# A suggested framework for decision making for the safe management of surplus mercury

*An output from the Integrating Knowledge to Inform Mercury Policy (IKIMP) Initiative*

- With suggested additions by Lars Olof Höglund and Sven Hagemann, May – December 2010

## About this suggested framework

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| What is this framework? | *This framework document informs about possible elements of a national or regional decision process that addresses the management of surplus mercury.* |
| Who is it for? | *Countries, or groups of countries, at an early stage in their considerations of the management of surplus mercury that could be restricted from international trade* |
| How has this document been produced? | *The development of this note was informed by a sub-group discussion at an international workshop held in Oxford (UK) on 13th and 14th October 2009 to discuss the scientific, technical and engineering issues associated with the storage and disposal of surplus mercury. In May to December 2010, some additions have been suggested by Lars Olof Höglund (Kemakta) and Sven Hagemann (GRS)* |

**Important independent sources of information and activities to help inform decision makers**
Users of this note are recommended to refer to the outputs of the two UN Environment Programme (UNEP) Regional Mercury Storage Groups (Asia Pacific, Latin America and Caribbean), including their options analyses. See http://www.unep.org/chemicalsandwaste/Mercury/GlobalMercuryPartnership/tabid/1253/Default.aspx

The UNEP Mercury Supply and Storage Partnership Area is also assisting with sharing knowledge and providing international leadership on this topic.

A bibliography of activities and publications related to the topic of the safe storage and disposal of mercury is available at: http://www.mercurynetwork.org.uk/safe_repositories_for_mercury/. This contains links to important regional activities, such as those in the European Union and United States of America.

A summary of technical information relevant to storage and disposal of elemental mercury and mercury compounds has been prepared in parallel

The **Oxford Workshop on the Safe Storage and Disposal of Redundant Mercury** was established to build on existing meetings related to this topic, including UNEP regional storage group meetings in Bangkok and Montevideo in 2008 and 2009. The meeting, held in October 2009 involved over 40 experts from 7 countries. It was supported by UK Department for Environment, Food and Rural Affairs. The event was focused on scientific and technical issues, but was followed by a sub-group discussion on considerations for the safe management of surplus mercury worldwide. For further information, see http://www.mercurynetwork.org.uk/safe_repositories_for_mercury/

## About surplus mercury

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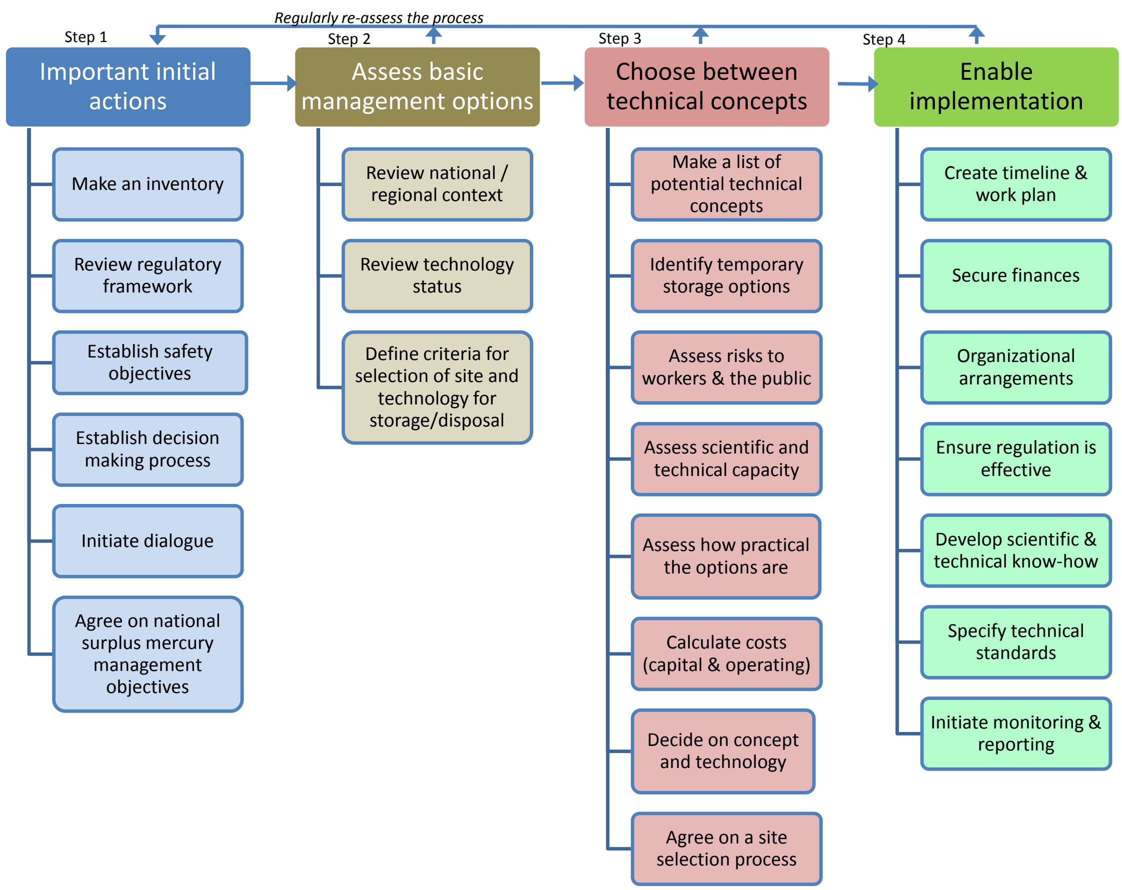
| What is surplus mercury and where does it come from? | Like any raw material, mercury is subject to changing supply and demand. With the uptake of cleaner technologies for industry worldwide and substitution of harmful materials in consumer products, the need for mercury is reducing quickly. At the same time, mercury is increasingly produced as a by-product of industrial processes such as non-ferrous metal production (e.g. zinc, gold), natural gas production or is recovered from decommissioned mercury cells from chlor-alkali plants. It may also be recovered from end-of-life consumer products.<br>Surplus mercury is the amount of mercury that is or might become available on a market that exceeds the amount of mercury required to meet demand from socially accepted applications of mercury in that market. Safe management of surplus mercury is essential because it is toxic, even in small quantities. |
| What forms of mercury does it cover? | Depending on its source surplus mercury may be produced as elemental mercury or as a mercury compound. Both types may enter the market as commodity mercury if the costs for chemical conversion and/or purification are lower than the costs for storage or disposal. |
| Are there other sources of mercury not covered here? | There exist large volumes of different types of spent consumer products and industrial wastes that contain mercury in varying concentrations. Despite lower concentrations, the total content of mercury in such materials may be high owing to the large volumes. The large volumes also mean that the necessary efforts to manage these types of materials may be more demanding than the commodity-grade mercury. It may therefore be important to be informed that other sources of mercury may need to be considered at a later stage when the commodity grade mercury has been managed. |

## An outline of the suggested framework

The following diagram shows possible elements of a decision making framework. It consists of the four steps ‘Initial actions’, ‘Assess basic management options’, ‘Choose between technical concepts’ and ‘Enable implementation’. Each step is characterized by a number of possible decision elements that could be taken into account when designing a national decision process. The elements discussed in this document should be understood as a proposal only. An individual decision making process may look different taking on board some of the elements, not including others but adding new elements as deemed necessary. It is advisable to re-assess a chosen process regularly. New information may become available that could lead to different conclusions and a revision of earlier decisions. In the following chapters the steps and the elements are described in greater detail. Not discussed here are possible aspects of a broader mercury strategy, like phasing out the use of mercury in products and processes nor any decisions during or after the actual implementation of a storage concept.




*Note that individual actions within any one stage are not necessarily in order of priority*

## A description of the suggested framework

### **Important initial actions** (Stage 1)

The first step is to **Make an inventory** of surplus mercury requiring management in the future. This work may have already been undertaken, at least in part, by national organizations involved in producing inventories of mercury emissions. Draft guidance on inventories for mercury sources and emissions is available at
http://www.unep.org/chemicalsandwaste/Mercury/ReportsandPublications/MercuryToolkit/tabid/4566/Default.aspx
In preparing an inventory suitable for safe management of surplus mercury, it will be important to consider the following:

- Define what forms of surplus mercury are to be included within the scope of the management initiative. Elemental mercury, which is a silver coloured liquid at room temperature, may be the predominant form but substances containing mercury such as mercury chloride may also require management. Ensure that each included form is clearly described.
- Identify how much mercury there is in each of the forms and establish their physical and chemical characteristics (for example, liquid elemental mercury easily evaporates at room temperature). Trade flows may be useful in informing inventory calculations. Countries may find value in establishing mass-balances for mercury: (import + production - export – consumption = changes in stored supply). Special attention should be paid to any discrepancies (imbalances) identified (this could imply illegal trade or other undesired handling).
- Prepare a list of where the mercury is produced or located and its ownership.
- Estimate future additions to the inventory. Consider mercury that may be recovered from other types of wastes, such as demolition waste or contaminated sites. Assessments of mercury supply and demand for Asia, and the Latin America and the Caribbean will assist in estimating future additions. The assessment reports are available at http://www.unep.org/chemicalsandwaste/Mercury/GlobalMercuryPartnership/SupplyandStorage/tabid/3546/language/en-US/Default.aspx For countries outside Asia, and the Latin America and the Caribbean, these reports will show how quantities of surplus mercury arising into the future may be calculated.
- Evaluate the risks/vulnerabilities from the mercury in its current locations, including consideration of the financial viability of the current holders.
- Define the capacity needs for storage and disposal based on the national and/or regional mass-balances/inventories. Make a forecast for different scenarios regarding the required capacity for sequestering of mercury.

It will be important to **Review the regulatory framework** that may influence the detailed technical options available. This will include national or regional policy on hazardous waste management. During this step, it will be important to:

- Decide if the basic management option is consistent with international legislation/commitments (**Box 1)**
- **Establish safety objectives** and safety standards.

Safety objectives are general principles that address the protection of human health and the environment**.** They may include:

- **Protection of human health**: secure an acceptable level of protection for human health.
- **Protection of the environment**: provide an acceptable level of protection of the environment/ level of environmental quality to be maintained.
- **Protection beyond national borders**: possible effects on human health and the environment beyond national borders will be taken into account.
- **Protection of future generations**: 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**: not impose undue burdens on future generations.

For each objective safety standards could be defined, like a maximum concentration of mercury in drinking water, maximum allowable daily intake or a maximum exposure at workplaces. Such standards may be needed in the later stage of the decision process, when the potential environmental and health impact of management facilities has to be assessed. Recommendations for such standards may be found, for example in the following documents:

- WHO (2008) Guidelines for drinking-water quality. Third edition incorporating the first and second addenda. Volume 1. Recommendations http://www.who.int/water_sanitation_health/dwq/fulltext.pdf
- UNEP (2008) Guidance for identifying populations at risk from mercury exposure http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Documents/IdentifyingPopnatRiskExposuretoMercury_2008Web.pdf

It may be necessary to make changes to the regulatory framework. Re-visit the framework when a technical option has been chosen to ensure that it is adequate.

**Box 1: Key international commitments affecting where surplus mercury can go**

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| Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal | www.basel.int |
| Stockholm Convention on Persistent Organic Pollutants | http://chm.pops.int/ |
| Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International trade | www.pic.int |

Alongside the review of regulatory framework, it will be important to **Establish a decision making process**:

- Identify any existing mechanisms for co-ordinating decisions about hazardous materials, public health and environmental protection.
- Define the roles of central and regional government departments as well as other official agencies, and other stakeholders (such as civil society and research institutions responsible for public health and environmental protection).
- Establish any need for new organisations (e.g. expert panels, inspection teams etc).
- Decide on the nature and extent of stakeholder engagement etc.

An important initial action is to **Initiate a dialogue** wherever possible at the international, national and regional scales. The involvement of a range of stakeholders is important in this process. The potential for creating a set of solutions to serve the widest possible geographical area needs to be carefully considered, as this may lead to more cost-effective and safer solutions.

At the end of the dialogue process it is necessary to **Agree on national surplus mercury management objectives** for example that surplus mercury is an issue to be addressed and that a process is started to find environmentally sound management solutions.

## Assess the basic management concepts (Stage 2)

Once an inventory is available, it will be possible to assess the basic management concepts. These are not the detailed technical concepts, but just the general types of action that might be possible. The basic options that have been discussed are shown in **Box 2**. The listing of a concept in this table does not mean that they are generally regarded as environmentally safe. Further investigations are necessary in order to assess their feasibility and the level of safety they could provide.

### Box 2: Basic management concepts

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| Temporary storage | On sites where the surplus mercury has been produced (as long as they will be safe and secure for as long as necessary) | |
| | In a national storage facility – restricted to national mercury or providing a regional/international facility | Aboveground |
| | | Underground |
| | Export to an international/regional storage facility | Aboveground |
| | | Underground |
| | Return to point of origin (e.g. the owner or producer if identifiable) | |
| Disposal in a specially engineered landfill | National facility – restricted to national mercury or accepting mercury from other countries | Stabilized mercury |
| | Export to an international/regional storage facility | Stabilized mercury |
| Deep Well injection | Use of existing deep wells, e.g. oil wells that provide a sufficient level of safety. | Slurry of Stabilized mercury |
| Disposal in an underground repository (permanent storage) | National facility – restricted to national mercury or accepting mercury from other countries<br>Rock types: igneous rock, salt dome, disused mine | Stabilized mercury/ mercury compounds |
| | | Elemental mercury |
| | Export to international/regional disposal facility<br>Return to the point of origin | |

An important consideration is whether to:

**STORE** , i.e. put the mercury somewhere where it can easily be moved or taken for further processing

**or**

**DISPOSE**, i.e. put the mercury in a place and in a form where long-term safety can be assured without any ongoing maintenance or any other actions. Later retrieval is not intended and technically difficult.

Some of the basic management options may not be available due to political constraints, lack of suitable local geologies or because the technology involved has not yet been demonstrated. It is therefore important to **Review the national and regional context** as well as **Review technology status**.

In reviewing the national and regional context, available geology for underground disposal sites may be important. Some basic types of geology are given in **Box 3**. Activities required to retrieve, collect and transport the wastes, and capacity to carry them out, are a further consideration. In order to decide on the feasibility of regional or international facilities, review any constraints arising from international legislation and agreements (see, for example, **Box 1**) and the availability of financial incentives.

Information on the status of technologies for storage and disposal is available following the links available on the following webpages:

- http://www.unep.org/chemicalsandwaste/Mercury/GlobalMercuryPartnership/SupplyandStorage/tabid/3546/Default.aspx (with links to studies of technical options by UNEP Regional Mercury Storage Groups)
- http://www.mercurynetwork.org.uk/safe_repositories_for_mercury/ (with links to studies and information authored by a variety of stakeholders worldwide).

**Box 3: Basic types of geological formations for consideration**

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| Low permeability, water -bearing rocks | Examples include granites, clay, and metal ore deposits | Note that these types of rocks (including excavations within them) can never be kept totally dry. This means that there is a risk of corrosion of storage vessels and mobilization of elemental mercury. Consider the potential for fractures that may act as a transport path for dissolved mercury. The disposal of more stable forms of mercury such as mercury sulphide is consequently considered necessary to reduce its mobility. Existing underground mines in metal ore deposits might serve as an additional option if the overall geological situation (barrier systems) is favorable. |
| Dry formations | Salt deposits | Important properties of salt deposits is that they are dry, reducing the chance of mobilization of elemental mercury. Also salt has some degree of plasticity, meaning that any routes for escape of mercury may self-seal in the long-term. Consider how the types of rock above and below a salt deposit might protect it from water intrusion in the long-term. |

Important initial considerations when assessing whether the option of underground storage or disposal is available in any one country or region:

- The potential for human intrusion (accidental or deliberate). For example, mineral exploration and mining may create new routes for the escape of mercury.
- Seismicity (earthquakes etc.) and rock fractures
- Sea level fluctuations and flood risk (from rivers, lakes and the sea)
- Temperature gradients in the rocks (a constant temperature is advisable)
- Microbiological conversion of mercury in the long-term (to be avoided)
- Groundwater flow and abstraction (including drinking water sources)

Based on objectives, standards and experience in similar selection processes, it is possible to **Define criteria for selection of site and technology for storage/disposal**. Examples for site selection criteria are given in **Box 4**. Such criteria may help to evaluate whether a technical concept is feasible in a country, e.g. whether there are enough sites not prone to flooding or underground mines that could be used for disposal of waste. Such criteria can be further refined for the implementation phase in order to guide a site selection process as they help identifying sites that probably will not provide a sufficient level of safety.

Further parameters could address aspects important to local communities like conflicting land uses (e.g., use of a stream for fishing, use of a vacant lot for community vegetable gardening), vision of sustainable uses of land, water, and air resources, religious, cultural, or other special values of the land. More information on how to consider social aspects and how to involve local communities is given, for example in

- US EPA (2000) Social Aspects of siting RCRA Hazardous waste facilities http://www.p2pays.org/ref/05/04303.pdf

**Box 4: Examples for site selection criteria (aboveground facilities)**

- **Floodplains :** avoid floodplains, build facilities above 100 year flood-level
- **Unstable Terrain:** avoid unstable terrain: the movement of rock and soil on steep slopes by gravity (e.g., landslides), and rock and soil sinking, swelling, or heaving
- **Wetlands:** avoid wetlands like swamps, marshes, bayous, bogs, and Arctic tundra
- **Unfavorable Weather:** avoid areas with stagnant air
- **Groundwater Conditions :** not be located over high-value groundwater or areas where the underground conditions are complex and not understood
- **Earthquake Zones:** no facility within 200 feet of a Holocene fault (that is, faults that have been active within the last 10,000 years)
- **Incompatible Land Use:** avoid locating near sensitive populations or in densely populated areas
- **Karst Soils:** avoid locating in "active" karst areas

Source: US EPA (1997) Sensitive Environments and the Siting of Hazardous Waste Management Facilities http://www.epa.gov/oswer/ej/pdf/sites.pdf

Site selection criteria for underground storage (disposal) facilities have been derived for radioactive waste disposal

- IAEA (1994) Siting of Geological Disposal Facilities. http://www-pub.iaea.org/MTCD/publications/PDF/Pub952e_web.pdf
- IAEA (2006) Geological disposal of radioactive waste, IAEA Safety Series WS-R-4. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1231_web.pdf
- Nuclear Waste Management Organization (Canada) Canada's plan for the long-term management of used nuclear fuel. Site selection process. http://www.nwmo.ca/sitingprocess_theprocess

## Choosing between the technical options (Stage 3)

Once the basic management concept has been chosen (see **Box 2**), it will be possible to **Make a list of potential technical options**. These will likely not only include aboveground storage and underground storage (disposal) concepts but also combinations with additional technological options like prior stabilization of elemental mercury or direct disposal of by-product mercury compounds.

Beside long-term management options that may need some time for full implementation, it is important to **Identify temporary storage options**, possibly on a decentralized basis that could be used to manage surplus mercury before central storage or disposal facilities become available. Timescales for temporary storage need to be established so as to ensure that facility design is appropriate. These timescales will be influenced by the consideration of timescales for disposal as the ultimate solution. The environmental risk associated with taking no further action to ensure the safe management of surplus mercury is also an important consideration.

For temporary storage, draft guidelines on the management of mercury waste are developed under the Basel Convention and are likely to assist in identifying options. The guidelines are not agreed yet (January 2011). The current drafts may be found at

http://www.basel.int/techmatters/code/techguid.php?topicId=mercury

For each option there will be a need to **Assess risks to workers and the public**. This assessment will involve identifying the hazards (such as the chemical toxicity of mercury, structural stability) as well as the likelihood of harm. This includes hazards and associated risks from processing and transporting mercury (e.g. spillages), as well as the operating period of a store, and the post-closure period for a disposal facility. At this stage the assessments will generally be made on the basis of parameters typical of potential physical settings rather than specific to particular candidate sites.

Assessments will require comparison with national and international safety standards. The significance of the risks may need to be compared to other environmental and human health risks so that actions are proportionate and cost-effective with the overall goal of ensuring safety for people and protecting the environment.

An essential criterion will be to **Assess scientific and technical capacity** to deliver the options: according to the roles and responsibilities of current owners of mercury, operators of facilities that may accept surplus mercury, regulators etc.

Financial considerations often play an important role in selecting a technical concept. Therefore, it will be necessary to **Estimate costs (capital and operating)** for each option. A detailed cost analysis that could be basis for an investment will only be possible after the selection of one or several potential sites.

Alongside scientific and technical capacity, it will be important to **Assess how practical the options are** in terms of:

- governance at the national and local level;
- whether the regulatory framework can be implemented in practice; and
- public acceptance of options.

Based on these considerations, the likelihood of a successful outcome for each option can be estimated. A systematic approach should be taken to comparing and weighting the factors in choosing between the options..

At the end of the process decision makers may **Decide on concept and technology** . This includes a decision whether each step of the handling/treatment/storage/disposal – chain for mercury, as well as the total system, (the potential physical settings, the disposal technique and facility, and stabilization techniques) is acceptable.

After this decision it is advisable to **Agree on a site selection process.** A site selection process is a structured and transparent procedure that guides decision makers and stakeholders through all steps between the fundamental decision to store or dispose surplus mercury and the final site selection. The process could include elements like

- The desired output (like identification of one or several suitable sites, timelines)
- Safety objectives
- Site selection criteria: minimum requirements and exclusion criteria
- Actors and responsibilities
- Timelines
- Steps of site identification, investigation and assessment
- Involvement of stakeholders
- Decision process (who will decide and which information is necessary)

The extent of site selection process should be in an adequate relation to the potential risk the site might pose to the environment or human health. A regional storage facility for elemental mercury might need a more detailed and extensive process than the selection of a local waste collection centre for the temporary storage of small quantities of end-of-life products. Countries may decide to directly identify just a single potential site and then assess its feasibility and safety. Thus a site selection process may be rather short, but nevertheless should contain some or all of the elements shown above.

## Activities to enable implementation (Stage 4)

Having decided on a preferred option, or set of options, it will be necessary to take action to ensure effective implementation of the chosen management strategy. This will include

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| **Create timeline & work plan** | The establishment of realistic timescales for implementation is essential. A work plan should be published and then regularly reviewed. |
| **Secure finances** | Decide who will bear the cost of surplus mercury management (e.g. producers of surplus mercury); find a way to raise necessary funds for investments and decide how to refinance investment and operating costs by charging fees or taxes. |
| **Organizational arrangements** | Decide on roles and responsibilities. Identify a lead organisation responsible for the process (including site selection) and make this known. Make decision on who will be the operator of a storage/ disposal facility (private/ public) |
| **Ensure regulation is effective** | Check that the regulatory framework is appropriate. Ensure that regulatory bodies are in place to make checks. |
| **Develop scientific & technical know-how** | This may involve regional or international co-operation (such as workshops to share experience, training courses, site visits and the exchange of experts). Operators of storage or disposal facilities must be adequately qualified and experienced. |
| **Specify technical standards** | This includes environmental quality standards, as well as construction and health and safety standards. |
| **Initiate monitoring and reporting** | Ensure that a responsible and qualified organization undertakes an appropriate level of environmental monitoring. |

### Note regarding the importance of national and regional contexts

This suggested framework is not intended to be definitive guide to all the issues relating to mercury storage and disposal. While thorough assessment is required, the importance of certain issues mentioned in this document will depend on national and regional contexts. Regional assessments of technical options and appropriate decision making processes are strongly recommended.

After the decisions in stage 4 the actual implementation of the chosen concepts would be started. Typically it would start with a site selection process that helps to identify potential sites and provides necessary information (feasibility, costs, and acceptance) to allow for a site decision. During the selection process additional decisions might be necessary, like going back to stage 4, 3 or even 2, if the process did not lead to suitable sites or new information demands a re-evaluation of concepts.