Technologies for the stabilization of elemental mercury and mercury-containing wastes

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Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH

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Final Report

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1 Executive Summary

As complementary input to ongoing UNEP's consideration on the issue of storage of mercury, the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), a Germany based independent expert- and research organisation on behalf of the German Federal Ministry for the Environment (BMU) has conducted a literature overview to identify and describe existing technologies for the stabilization/solidification of liquid (elemental) mercury and mercury-containing wastes. The goal of these methods is to chemically convert elemental mercury and mercury-containing waste into thermodynamically more stable and solid compounds with considerably less volatility and less solubility. Such compounds may pose a smaller risk to human health and the environment. This overview on stabilization/solidification methods is meant as contribution for further consideration how to facilitate national and (sub)regional efforts to manage, store and dispose waste mercury and mercury-containing wastes in an environmentally sound manner.

Based on an extensive literature survey, three existing stabilization approaches could be identified: conversion to sulphide / selenide, amalgamation, and stabilization within an insoluble mineral matrix. For each of these approaches a number of technological implementations were found which are described in detail. The degree of industrial scaling varied widely: some processes have been tested or, at least, documented, so far, only in laboratory, while others were already demonstrated in semi-industrial scale (~ 100 kg/d). Some are announced to reach full industrial scale (> 1000 t/a) in due time.

Key findings from the literature investigation include: Most processes succeeded in producing a chemically and physically more stable product. Standard leaching procedures showed that under defined conditions mercury concentrations in leachates were below regulatory standards (USA or Japan). The same result was often found when the vaporization of mercury from the products was tested. On the other hand some methods could be identified which, according to reviews in the recent ten years, were unable to reduce the leachability and volatility of mercury sufficiently. Unfortunately, for some procedures such investigations were insufficiently documented or not conducted, so far. Moreover, it seems to be questionable whether it is enough to apply standard leaching tests in order to assess the long-term behaviour of stabilized mercury-containing waste forms. The leachability and volatility of mercury in solids strongly depends on the physical and chemical pre-conditions at the place of storage.

These might not be the same as presumed in standard leaching procedures. Further experimental work assisted with geochemical modelling could be one way to identifying further suitable technological approaches that are tailor-made to the conditions of existing and potential future storage locations.

2 Glossary of some technical terms used in this report

Amalgamation

A chemical process unique to elemental mercury, in which another metal forms a semisolid alloy ("amalgam") with mercury. Mercury dissolves in the solid metal, forming a solid solution. The process is reversible, so that mercury can be released from these alloys by heating. Amalgams, although solid, show a significant vapour pressure and solubility of mercury. Both differ only little from pure liquid mercury.

Chemical stabilization

A chemical process that converts a chemical substance into another substance that is thermodynamically more stable, less soluble and less volatile under the geochemical conditions of the storage location.

Containment/ macroencapsulation

A technical process where a substance is contained into an impermeable matrix or an impermeable container. Once the matrix or the container is fractured or otherwise degraded, the containment completely looses is barrier properties.

Immobilization

Any chemical or physical process that leads to a lower mobility (leaching after contact with aqueous media or vaporization into the gas phase) of hazardous substances.

Solidification/ physical stabilization

A technical or chemical process that renders a liquid or paste-like material into a solid one with enhanced physical strength (e.g. compressibility).

NIOSH

US National Institute for Occupational Safety and Health. It has established a recommended exposure limit (REL) for mercury vapour of 0.05 mg/m^3 as a time-weighted average (TWA) for up to a 10-hour workday and a 40-hour workweek [46].

TCLP

The Toxicity Characteristic Leaching Procedure (TCLP) is designed by the US Environmental Protection Agency (US EPA) to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. The TCLP analysis tries to simulate landfill conditions. A waste or waste product is considered hazardous if one of the leachate concentrations exceeds certain limits defined in the Resource Conservation and Recovery Act (RCRA)/ Land Disposal Restrictions. The limit for mercury is set to 0.2 mg/l.