologic feature such as clay, to retain the mercury contaminant from migration to the aquifer. Geologic assessment for the site sitting will include soil lithology, structure and stability (BiPRO, 2010). The geological map of Indonesia for the screening of the storage location is available at Geology Agency – Department of Energy and Mineral Resources (http://psg.bgl.esdm.go.id/ pameran/index.php?kategori=indeks-peta&halaman=peta-geologi-indonesia&title= Peta%20Geologi%20Indonesia).

6.3.3. Hydrogeology

Although the storage is aboveground, hydrogeological aspect has the same important as the underground storage. Understanding the hydrogeology the proposed mercury storage allows reliable monitoring the storage site. In addition, the hydrogeology information can also be used for the basis of viable contingency measure that needs to be implemented in the case of there is an unexpected contamination of the groundwater. Therefore, installation of monitoring wells shall be based on this hydrogeological assessment.

For the protection of the groundwater, it is recommended that the proposed mercury storage is not located at the important groundwater recharge area, and has a minimum distance of 4 meters from aquifer.

6.3.4. Natural Disaster

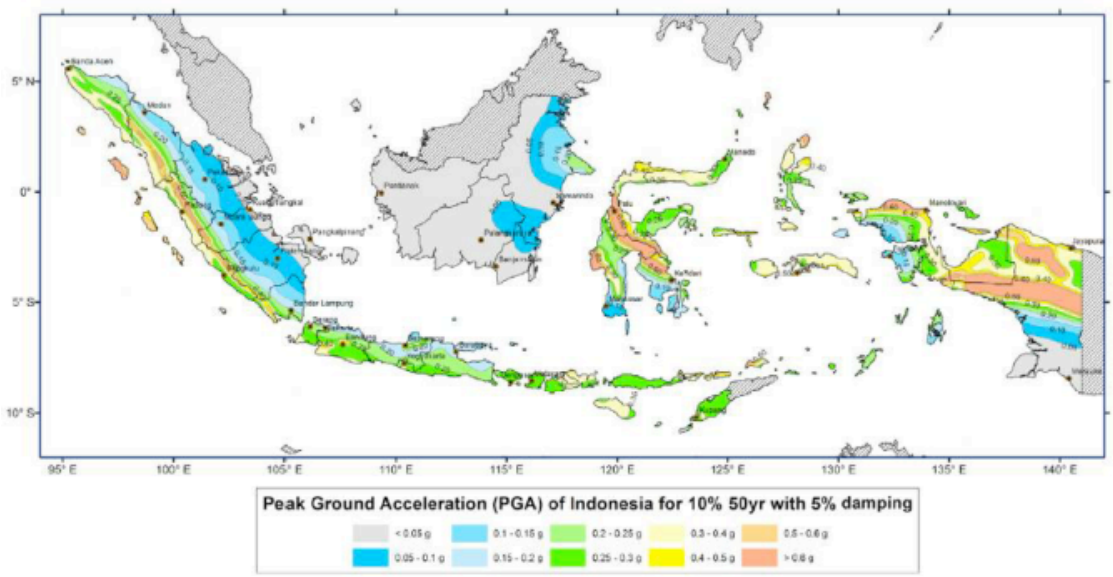
The location of the mercury storage shall be free from or least susceptible to natural hazards, such as the following:

- annual flooding
- volcanic eruptions
- earthquakes
- tsunamis
- storms.

The natural hazards that affect most of the area of Indonesia are earthquakes and floods, with half of the area being exposed to high levels of risk. Volcanic eruptions are relatively frequent, but mostly affect only small areas. Tsunamis and storm surges present moderate levels of risk affecting the least of the area, while tropical storms affect Indonesia only lightly (Hagemann, 2011). Earthquake is the most concern in site selection for establishing the mercury storage, since it may cause collapse or damage of the storage infrastructure. The damage risk to the storage structure can be minimized by selecting the site, which has a low seismic load during ground shaking.

Figure 14 below is the map of Peak Ground Acceleration in Indonesia provided by Masyhur, et al. (2010) that can be used as a guideline for estimating the peak level of earthquake hazard.

Figure 14. Map of Peak Ground Acceleration (PGA) of Indonesia



Source: Mansyhur Irsyam, et al., 2010

The map above shows the earthquake hazard in Indonesia. The colors show the minimum level of ground shaking that scientists expect to see in a 475 year period (Irsyam et al., 2010).

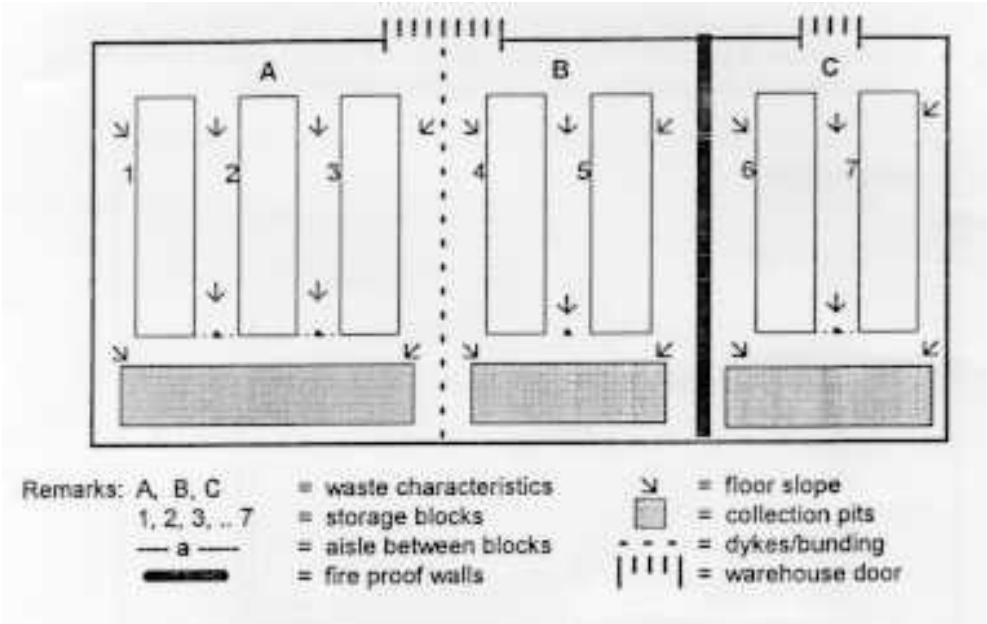
6.4. Storage Building

6.4.1. Layout/Design

The layout of mercury storage shall be designed such that it provides not only safety to personnel and environment, but also ease of handling the stored mercury. Drums of mercury flasks are to be put on pallets and stacked at a maximum of three levels. The drums stacks shall be managed such that provides enough wide of aisles for the passage of inspection personnel, loading/un-loading equipment, and emergency equipment.

The layout of the storage shall also include area for unloading loading/unloading bay at the entrance of the storage. This loading/unloading area is recommended to be located inside the storage building as to provide the same level protection against accidental spiils. Otherwise, similar roofing and containment system shall be implemented when the loading/unlading area is located outside the building.

Figure 15. Storage Lay-Out



Source: Head of BAPEDAL's Decree No.Kep-01/BAPEDAL/09/1995

6.4.2. Roof and Walls

One of the functions of roof and walls is to protect the the building from direct and indirect infiltration of the rain. Materials used for the construction of the roof and walls shall be fire and corrosion resistant, and not readily absorb mercury vapor. The roof shall be designed without ceilings, as to have sufficient air ventilation preventing accumulation of mercury vapor in the storage building.

It is recommended that the walls be fitted with appropriate screens or similar materials to prevent the entry of birds or small animals into the storage.

6.4.3. Floor

The storage building floor shall be made of concrete, that is water proof, flat, strong, and no cracks. Sealing the floor can be achieved by applying epoxy coating on floor surface. The floor and its coating shall be regularly inspected as to ensure that the floor has no cracks and the coating is still intact. The floor inside the building shall be designed with maximum slope 1 % to the direction of collection pits, which functions as secondary containers in case spill accidents. The slope of floor outside the building shall be designed in such a way, so that the rain is directed away from the storage building. It is recommended that the floor be able to withstand 50% more than the total load from the mercury that is being stored. No plumbing is recommended other than sloped floor and dikes, which are intended to collect and contain spills.

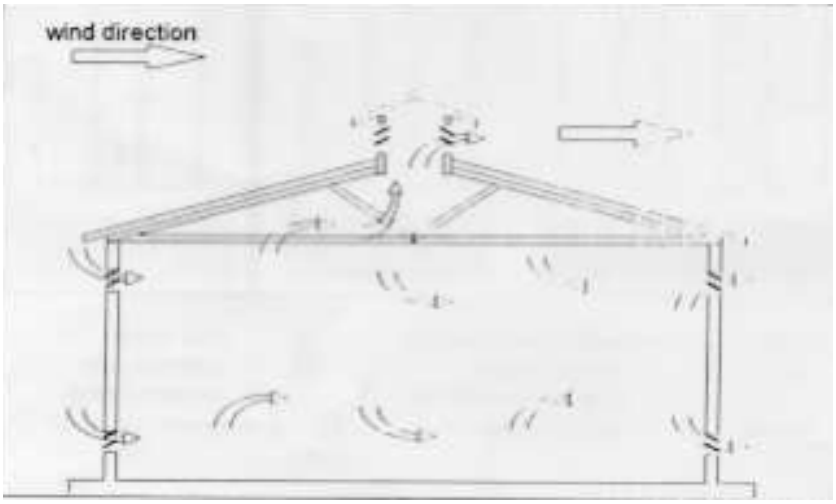
6.4.4. Ventilation

A proper ventilation system of the storage building is intended to prevent mercury vapor build-up in the storage that may pose the risks to the building constuction, endanger the health of the workers as well as surrounding community. Although the proper storage practices such as flasking and overpacking,will minimize the release of mercury vapors, it is recommended to adopt a prudent measures in managing the mercury vapor due to its mobility and toxicity.

In addition, proper ventilation could also prevent heat accumulation in the storage building, which may result in raising temperature on the building, especially in the tropical country like Indonesia. In case of leaks or spills, the mercury tendency to valatilize increases with the temperature elevation. Since maintaining storage at low temperature by using air conditioning units would be very expensive, implemtation of proper ventilation should be a necessity.

Instead of ventilation system, storage facilitymay also a implement negative pressure environment, as to control mercury vapor build up as well as release to the environment. The air is ventilated to the outide atmosphere through a series of filters consisting of sulphur or iodine impregnated activated carbons.

Figure 16. Air Circulation in the Mercury Storage Building



Source: Head of BAPEDAL Decree No. Kep-04/BAPEDAL/09/1995

6.4.5. Secondary Containment System

Secondary containment of the storage building is intended to give an essential line of defense in the event of failures of mercury flasking and overpacking. The system provides an early detection as well as temporary containment in case of mercury spills until the appropriate responses are taken to abate the source of spills. The requirement

of secondary containment is stipulated in the current regulation pertaining to the storage of hazardous waste.

For this purpose, the storage building shall have a sump area located at the lowest elevation of the building and adjacent to the storage walls, servicing as a drain or receptacle for mercury spills. From the sump, the spills are directed into a Collection Pit, constructed beneath the building. The sumps at Collection Pit shall be constructed from concrete or steel and epoxy-lined, and covered with a steel grating for safety purpose.

6.4.6. Name Board and Signs

Clear and visible signs are required to be placed at and around the facility site. These include:

- Perimeter fences: facing outside, the signs reminding the community or other people not to trespass the facility and warn that the facility is a hazardous area.
- Entrance of the storage facility: name board identifying the facility name, operating entity, and address
- Entrance of the storage building: (1) name board identifying the mercury storage building; (2) warning signs stating the hazard of mercury and mercury vapor; (3) instruction signs informing minimum PPE requirements to be worn when entering into the building
- Inside storage building: (1) safety signs; (2) signs indicating the location of emergency equipment such as eye fountains, spill kits, fire extinguishers; (3) emergency exit signs.

All signs is recommended be prepared in accordance with standard format, as required by prevailing regulations or GHS.

6.4.7. Lighting

Sufficient illumination is required to operate the storage facility, including routineinspections and maintenances, in effective and safety manners. Sun illumination is preferred to be applied intensively as to minimize electrical energy consumption, by using transparrent roofings at several spots of the building. Artificial lightings are required during operation, maintenance and inspection at the spots where sun lighting is not available.

6.4.8. Leak Detection

Leak detection is required to allow early detection on the presence of any release of mercury to the environment. This can be done by implementing regular monitoring of ambient air, soil and water (surface water and groundwater). For groundwater monitoring purpose, it is required to install monitoring wells at the strategic locations in the ground near the storage, considering prevailing groundwater flows. The locations and numbers of monitoring well are determined and approved by the authority during EIA/AMDAL process.

6.4.9. Fire Detection and Suppression System

Fire accident must be suppressed to an absolutely minimum, since mercury flasks will rupture and release the mercury, when exposed to a very high temperature. As the vapor pressure of mercury increases at elevated temperatures, release of its vapor will also increase in intensity, such that will create greater hazards. Therefore, intensive prevention of fire accident is highly recommended for the storage facility.

An important component of preventive fire protection is fire detection and alarm system, which can be automatically or manually activated. Temperature, smoke, or flames are quantified for early detection of fires that set off alarm when maximum values are exceeded. The alarm will actuate stationary extinguishing systems and also alert the fire department through a central fire alarm system. Note that the alarm system requires secure power supply and announcing devices such as sirens and flashing lights.

Dry sprinkler type for fire suppression is recommended to be installed inside the storage facility, especially if the building and/or interior furnishing contain combustible components. As preventive measures, it is preferable to construct the storage building using non-combustible materials. In addition, use non-combustible materials for pallets, storage racks, and other interior furnishings to the greatest practical extent.

6.4.10. Weigh Bridge/Weight Scale

Knowing the accurate quantity of the received mercury at the storage facility is very important. Prior to transport to the mercury storage, they may have been weighed at the sender's facility. However, the actual weight of the received load by the facility shall be measured by using either weigh bridge or weigh scale. For weigh measuring purpose, either weigh bridge or weigh scale can be used. For small quantity of receiving load, weigh scale of 2 tons capacity is adequate for weighing 4 drums on pallet at once. Weigh tickets generated from the weigh bridge or weigh scale shall documented and maintained for audit purpose, in addition to the electronic records.

7. REQUIREMENTS FOR THE MERCURY STORAGE MANAGEMENT

7.1. Pre-acceptance Criteria

Pre-acceptance criteria are defined as the requirements for the mercury to be accepted by the storage facility. Any discrepancy to the requirements as set in the pre-acceptance criteria may pose possible risks to the storage facility, workers, and the environment

Mercury Criteria

The proposed acceptance criteria for the mercury for the regional or national storage, are as the following (6):

- The mercury shall be in elemental form, with the purity of ≥99.9 %(w)
- Max. metallic contaminates (like iron, nickel, copper): <20 mg/kg each
- Presence of sodium <1 mg/kg
- No residual radioactivity (specifically from tracers used in the chlor-alkali industry)
- No impurities capable of corroding carbon or stainless steel (e.g. nitric acid solution, chloride salts solutions, or water)

The purity of the liquid mercury to be stored shall be strictly controlled very important, because the impurities may react with carbon or stainless steel of the containers, as well as the containment or storage environment. Mercury purity of 99.5%(w) is still acceptable, but the higher purity of the mercury to be accepted and stored, the lower risk of unforeseeable reactions.

Container/Packaging Criteria

In addition to the mercury to be stored, the pre-acceptance criteria are also applied to the containers and packaging of the mercury, as following:

- Elemental mercury shall be stored in standard 76-lb flasks
- The flasks are placed in metal UN-drum of 200-ltr, with the quantity of 6 flasks/ drum.
- The drums are on standard pallet, with the quantity of 4 drums/pallet
- Drums shall be clearly labeled

Proposed standards for packaging, container, pallet, and labeling are described in the following section.

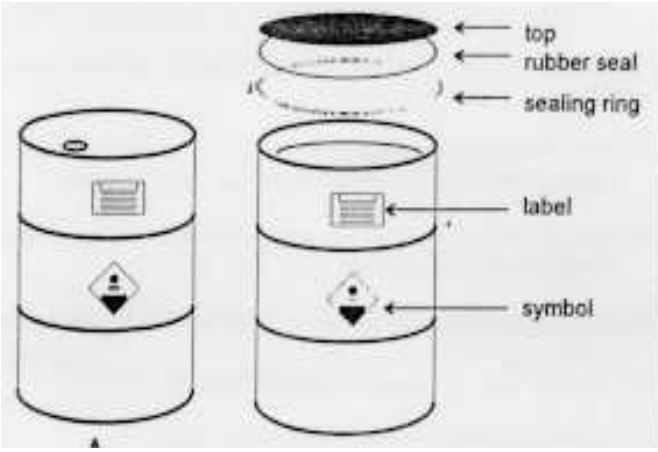
7.2. Containerizing and Packaging

In Indonesia, there are no specific regulations pertaining to the requirements for elemental mercury and mercury-containing wastes packaging. Government Regulation No. 74/2001 regarding the Hazardous Material Management classifies mercury and mercury compounds as ‘Hazardous Materials for Limited Uses”. However, specific requirements are not stipulated in this regulation.

Government Regulation of Republic of Indonesia No.18/1999 regarding Hazardous Waste Management classifies mercury and mercury containing wastes as hazardous wastes, and as a consequence, the management of the mercury and mercury containing wastes shall comply with the prevailing regulations related to the hazardous waste management. The available regulation related to the packaging and handling of the hazardous waste is Head of BAPEDAL's Decree No. Kep-01/BAPEDAL/09/1995 regarding Procedures and Requirements for the Storage and Collection of Hazardous Waste. Summary of the requirements for the hazardous waste packaging is as following:

- Packaging for hazardous and toxic waste shall be in good condition, undamaged, and free from corrosion and leakage.
- The shape, size, and material for hazardous waste packaging shall be appropriate to the hazardous characteristics with due regard to safety and ease of handling
- The container/package can be made of plastic (HDPE, PP, PVC or teflon), metal (carbon steel SS304, SS316, or SS440).
- Packaging material used shall not react with hazardous waste, of which it is containerized
- The packaging shall be designed to account for the possibility of waste expansion, gas formation, or pressure increase as to prevent risks during storage
- Containers shall be equipped with a strong lid to prevent spills during transfer or transport (refer to Figure 17)
- Wastes can be packaged in drums/casks of 50 liter, 100 liter or 200 liter capacities.
- Each package shall contain only one type of waste or have only types of wastes with similar or mutually compatible characteristics

Figure 17. Packages for Hazardous and toxic waste storage:
(a) drum for liquid hazardous waste; (b) drum for sludge or solid hazardous waste.



(a) drum for liquid hazardous wastes

(b) drum for sludge or solid hazardous wastes

Source: Head of BAPEDAL's Decree No. Kep-01/BAPEDAL/09/1995

Flasks

There are 2 (two) main types of containers commonly used for storage and shipping of elemental mercury in global market, that are 76-lb flasks and 1-MT containers. For sturdiness and corrosion resistance, these containers are typically made of cast iron or carbon stainless steel, because the mercury dissolves with several metals to form amalgams, except iron. Seamless flasks and containers are recommended in order to eliminate the risk of mercury breaches through the seams.

Figure 18. 76-lb Mercury Flasks

For ease of handling during collection and transportation, use of 76-lb mercury flasks is preferred, rather than 1-MT containers. This also gives flexibility in the quantity of the mercury to be collected and transported. When storing mercury in either type of container, some head space shall remain in each container to allow for thermal expansion of mercury (US-EPA, 2003). It is recommended that 15 to 20% head space is allowed

UN-Approved Steel Drums

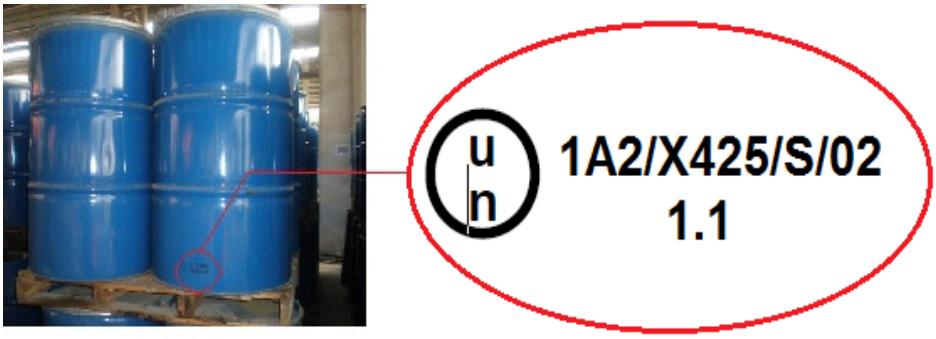
For mercury containing waste or mixed waste, use of 200-liter steel drums is recommended. Depending on the physical form of the waste, the drums can be open head or tight head openings. The former is commonly used for solid or semi solid waste, while the later is liquid waste. Steel drum will also be required for overpacking the mercury flasks, with the purpose of providing a secondary containment. Flask overpacking will also provide safe stacking during storage, as well appropriate packaging during land or sea transportations.

US Department of Transportation (DOT) classifies the elemental mercury as hazardous material, so that it shall be packaged in accordance with the DOT regulations.

Referring to the 49 CFR 172.101[6], the mercury shall be packaged in a container meeting the requirements of packaging group III, which is a list of approved container and liner combinations.

Although not legally binding on individual countries, "the United Nations Recommendations on the Transport of Dangerous Goods' can also be used as guideline in setting specifications for steel drums used for mercury packaging (UNECE, 2011).The UN Recommendations specify the packaging requirements for dangerous goods, including types of packaging, marking and testing. Steel drums used for mercury packaging shall be pre-tested and permanently marked conforming to this UN's requirement.

Figure 19. Standard Marking on UN-approved drums
Where 1 = Drum; A=Steel; 2=Open Head; X=Packing Group Level Tested;
425=Maximum Gross Mass (kg); S=Solid; 02=Year of Manufacture;
1.1=Nominal Steel Thickness (Head/Body/Bottom)



7.3. Container Handling

As stated previously, there are no specific regulations in Indonesia pertaining to the mercury handling. As a technical guideline, Head of BAPEDAL's Decree No. Kep-01/ BAPEDAL/09/1995 regarding Procedures and Requirements for the Storage and Collection of Hazardous Waste, can be used as a general guideline for handling mercury wastes in Indonesia. The summary of the regulation related to the container handling is as following:

- Entities collecting/storing hazardous waste shall be aware of the hazardous characteristic of their waste stored.
- Containers or packaging of the hazardous waste shall be marked with symbol and label, and stored pursuant to BAPEDAL's requirements.
- the containers can be reused provided that the waste to be stored is the same type or is compatible with the previous waste.

[6] *Electronic Code of Regulation, National Archives and Records Administration, 2012. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl.*

- if the hazardous waste packages/containers have deteriorated due to corrosion, stiffer permanent physical damage, or leakages are evident, the waste shall be repackaged.

7.3.1. Re-containerizing/Repacking

Entities delivering the mercury or mercury containing wastes, shall be encouraged to transport their mercury waste in storage grade containers, as to minimize the need for re-packing/re-containerizing of the waste, as well as its associated risks during transportation. It is preferable that the mercury wastes delivered to the storage facility are in ready-to-store containers. If mercury arrives in other types of containers, they should be repackaged into either the 76-lb flasks or the one metric ton containers.

Re-packing/re-containerizing of mercury at the storage facility must be conducted in a dedicated re-packing area. When transferring the mercury from the old containers, new empty flasks shall be placed on a secondary containment pan, as to control spills and prevent floor contaminations. Mechanical devices for lifting and pouring the mercury should be available for this purpose. It shall be noted that repacking/re-containerizing elemental mercury poses higher risk and hazard than mixed wastes or mercury containing wastes. In addition to fully trained personnel, provisions of protective equipment and proper air ventilation are required as to minimize exposure to the mercury.

7.3.2. Flask Overpacking

Overpack is intended to provide a secondary containment for the mercury flasks. One of the options for this overpacking purpose is by placing the flasks into 200-liter, open-head, UN-approved drum. The proposed overpacking procedure is as following:

- Place on pallet a new open-head UN-approved drum
- Put an inner liner of plastic bag into the drum
- Place a cushioning material, which also functions as an absorbent mat at the bottom of the drum.
- Put the mercury flasks into the drum. One drum can be filled with 6 (six) 76-lb flasks, giving the total weight of approx. 480 lbs including the weight of flasks.
- Insert tightly sponge rubber or cardboard dividers between the flasks, as well as between flasks and inner body of the drum.
- Tight up the inner plastic bag and put the drum lid.
- Place the locking ring and tight its bolts.

Figure 20. Mercury Flasks Overpacking in 200-ltr UN-approved Drum

Source: PT PPLI and DNSC

7.3.3. Palleting and Strapping

For ease of handling and safety purpose, the drums shall be placed on pallet and strapped during handling, storage, and transport. The following discussion describes evaluation on options for mercury drums palleting and strapping.

<u>Palleting</u>

Various materials of pallets are available on the markets, including steel, aluminum, plastic, and wood. Selection of the pallet material is an important factor, due to the following reasons:

- Together with the mercury containers or drums, the pallets may be transported across national borders, where the receiving country may implement specific requirements for the pallet materials
- The pallets will be used for a long term in the storage (20-30 years)

The International Plant Protection Convention (IPPC) requires that pallets shipped across national border shall be made of materials that are incapable of being a carrier of invasive species of insects and plant diseases. The standard requirements for wooden pallets are specified in the International Standards for Phytosanitary Measures No.15 (ISPM-15) (ISPM, 2006). Indonesia has adopted the ISPM-15 through Ministry of Agriculture Regulation No. 12 Year 2009 regarding Requirements and Procedures for Plant Quarantine on Wood Importing into Indonesian Territory.

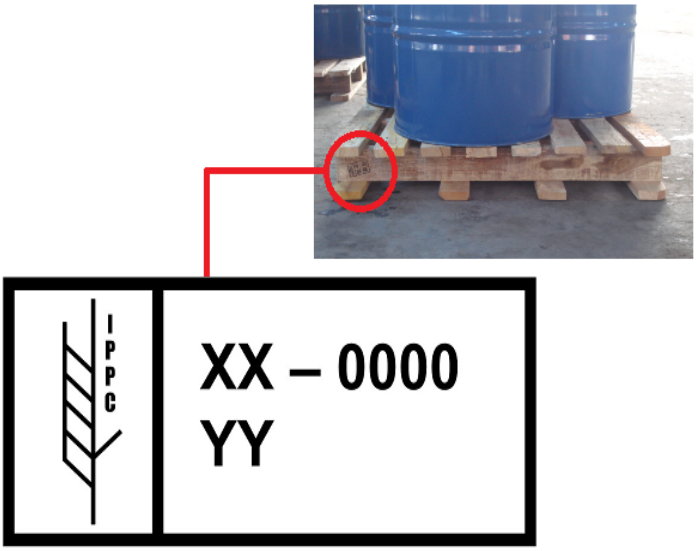
Wooden pallets complying with the ISPM-15 bear the IPPC logo, which stamped to the pallet. In order to the comply with this regulation, the wood must be treated by either of the following methods under supervision of an licensed agency:

- Heat treatment:
  The wood is heated to a temperature of minimum 56°C for at least 30 minutes. Pallets treated via this method bear the initials HT next the IPPC logo.

- Chemical fumigation

  The wood must be fumigated with methyl bromide. Pallets treated via this method bear the initials MB next to the IPPC logo.

Figure 21 Standard Marking on IPPC-approved Pallets
Where “XX”=ISO two-letter Country Code; “0000”=Producer Unique Code;
“YY”=Type of Treatment (HT or MB)



It shall be noted, that pallets made of non-wood materials such as steel, aluminum, plastic, or wood based products (such as: plywood or fiberboard)are exempted from this ISPM-15 regulations.

For the pallets used during the interim or long term mercury storage, pallets made of durable, corrosion-resistance material are recommended, such as HDPE, steel or aluminum. The recommended dimension of pallet is 120 x 120 x 15 (cm), that will suit 4 (four) 200-ltr UN-approved drums per pallet. When the drums are to be shipped from one location to another, pallets with this standard dimension will also securely fit the space of 20-ft dry container, with the capacity of 40 drums (one layer) or 80 drums (double stacked).

7.3.4. Strapping/Banding

Strapping or banding is intended to secure the drums on pallet, preventing them from being shifted or falling down during storage or transport. Steel or plastic straps can be used for the mercury storage purpose, although the steel material is more preferred. In addition to the strapping/banding, wrapping the entire drums and pallet may also be required using a plastic wrapping sheet.

Figure 22. Drums Strapping and Wrapping

Drum strapping

Drum wrapping

Photo: Courtesy of PT PPLI

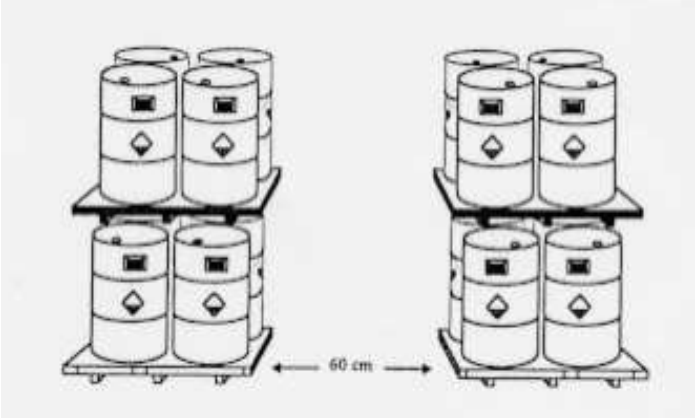
7.4. Container Handling

Technical guideline for hazardous waste management in relate to its container handling is stipulated in the Head of BAPEDAL's Decree No. Kep-01/BAPEDAL/09/1995. This minimum requirement shall also be implemented for handling of mercury containers, as summarized below:

- Packages containing hazardous waste shall be marked with a symbol and label complying with the provisions regarding markings for hazardous waste packages;
- The packages shall be subjected to inspections by the person responsible for the hazardous waste storage facility, to ensure that the package is not damaged or leaking due to corrosion or other factors.
- A package that has been led with hazardous waste shall be marked with a symbol and label complying with the provisions regarding markings for hazardous waste packaging.
- Waste package/containers shall always be tightly capped and only opened for adding or removing wastes;

- Waste package/containers shall be stored in a place meeting the requirements and procedures for hazardous waste storage.
- Spills or leaks of hazardous waste shall be cleaned up and the materials repackaged in suitable containers.
- If an empty container is to be reused to pack hazardous waste with the same characteristic, they shall be stored with similar hazardous materials. If they will be used to store hazardous waste having incompatible characteristic with the previous hazardous waste, the packages shall be first cleaned and labeled "EMPTY" pursuant to provisions regarding marking of hazardous and toxic waste packages.
- Damaged containers that cannot be reused shall be treated as hazardous waste.
- Containers may be stored in stacks as shown in Figure - 21 to facilitate inspection and action if there is an accident or damage.
- The width of the aisle between stacks shall be adequate for the purpose. The minimum aisle width for people shall be 60 cm and the minimum aisle width for the vehicles (forklift) traffic shall suit their operational requirements

Figure 23. Distance Between Stack is 60 cm min Providing Aisle for Inspection



Source: Head of BAPEDAL Decree No.Kep-04/BAPEDAL/09/1995

- The stability of packages piles shall be taken into consideration when stacking the hazardous and toxic waste containers. For metal drums (200 liter capacity), the maximum height stack shall be 3 (three) pallets, where each pallet supporting 4 drums. If more than 3 (three) layers high or the containers are plastic, racks shall be used as shown in the Figure 24 below.

- The distances from the top container stack and the outermost containers to the roof and walls of storage building respectively shall be minimum of 1(one) meter.

Figure 24. Drum Stacking and Distance Between Stacks

Source: Head of BAPEDAL Decree No.Kep-04/BAPEDAL/09/1995

7.5. Label and Symbol

The mercury drums or containers shall be properly labeled as part of hazard communication. Current legislations in Indonesia related to label and symbol for hazardous materials and hazardous wastes, are set by several departments. These prevailing regulations are:

- Ministry of Environment Regulation No.03 Year 2008 regarding Procedures for Application of Symbol and Label for Hazardous Materials
- Head of BAPEDAL's Decree No. Kep-05/BAPEDAL/09/1995 regarding Hazardous Waste Symbol and Label
- Decree of General Directorate for Land Transportation No. 725/AJ/DRJD/2004 regarding Road Transportation of Dangerous Goods

In fact, Indonesia differentiates the format of label and symbol between dangerous goods and hazardous wastes. In principle, the symbol requirement for dangerous goods transportation implemented by the Ministry of Transportation, is adopted from United Nation-Transport of Dangerous Goods (UN-TDG). Meanwhile, symbols for

hazardous materials adopted by Ministry of Environment, refer to the Globally Harmonized System (GHS). For hazardous waste, Ministry of Environment implements specific symbol and label for communicating its hazard. The figure below shows the example of symbols based on each regulation.

Figure 25. Label Format for Dangerous Goods and Hazardous Wastes

1	2	3
		

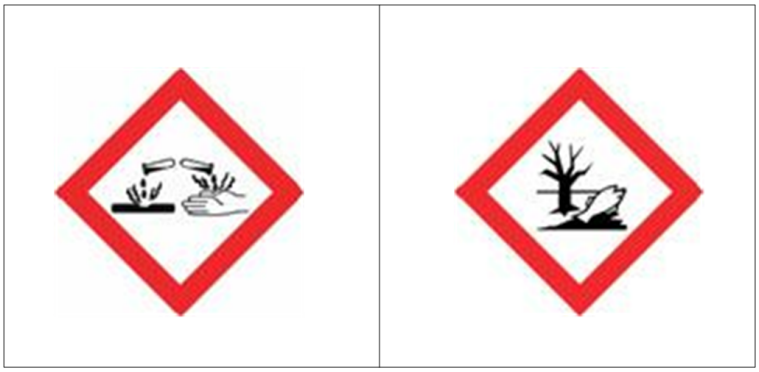
(1) Decree of General Directorate for Land Transportation No. 725/AJ/DRJD/2004; (2) Ministry of Environment Regulation No.03 Year 2008; (3) Head of BAPEDAL's Decree No. Kep-05/ BAPEDAL/09/1995

"Globally Harmonized System (GHS) of Classification and Labeling of Chemicals" (32), addresses classification of chemicals by types of hazard and proposes harmonized hazard communication elements, including labels and safety data sheets. The objective of the system is to ensure that information on physical hazards and toxicity from chemicals is available, to protect the human health and its environment during handling, transport and use of these chemicals. The GHS also provides a basis for harmonization of rules and regulations on chemicals at national, regional and worldwide level, an important factor also for trade facilitation.

Indonesia, as a member of APEC who has agreed to implement the GHS within its countries, has been appointed to become a pilot project for the implementation of GHS in Asia-Pacific, especially for the ASEAN region. The current legal situation in Indonesia, is that the final draft of the Presidential Decree is being reviewed by the Ministry of Law and Human Rights. Once the decree issued to enforce, all current legislations shall be revised to conform the Presidential Decree.

For the purpose of the mercury storage, it is recommended that the GHS be used for the implementation of the symbol and label in its hazard communication. For elemental mercury, the Figure 26 below is a proposed pictogram, which shall be put on every mercury container/packaging.

Figure 26. Symbols used for Mercury Container/Packaging



Note that an additional symbol of marine pollutant may also be required, when the mercury needs to shipped by sea transportation.

In addition to the hazard symbol (or 'pictogram'), the label for the mercury container shall also contain information on the following:

- Signal Words, such as "Danger" or "Warning" to emphasize hazards and indicate the relative level of severity of the hazard
- Hazard Statements, phrases that describe the nature of the hazard, including: precaution, storage, response, and disposal method.

7.6. Personal Protective Equipment (PPE)

Personnel working in the mercury storage, especially those who directly handling the mercury re-containerizing, will have a potential risk to being exposed into the mercury vapor. Exposure for the extended periods poses a health hazard, which must be controlled and minimized. Therefore, during working in the storage area, the personnel shall be equipped with appropriate Personal Protective Equipment (PPE). In general, hazard assessment shall be conducted prior to determining the type of PPE to be used by the personnel.

A typical PPE required for the personnel working at the mercury storage facility are:

- Body Suit/Coveralls
- Safety hat
- Safety shoes
- Half-face respirator, with mercury cartridge
- Gloves, nitrile material
- Safety goggles or glasses with side shields

Respirator cartridges have a life-time period, depending on usage period and the mercury concentration in the airborne. The cartridges shall be replaced before they get saturated, as directed by the manufacturer's recommendation. In general, the PPE shall be:

- properly assessed before use to ensure its suitability with the posed hazard;
- provided with instructions and training on how to use it safely;
- worn in proper manner.
- maintained and stored properly;
- replaced when it is getting worn or damage

All PPE shall remain in the workplace area after working hours, and workers are prohibited of getting the PPE out of the mercury storage. It is recommended that before going home, the personnel getting a shower at the facility.

All of the PPE used must meet the standard type and government's requirements. Used PPE shall be discarded and handled as hazardous wastes. Disposal of used PPE shall comply with the Regulation of the Government of the Republic of Indonesia No. 18 Year 1999 regarding Hazardous Waste Management.

7.7. Environmental Monitoring

Prior to establishment of the mercury storage project, an Environmental Impact Assessment (called AMDAL) must be carried out and approved by the Ministry of Environment. Environmental Management Plan and Environmental Monitoring Plan (RKL/RPL) is a document, which shall be established and approved following the AMDAL approval. The RKL/RPL detailed describes how the environment impact is controlled and monitored. The document also specifies the monitoring methods as well as their criteria for compliance, based on the prevailing regulations.

For the mercury storage activity, impacts to the air, soil and water would be the main concerns. The following subsections describe typical environmental monitoring, which shall be conducted by the storage operator.

7.7.1. Indoor Air Monitoring

At normal air temperatures elemental mercury evaporates slowly. Mercury vapors are heavier than air and tend to remain near the floor or source, but as the temperature rises and as the mercury is disturbed, more vapors can become airborne. Outdoors, mercury vapors tend to go away quickly, but indoors (particularly in poor ventilated storage), mercury vapors will accumulate in the air (Hagemann, 2011). Air monitoring program can be used as a tool to detect possible leaks during normal and extraordinary events. In addition, the program can also be used to measure the exposure of mercury to the personnel dealing with the mercury handling and storage.

The air quality measurements shall be conducted by trained and qualified personnel, in order to get an accurate and reliable data. Any monitoring results above regulatory

levels should be verified and documented. In addition, the source of the emissions should be investigated, and remedial actions should be taken.

Detecting personnel exposure to the mercury vapor can be performed in two method of sampling, i.e. passive and active air samplings. Passive sampling uses a principle of controlled diffusion into a diffusion badge, whereas active sampling involves drawing a known volume of air through a solid sorbent tube using a portable pump. In Indonesia, the active sampling has been widely used, whereas mercury vapor enters the sorbent tube by positive, controlled diffusion, whereas a known sample volume is taken for a given period of time. The sorbent tube is then delivered to an accredited laboratory, for further analysis using Cold Vapor - Atomic Absorption Spectrophotomer. This method measures worker exposure levels as a Time-Weighted Average (TWA) and allows the positive analysis of the airborne mercury (HSE, 2002).

The Threshold Limit Value (TLV) for the mercury is regulated through Circulation Letter of the Minister of Manpower No. SE-01/MEN/1997 regarding Threshold Limit Value for Airborne Chemicals in the Workplace. This regulation has also been adopted into Indonesian National Standard (SNI) under Code No. 19-0323-2005. Below are the TLV values for mercury and mercury compounds, according to these regulations.

Table 3. Threshold Limit Value for Mercury and Mercury Compounds in the Workspace

Chemicals	Threshold Limit Value (TLV)* mg/m3
Elemental and inorganic Mercury	0.025
Alkyl compounds of Mercury	0.01
Aryl compounds of Mercury	0.1
**) Note: time weighted average (TWA) over 8 hour day and 40 hour week*	

Source: Circulation Letter of the Minister of Manpower No. SE-01/MEN/1997 regarding Threshold Limit Value for Airborne Chemicals in the Workplace

Note that the regulation, in addition to the individual TLV, also introduces the term of “Mix TLV”, which takes into account mutual effects resulted from more than one chemicals. Detailed procedure in calculating the Mix TLV is provided in the regulation.

7.7.2. Monitoring Frequency and Schedule

In general, the air monitoring frequency and schedule shall follow the UKL/UPL document approved for the facility. This is a minimum requirement and becomes a mandatory for government reporting purpose. However, the facility may develop its own monitoring plan, considering the hazard evaluation results specific to the mercury storage facility.

- Continuous monitoring:
  It is recommended that all personnel working in the storage area to wear a personal colorimetric badge during their working hours. This is a screening measure that

gives a direct reading of the TWA exposure by comparing the color with the manufacturer provided chart. If the monitoring result indicates that the exposure level close to or above the regulatory limit, re-monitoring is required using tube and pump method, as to verify and quantify the result obtained from the diffusion badge.

- Weekly Monitoring:
  Weekly monitoring is a spot-check measurements performed within the storage facility. For this monitoring purpose, use of a portable mercury analyzer is recommended. It shall be noted that the equipment shall be properly calibrated following its manufacturer's instructions. Details of the calibrations shall be recorded and maintained properly.

- Quarterly monitoring:
  Quarterly monitoring is a spot-check measurements, which is conducted at random locations within the storage facility. It is recommended that the measurement be conducted using active sampling method, where the mercury vapor entering either passive or active device is collected on a solid sorbent (Hydrar® or hopcalite) which has an irreversible affinity for mercury (36). After sample collection the sorbent is initially dissolved with concentrated nitric acid and then hydrochloric acid. Stannous chloride is added to an aliquot of the sample to generate mercury vapor. This vapor is then driven into an absorption cell of a flameless atomic absorption spectrophotometer for analysis.

  The alternative method for this monitoring is use of a portable mercury analyzer, which is adopted by the Indonesian National Standard (SNI) No. 19-4173-1996. It shall be noted that quarterly monitoring results are commonly used for the government reporting purpose, and the records shall be maintained for formal audits.

- Non-routine/Accidental Monitoring
  Non-routine monitoring is performed during or after extraordinary events, such as: major or minor spills, or any incidents that may pose to the release of mercury into environment. This accidental monitoring is also conducted during/after emergency situation, to ensure that the facility is recovered and in safely manner.

7.7.3. Ambient Air Monitoring

In addition to the indoor air monitoring as described above, ambient air monitoring is also required as part of the environmental impact monitoring. The objective of the ambient air monitoring is to ensure the compliance with ambient air quality standard, as well as to develop database for trend analyses. For the trend analysis, a series of baseline of mercury level in the area shall be obtained prior to establishment of the long-term mercury storage. Sampling locations for the regular monitoring are commonly determined and approved during AMDAL/EIA preparation, that represent upstream and downstream of the prevailing wind direction.

Monitoring frequency and schedule for the ambient air quality might be in line with those for indoor air monitoring.

7.7.4. Water Monitoring

The following procedures can be used to acquire baseline data on potential storage sites, to monitor after a suspected breach of secondary containment, to determine historic spill and contamination information, to document potential offsite migration, and to assess the site prior to decommissioning.

Water Monitoring (wells, plumbing, drains, downstream water bodies) Discharges- The discharge of effluents from mercury storage facilities is discouraged. However, if such discharges are possible, a baseline mercury analysis should be performed. Runoff from areas where mercury is handled should also be analyzed for total mercury (per EPA, Method 16318, or equivalent) in accordance with federal, state, and local requirements, or at least once per year during typical operation.

Groundwater- Total mercury analysis (using lowest available method detection limits per EPA or an equivalent method) on groundwater use and monitoring wells should be performed as a baseline and/or once per year for users who have evidence of current or historical spills.

Plumbing/drains- Mercury may remain as a residue contaminant in plumbing/drains and drain traps. Especially important in decommissioning a user facility, analysis for total mercury is useful in determining appropriate disposal options for any residuals.

7.7.5. Soil Monitoring

Soil sampling and testing are intended to determine possible deposition and accumulation of the mercury in soil at the surrounding area of the storage facility. ASoil monitoring plan shall be established and approved during EIA preparation and approval process. Series of soil testing shall be conducted prior to storage construction, the results of which will be used as a baseline for further periodical monitoring during the storage operation. In addition to the priodical monitoring, a non-routine soil sampling and testing shall also be conducted if there is any breach of the secondary containment and prior to facility closure.

7.8. Medical Check-Up Program

Prior to employment at a mercury storage facility, all personnel should have a pre-medical ckeck-up (MCU) program. This pre-employment MCU results will be used as a baseline of the employee physical conditions, including their mercury background levels. The program is intended to ensure that the personnel has a required physical condition for working in the possible mercury containing environment. For instance, they should have a proper kidney function for removal of low level of mercury in their bodies.

The MCU program should be conducted in regular basisduring their employment period, including blood tests, urine tests, and hair tests. It could be once a year or based on exposure assessments on each employee's job responsibilities. The tests must be conducted by competent medical authorities, and the results are reported to

the Department of Manpower or relevant authorities as required by the prevailing regulations. Precautions shall be taken in measuring and interpreting the result of mercury levels, as there may be a bias due to very low level of mercury. If there is any indication that an employee has been exposed to mercury, more frequent blood and urine tests, or interventional procedures may be required.

7.9. Security

One of the issues related to the aboveground storage in Indonesia is un-authorized acces or theft to the stored mercury for further illegal trade and use. To tackle this issue, a sufficient and effective security system must be implemented by the mercury storage facility.

The main objective of the security requirements is to prevent inadvertent or deliberate unauthorized entry on the mercury storage area. Site specific requirements unique to a specific facility should be evaluated in consultation with security experts. In general, the typical approaches for the security aspect of the mercury storage facility are:

- An artificial barrier such as barbed wire or concrete fence, which is installed surrounding the perimeter of the facility. Warning signs not to enter the facility are installed on the fences facing outside.
- 24-hour Security guards
- Surveillance devices such as CCTV
- Special personnel I/D ,
- Controlled entrance road to the facility.

7.10. Record Keeping

The requirements for record keeping in handling and storage of hazardous wastes are stipulated in the various Indonesian legislations, including GR-18/1999 and Head of BAPEDAL Decree No. Kep-01/BAPEDAL/09/1995. The facility shall maintain at least the following records: quantity of mercury received, type of packaging, trnasporter name and adress, vehicle type and license number, driver nad/or person who sending the mercury, date of receival, and packaging conditions.

According to the regulation, the facility should submit a report the recapitulation of the above record to the local and national authorities every three months.

7.11. Personnel Training

All Personnel working at the mercury storage must receive adequate training, which is required to operate the storage. The training may include general hazardous material management, as well as specific to the mercury management. Prior to starting their assignment, new personnel should be trained and have a minimum competency in executing their works. This requirement is stipulated in following legislations:

- Law of the Republic of Indonesia No. 32 Year 2009 pertaining to the Protection and Management of the Environment,
- Regulation of the Government of Republic of Indonesia No. 27 Year 2012 pertaining to the Environmental Permit,
- Regulation of the Government of Republic of Indonesia No. 18 Year 1999 regarding Hazardous Waste management
- Head of BAPEDAL Decree No. Kep-01/BAPEDAL/09/1995 regarding Procedures and Technical Requirements for Hazardous Waste Storage and Collection.

The training may consist of two main categories, that are: Basic Safety Trainings and Operation Trainings. All trainings received by the storage personnel shall be documented and the records shall be easily accessed for audit purpose. Refreshment trainings are required to all personnel at the minimum of once a year.

7.12. Emergency Response Plan

In addition to the standard operating procedure for spill control and response, the facility must also have a site-specific emergency response plan. The Emergency Response Plan (ERP) should address employee evacuation, internal and external reporting mechanisms, public notification and evacuation, and remedial response. The ERP covers the response procedure in the event of sabotage or terrorism, fire, and other disastrous events that could cause significant mercury releases beyond the building perimeter. The ERP should comply with local and national requirements and should include procedures for first responders, including fire department staff, state emergency response personnel, and local hospitals.

It is recommended that the following specific information be included in the ERP:

- Facility description, including facility location and map, adjacent activities,
- Incident assessment and decision process, describing a logic diagram of the preparation, response, and post-emergency procedures, as well as evaluation criteria for implementation of the ERP;
- List of names, addresses, and phone numbers (office, home, and mobile) of the emergency coordinator, emergency response team (ERT) members and the chain-of-command of these personnel;
- Containment and control activities, designed to minimize the potential hazards to facility personnel, contain released materials and prevent their movement from the facility.
- Evacuation procedure for the facility personnel (including visitors and contractor), describing signal used to trigger evacuation, routes, and alternate evacuation routes;
- Casualty response, covering the preparation for the first-aid measures and outside medical assistance.

- Available emergency equipment at the facility (such as fire extinguishing systems, spill control equipment, internal/external communications and alarm systems, and decontamination equipment), including their locations and brief description of each system.
- Arrangement with local authorities, police departments, fire departments, hospitals, and national and local emergency response teams to coordinate emergency services;
- Community impact considerations, in anticipation of the possibility that areas adjacent to or near the facility may be endangered due to spill or material release, including coordination with local authorities for evacuating the surrounding areas.
- Criteria and procedure re-occupancy of the facility
- Post-emergency procedure, which describes the aspects of prevention of re-occurrence, treatment/disposal of contaminated materials and clean-up residue, equipment decontamination and maintenance, personnel debriefing and re-training, and incident investigation/reporting.

7.13. Closure Plan

Closure Plan consists ofwritten procedures on how the storage facility willl be closed down in an environmentally sound manner, whenthe mercury is going to be permanently stored, either through stabilization processs or diirect reposition in a permanent storage. The plan also includes fund allocation reserved for building demolition, including site assessment and decontamination.

The management of demolition wastes shall follow the prevailing regulations concerning hazardous waste management, since the waste may be contaminated with the mercury or mercury vapor. Decontamination procedure may have to be done to all equipment or used materials such as flooring, roofs, racks, pallets, Other option is that these hazardous waste is handed over to a licensed hazardous waste treatment and disposal facility.

Soil and sub-soil investigation shall be done upon the facility closure to determine if there is any mercury contamination. If the mercury level in the soil or sub-soil is found above the regulatory limits, soil clean-up or remediation is required and acceptance or approval from the authority shall be obtained.

8. COST ESTIMATE FOR THE ABOVEGROUND MERCURY STORAGE

As discussed previously, the implementation of environmentally sound management for excess mercury in Indonesia shall be started from the sources, where they are initially generated. Consequently, the cost components associated with the management of excess mercury will comprise of the costs occurred at each stages of the management, that are:

- Cost for handling, containerizing/flasking and temporary storage at generator premises
- Transportation from the sources/generators to the Local Storage (for elemental mercury) or Recovery Facility (for mercury containing waste)
- Segregation, containerizing/flasking, and temporary storage at temporary storage at the Local Storage
- Recovery of mercury from mercury containing waste at Recovery Facility for volume reduction
- Stabilization and final disposal of low level mercury containing waste and/or residue from the Recovery Facility
- Transportation of containerized/flasked elemental mercury from Local Storage and/or Recovery Facility to the National Storage
- Long term storage of elemental mercury at National Storage.

The following assessment will only discuss the cost associated with the establishment of National Storage for the long term storage of the excess mercury in Indonesia. It shall be noted that, due to the limitation of data regarding the quantity of excess mercury to be stored, several assumptions are made for this rough estimation. These assumptions includes:

- the proposed storage is located in Java island
- mercury to be stored is in the form elemental mercury
- mercury received in the facility is containerized in flasks
- the storage is designed for the capacity of 1,000 tons of elemental mercury

The cost associated to the establishment of National Storage can be categorized into three components that are: capital and recurring costs.

8.1. Capital/investment Cost

The capital/investment cost consists of three components, i.e.:

- Pre-construction: feasibility study, AMDAL/EIA, detailed engineering design and permitting/public consultation.
- Construction: civil, mechanical, electrical and fire suppressant system

- Closure: building demolition/facility dismantling, hazardous/non-hazardous waste disposal, and site assessment and site-rehabilitation.

Note that the cost for facility closure will be incurred at the end of the storage period, which is about 30 to 40 years after its operation, after which the excess mercury will eventually be permanently stored at the regional facility. Cost associated with this management is also excluded in this assessment. The summary of cost estimation for establishment of the storage facility is shown in Table 4 and Table 5 below.

Table 4. Basis and Assumptions for Cost Estimation

Basis of Cost Estimation	
Storage type	Aboveground
Total excess mercury to be stored	1,000 tons
Number of mercury flasks @76lbs	28,572 ea
Number of drums @200 ltr	4,762 ea
Storage Building Area	1,373 m2
Land Area	5,000 m2

Table 5. Summary of Estimated Capital/Investment Cost

Cost Component	**Cost (USD)**
Pre-construction	
Feasibility Study & Site Sitting	120,000
EIA/AMDAL	140,000
Detail Engineering Design	15,000
Permit and Public Consultation	150,000
Sub-total	425,000
Facility Construction	
Land Acquisition	1,000,000
Civil Structure	436,550
Electrical Work	56,285
Mechanical Work	13,728
Fire Service	146,890
Equipment	100,000
Weighbridge/ Weighscale	50,000
Drums & pallets	464,286
Closure/De-commissioning	200,000
Sub-total	2,467,739
Total	**2,892,739**

8.2. Operating Cost

Operating cost for the operation of the mercury storage consists of several components, such as:

- Personnel
- Maintenance and Utilities
- Consumables & PPE
- Environmental Monitoring

Rough estimation for this recurring cost is presented in Table 6 below.

Table 6. Summary of Estimated Annual Operating Cost

Cost Component	Cost (USD/year)
Manpower	
Operator/Labor	104,400
Safety / Compliance officer	18,000
Security	75,600
Manager / Supervisor	72,000
Routine maintenance	12,000
Utility (electricity/water)	30,000
Consumables & PPE	10,000
Environmental Monitoring	
Air	12,000
Water	6,000
Soil	6,000
Other contigency	24,000
Total Operating Cost/year	**370,000**

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Conclusions

A solid understanding on mercury flows and estimated quantity of the excess mercury in Indonesia are fundamental foundation in determining subsequent steps by the country for the implementation of an ESM of mercury, such as estimating the storage capacity, securing financial and technical support, assessing technical criteria for mercury storage including its site assessment, and identifying the overall management of elemental mercury and mercury containing waste.

Currently there is no available data from previous studies related to the quantification of potential excess mercury in Indonesia. However, an interim report on Inventory Level-1 of Mercury Release using UNEP Toolkit indicated that the main sectors of the sources for the mercury release are:

- Gold extraction with mercury amalgamation
- Informal dumping of general waste
- Waste incineration and open waste burning
- Oil and gas production
- Use and disposal of other products
- Coal combustion and other coal use

The inventory result reveals that there are also fundamental issues related to the implementation of proper hazardous waste management in Indonesia, that significantly contribute to the release of not only mercury into the environment, but also other hazardous and toxic substances.

Currently, a comprehensive regulatory infrastructure related to the industrial hazardous waste management have already implemented in Indonesia. The regulations cover for the hazardous waste temporary storage, transportation, collection, treatment, utilization and disposal. Principally, most of these regulations may also be adopted for the management of the excess mercury in Indonesia. However, awareness and enforcement of the regulations still need further advanced. In addition, regulatory framework for the concept of excess mercury management, including detailed technical requirement for its long term storage, shall be further developed.

9.2. Recommendations

Considering the wide distribution of the mercury sources in Indonesia, the environmentally sound management for excess mercury will involve proper storages at each stages of its management, that are:

- Temporary storage at generator's sites
- Temporary storage at Local Storage or Collection Facility
- Long term storage at National Storage

For the cost effectiveness, temporary storage of excess mercury at generator's site and Local Storage can be combined with the regular hazardous wastes, provided that proper segregation is implemented according to their compatibility.

The current infrastructure for the hazardous waste management can be utilized to resolve issues of low mercury containing waste, as part of the solution for the excess mercury in Indonesia. The available infrastructures cover the availability of facilities for stabilization/macro-encapsulation and secure landfill of low level mercury containing waste. The regulatory level for the mercury content, that allowed for the stabilization/ macro-encapsulation treatment and final disposal in the secure landfill, shall be determined by the government of Indonesia. Otherwise, the limit of 260 mg of mercury/ kg as currently used by the US-EPA could also be adopted.

In addition to the utilizing the currently available infrastructure, establishment of mercury recovery facility in Indonesia is very important factor in the management of high level mercury containing waste, as to reduce the volume of waste allowing the storage only for the elemental mercury. The recovery process may involve retort or incineration depending on the type of mercury containing waste. Currently, this type of waste is exported to Europe, which could be no longer feasible in the future.

Establishing an aboveground warehouse for long term period (30 to 40 years) using the US concept is the most feasible option in Indonesia for the storage of excess mercury. The grounds for the selection of this option are:

- geological condition
- susceptibility to natural disasters
- un-availability of appropriate salt mines or deep rock underground mines
- proven approach of the concept
- authority and public acceptability

Other advantage of having an aboveground warehouse is that it provides a 'mercury bank', which could be required during transition period, allowing appropriate control to the mercury trade in Indonesia.

Site sitting for the long term storage of excess mercury shall consider the following factors:

- Public involvement and acceptance
- Technical requirements:

- Geological/hydro-geological condition
- Natural disasters
- Proximity to the sources

Further regulatory framework for the site sitting of long term storage for the excess mercury shall be further developed. Current regulations pertaining to the technical requirements for hazardous waste storage, treatment and disposal (TSD) can be used as a basis for filling this gap.

The design of mercury storage building shall have minimum requirements as stipulated in the Head of BAPEDAL's Decree No. Kep-01/BAPEDAL/09/1995 regarding the Procedures & Technical Requirements for Hazardous Waste Collection & Storage, including:

- Building Layout/Design
- Roof and Walls
- Floor
- Ventilation
- Secondary Containment System
- Name Board and Signs
- Lighting
- Leak Detection
- Fire Detection and Suppression System

Cost components associated with the management of excess mercury comprise of:

- Cost for handling, containerizing/flasking and temporary storage at the sources
- Transportation from the sources/generators to the Local Storage (for elemental mercury) or Recovery Facility (for mercury containing waste)
- Segregation, containerizing/flasking, and temporary storage at temporary storage at the Local Storage
- Recovery of mercury from mercury containing waste at Recovery Facility for volume reduction
- Stabilization and final disposal of low level mercury containing waste and/or residue from the Recovery Facility
- Transportation of containerized/flasked elemental mercury from Local Storage and/or Recovery Facility to the National Storage
- Long term storage of elemental mercury at National Storage.

Establishment of the aboveground storage requires capital/investment cost as well as operating cost for running the storage facility. Due to no data available for the possible quantity of excess mercury in Indonesia, the cost estimation is made based on 1,000 tons of elemental mercury to be stored.

Table - 7. Summary of Costing Component and Cost Estimation

Basis for Cost Estimation	
Storage type	Aboveground
Quantity of excess mercury to be stored	1,000 tons
Storage Building Area	1,373 m2
Land Area	5,000 m2
Capital cost	
Pre-construction studies/permitting	USD 425,000
Facility construction	USD 2,267,740
Facility Closure	USD 200,000
Operating Cost/year	USD 370,000

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