Technical options for storage and disposal of mercury

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Introduction

This study has been undertaken under contract with UNEP Chemicals during a temporary leave of absence.

Definitions used in this document

Mercury: All mention of mercury in this document relates to the management of excess supply of commodity-grade elemental mercury and mercury compounds in their pure form. It is recognised that significant amounts of other materials containing mercury exist that may call for attention in similar respect at later stage.

Storage facility: A facility where mercury is temporarily put under supervised conditions during a limited period of time. The time may be short-term, e.g. some months or a few years, or long-term, e.g. several years or a few decades.

Disposal facility: A facility where mercury is put permanently (during indefinite time), essentially with no or only very limited need for supervision and/or maintenance.

Storage facility options

- Above ground in storage building, stored in retrievable manner
- Above ground in landfill, stored in retrievable manner
- Near surface below ground in landfill, stored in retrievable manner
- Near surface in shallow rock cavern, stored in retrievable manner
- Near surface in excavated storage location in surface soil, stored in retrievable manner
- Deep rock storage in crystalline rock caverns, stored in retrievable manner
- Deep rock storage in salt rock caverns, stored in retrievable manner
- Deep rock storage in sedimentary rock caverns, stored in retrievable manner

Options for the physical and chemical form of stored mercury

- Liquid mercury in free form
- Liquid mercury in steel flasks (a few liters size)
- Liquid mercury in containers (up to about 1 m^3)
- Physical stabilization of mercury, e.g. cement solidified form and amalgamation
- Chemical stabilization of mercury into solid form, e.g. as mercury sulphide
- Combined physical and chemical stabilization, e.g. cement+sulphide stabilization, the SPSS-method, the MBS-method and the Mersade-method.

Disposal facility options

- Above ground in storage building
- Above ground in landfill, stored in a manner not depending on supervision and/or maintenance
- Near surface below ground in landfill, stored in a manner not depending on supervision and/or maintenance
- Near surface in shallow rock cavern, stored in a manner not depending on supervision and/or maintenance
- Near surface in excavated storage location in surface soil, stored in a manner not depending on supervision and/or maintenance
- Deep rock storage in crystalline rock caverns, stored in a manner not depending on supervision and/or maintenance
- Deep rock storage in salt rock caverns, stored in a manner not depending on supervision and/or maintenance
- Deep rock storage in sedimentary rock caverns, stored in a manner not depending on supervision and/or maintenance

Options for the physical and chemical form of disposed mercury

- Liquid mercury in free form
- Liquid mercury in steel flasks (a few liters size)
- Liquid mercury in containers (up to about 1 m^3)
- Physical stabilization of mercury, e.g. cement solidified form and amalgamation
- Chemical stabilization of mercury into solid form, e.g. as mercury sulphide
- Combined physical and chemical stabilization, e.g. cement+sulphide stabilization, the SPSS-method and the MBS-method

Options for additional barriers in disposal facilities

- Tight disposal containers
- Concrete barrier constructions
- Clay sealing layers
- Synthetic sealing layers (e.g. plastic membranes, rubber membranes)
- Hydraulic barriers (e.g. drainage layers, gravel, crushed rock)
- Mechanical support (backfill material to support the host rock, gravel, crushed salt, crushed rock, concrete backfill)

Short descriptions of the general construction and performance principles of the different storage facility options

From a technical point of view, mercury can be stored over several years in suitable storage facilities. Mercury as such is not inherently different from many other types of chemicals that are commonly stored under well controlled conditions. However, legal issues may call for further measures to be taken regarding mercury.

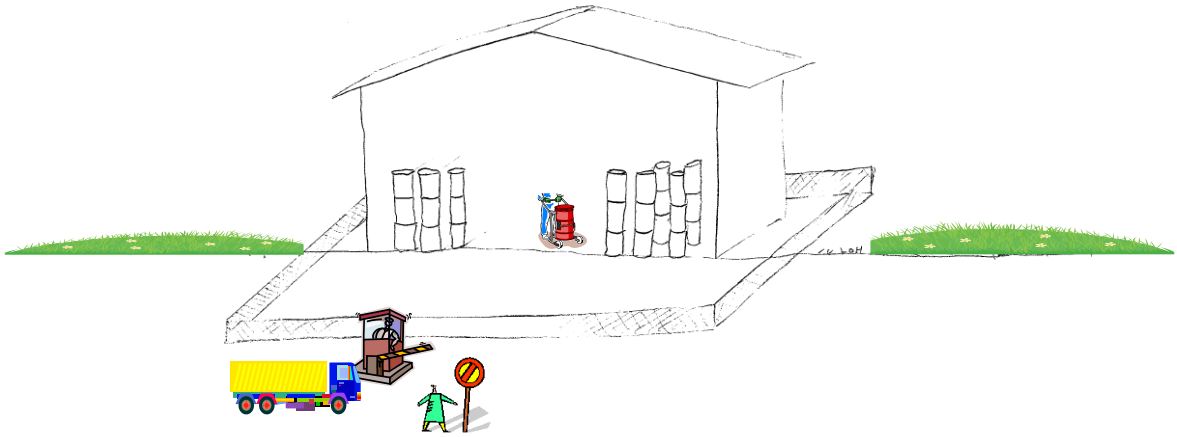
In the following some examples of different options available for storage of mercury are briefly described in text and simple illustrations. To give the reader an overview the different options are first summarized in Table 1.

Table 1 Overview of different storage options.

	Storage facility options	Above ground in storage building	Above ground in landfill	Near surface below ground in landfill	Near surface in shallow rock cavern	Near surface in excavated storage location in surface soil	Deep rock storage in crystalline rock caverns	Deep rock storage in salt rock caverns	Deep rock storage in sedimentary rock caverns
Common demands	Mercury can be stored over a limited period of time.	X	X	X	X	X	X	X	X
	Method require supervision and a certain amount of maintenance.	X	X	X	X	X	X	X	X
	Mercury can be stored in a retrievable manner.	X	X	X	X	X	X	X	X
	Mercury is a toxic element. The storage facility can be protected against intrusion to avoid risk of human health and the environment.	X	X	X	X	X	X	X	X
	The stored mercury can be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions etc	X	X	X	X	X	X	X	X
	Mercury stored in the storage facility can be kept separate from other contaminants and materials in the storage facility, e.g. by compartmentalization of the storage facility.	X	X	X	X	X	X	X	X
	Mercury put into a disposal facility intended as a temporary storage solution can be constructed in such a way that retrieval of the mercury can be done efficiently and without jeopardizing the integrity of the facility, or that any risk for uncontrolled release of mercury would appear.	X	X	X	X	X	X	X	X
	Certain requirements must and can be fulfilled regarding the competence of the storage facilities where the mercury is kept.	X	X	X	X	X	X	X	X
Specific demands	The geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the storage facility	X	X	X	X	X	X	X	X
	Protection against digging and construction work etc	X	X	X		X			
	Protection against mining/quarrying etc				X		X		X
	Protection against digging, salt mining/salt extraction and construction work etc							X	
	The rock mechanic conditions at the site must be thoroughly evaluated to ensure physical stability of the storage facility				X		X	X	X
	These factors can be expected to be well fulfilled	X	X	X			X	X	X
	Under the condition that the requirements on geotechnical and tectonic stability can be assured, all these factors can be expected to be well fulfilled					X			
	Can be excavated in hill slopes or vertically in shallow bed rock				X				
	A typical rock overburden required is on the order of a few tens of metres				X				
	Cavern may have been excavated and used for other purposes, such as oil storage, military purposes etc. This may call for specific measures before use, e.g. clean-up				X	X	X	X	X
	A typical surface soil deposit depth required for an excavated storage facility is on the order of a few tens of metres					X			
	Supporting constructions in the excavated facility, e.g. supporting walls may be required to assure mechanical stability			X		X			
	Excavations may be quite large and finding separate storage locations for mercury would seem possible				X		X	X	X
	Storage facility would typically be located at a depth of several hundred metres below ground						X	X	X
	Storage facility may be situated below the natural groundwater table and may require pumping of drainage water during operation				(X)	(X)	X		X
	Storage facility may be situated below the natural groundwater table, whereas the salt formation may be quite impermeable to water. However, the construction of the underground facilities, such as excavations, shafts etc, may constitute passages for water into the facility, hence it cannot be ruled out that the facility may require pumping of drainage water during operation							X	

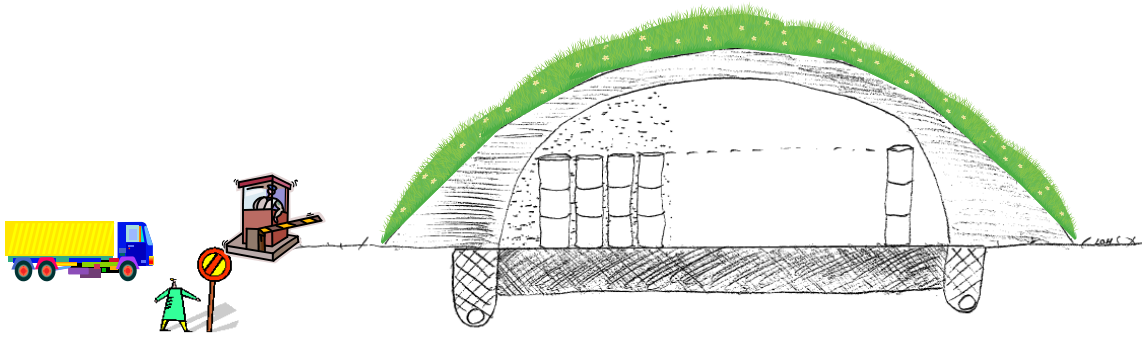
Above ground in storage building, stored in retrievable manner

Mercury can be stored in conventional storage buildings over a limited period of time. The method requires supervision and a certain amount of maintenance. Mercury being a toxic element requires that the storage building is protected against intrusion to avoid risk of human health and the environment. The stored mercury should be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions etc. This puts some requirements on the competence of the storage facilities where the mercury is kept. Further, the geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the storage facility.



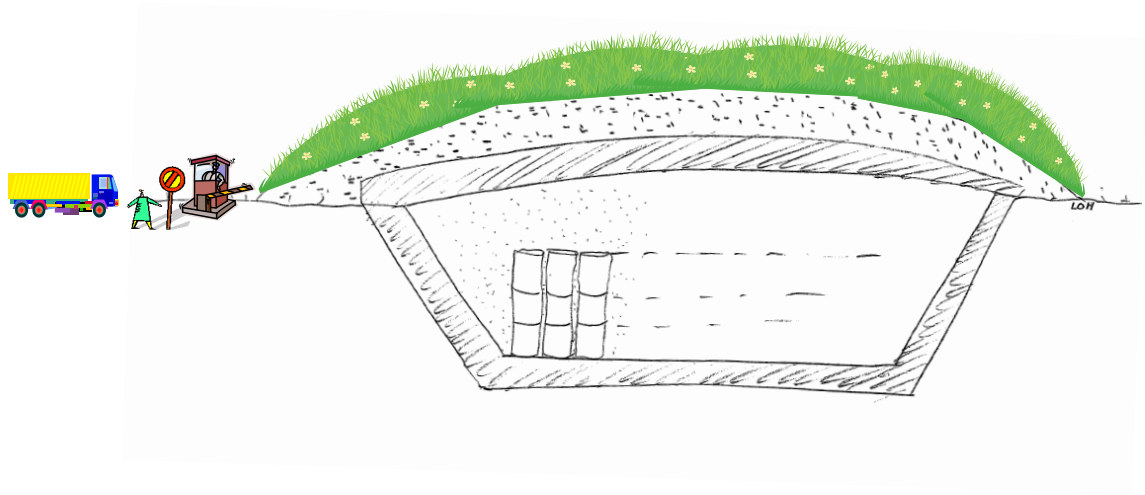
Above ground in landfill, stored in retrievable manner

Mercury can be stored in an above-ground landfill over a limited period of time. The method requires supervision and a certain amount of maintenance. Mercury being a toxic element requires that the landfill is protected against intrusion to avoid risk of human health and the environment. The stored mercury should be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions, digging and construction work etc. This puts some requirements on the competence of the landfill where the mercury is kept. Further, the geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the landfill. It is also important that mercury put into a landfill intended as a temporary storage solution is constructed in such a way that retrieval of the mercury can be done efficiently and without jeopardizing the integrity of the landfill facility, or that any risk for uncontrolled release of mercury would appear. It is important that mercury stored in the landfill is kept separate from other contaminants and materials in the landfill, usually this can be achieved by compartmentalization of the landfill.



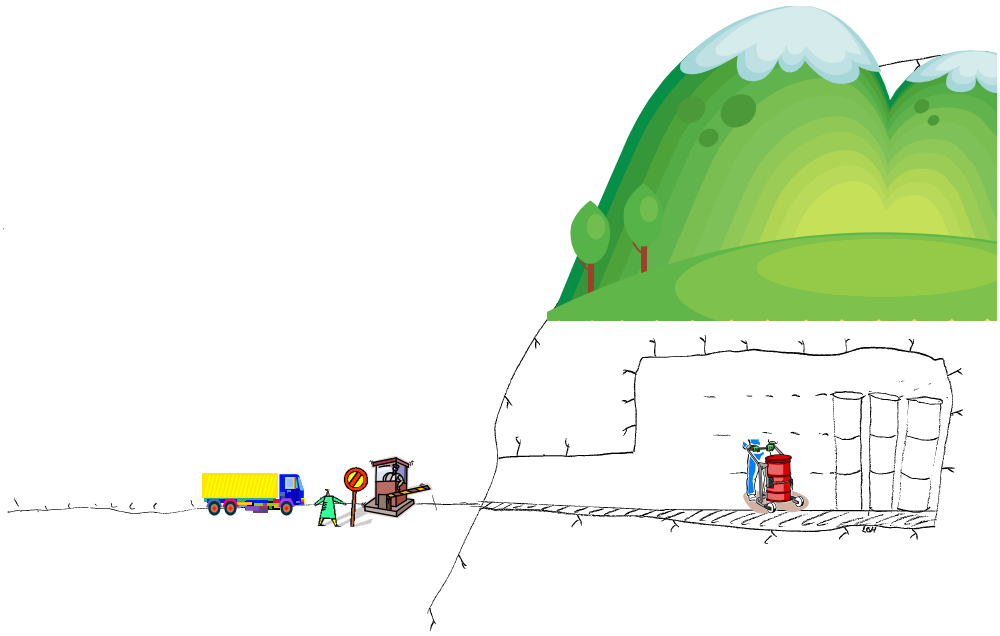
Near surface below ground in landfill, stored in retrievable manner

Mercury can be stored in a below-ground landfill over a limited period of time. The method requires supervision and a certain amount of maintenance. Mercury being a toxic element requires that the landfill is protected against intrusion to avoid risk of human health and the environment. The stored mercury should be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions, digging and construction work etc. This puts some requirements on the competence of the landfill where the mercury is kept. Further, the geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the landfill. It is also important that mercury put into a landfill intended as a temporary storage solution is constructed in such a way that retrieval of the mercury can be done efficiently and without jeopardizing the integrity of the landfill facility, or that any risk for uncontrolled release of mercury would appear. It is important that mercury stored in the landfill is kept separate from other contaminants and materials in the landfill, usually this can be achieved by compartmentalization of the landfill.



Near surface in shallow rock cavern, stored in retrievable manner

Mercury can be stored in a shallow rock cavern over a limited period of time. The method requires some supervision and a minor amount of maintenance. Mercury being a toxic element requires that the storage facility is protected against intrusion to avoid risk of human health and the environment. The stored mercury should be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions, digging and construction work etc. This puts some requirements on the competence of the rock storage facility where the mercury is kept. Further, the rock mechanic, geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the storage facility. All these factors can be expected to be well fulfilled by rock cavern storages. It is also important that mercury put into a rock cavern intended as a temporary storage solution is constructed in such a way that retrieval of the mercury can be done efficiently and without jeopardizing the integrity of the storage facility, or that any risk for uncontrolled release of mercury would appear. It is important that mercury stored in the rock cavern is kept separate from other contaminants and materials in the storage facility, usually this can be achieved by compartmentalization of the caverns. Rock caverns can be excavated in hill slopes (as inferred by the illustration) or vertically in shallow bed rock. A typical rock overburden required for a shallow rock storage cavern is on the order of a few tens of metres. A shallow rock cavern may have been excavated and used for other purposes, such as oil storage, military purposes etc. This may call for specific measures before use, e.g. clean-up.



Near surface in excavated storage location in surface soil, stored in retrievable manner

Mercury can be stored in a excavated storage facilities in surface soils over a limited period of time. The method requires some supervision and a certain amount of maintenance. Mercury being a toxic element requires that the landfill is protected against intrusion to avoid risk of human health and the environment. The stored mercury should be protected from the direct exposure to rain, sun, wind, flooding, extreme cold conditions, digging and construction work etc. This puts some requirements on the competence of the excavated storage facility where the mercury is kept. Further, the geotechnical and tectonic conditions at the site must be thoroughly evaluated to ensure physical stability of the storage facility. Under the condition that the requirements on geotechnical and tectonic stability can be assured, all these factors can be expected to be well fulfilled by excavated storage facilities in surface soil. It is also important that mercury put into an excavated storage facility in surface soil intended as a temporary storage solution is constructed in such a way that retrieval of the mercury can be done efficiently and without jeopardizing the integrity of the storage facility, or that any risk for uncontrolled release of mercury would appear. It is important that mercury stored in the storage facility is kept separate from other contaminants and materials in the storage facility, usually this can be achieved by compartmentalization of the storage facility. Storage facilities can be excavated in hill slopes or vertically in shallow soil deposits (as inferred by the illustration) of sufficient depth. A typical surface soil deposit depth required for an excavated storage facility is on the order of a few tens of metres. Supporting constructions in the excavated facility, e.g. supporting walls may be required to assure mechanical stability.