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Long-term Environmentally-sound Management of Treated Waste Consisting of Elemental Mercury in an Aboveground Facility

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The Minamata Convention on Mercury entered into force on August 16, 2017, notably decreasing the demand for mercury and changing the global supply-demand balance. Inevitably, the mercury recovered from mercury waste and industrial processes is in excess. This has necessitated long-term environmentally-sound management of elemental mercury. This research project has examined long-term management of treated waste consisting of elemental mercury in an aboveground facility as well as in a landfill site with suitable storage and treatment facilities.

It is of importance to evaluate the atmospheric release of mercury from treated wastes in aboveground facilities. Therefore, a head space test was developed, and specific testing conditions (sample amount, temperature, humidity, gas flow rate, duration) and operations were proposed. The solidification of treated waste consisting of elemental mercury using a thermosetting epoxy resin was examined in terms of weathering, evolved gas, gas transmission rate and microbiological deterioration, as well as uniaxial compression strength, leaching behavior, and thermal, chemical and freeze-thaw resistances (Photo 1). This demonstrated that material solidified using the epoxy resin was similar to or better than that processed using a dicyclopentadiene (DCPD)-modified sulfur, which had been already approved in Japan (Table 1). Coating with stabilized, solidified waste mercury using this epoxy resin was an effective additional measure for secure containment of mercury.

Photo 1 Monolithic specimens solidified with epoxy resin (left) and modified sulfur (right).

Table 1 Overview of solidification using epoxy resin and modified sulfur.

	Criteria or standard	Epoxy resin	Modified sulfur
HgS (wt%)	-	80	50
Compression strength (MPa)	≧0.98	107.0	30.6
Leaching test (JLT-13) (μg/L)	≦0.5	0.09	0.05
Tank leaching (μg/L)	≦0.5	＜0.01	＜0.01
Head space (μg/m^3)	≦1.0	＜0.1	＜0.1

Landfill experiments using lysimeters were conducted to examine mercury dissolution and diffusion in mercury waste. These processes were simulated using powdered mercury sulfide or material solidified with cement and mixed with incineration ash with organic sludge compost as shown in Fig. 1. According to the mercury concentration of leachate from the lysimeters, the lysimeter in which mercury sulfide was solidified using cement was shown to be faster than the others at achieving levels below the environmental standard (0.0005 mg/L). From a comparison of landfill types, the amount of mercury leaching in the anaerobic type was higher than that in the semi-aerobic type. In all experiments, the amount of leached mercury exceeded that of vaporized mercury in the lysimeters. The remaining percentage of mercury in the lysimeters after the five-year experiment was calculated at more than 99.9999%, meaning that cement solidification would maintain almost complete stability of mercury when treated mercury waste was exposed to real landfill environments over long periods. Therefore, solidification of mercury waste is key. From these results, the optimal site for landfilling of mercury waste is proposed to be the middle and upper layers in a controlled landfill of a semi-aerobic landfill type. In addition, pretreatment processes such as washing of solidified mercury waste before landfill disposal were effective at reducing the risk of mercury emissions, because the vaporization of mercury was supressed by removal of the powdered mercury sulfide on the surface of the solidified materials. Also, it was demonstrated that the semi-aerobic landfill type had reduced solubilization and vaporization risks from sulfurized/solidified mercury wastes.

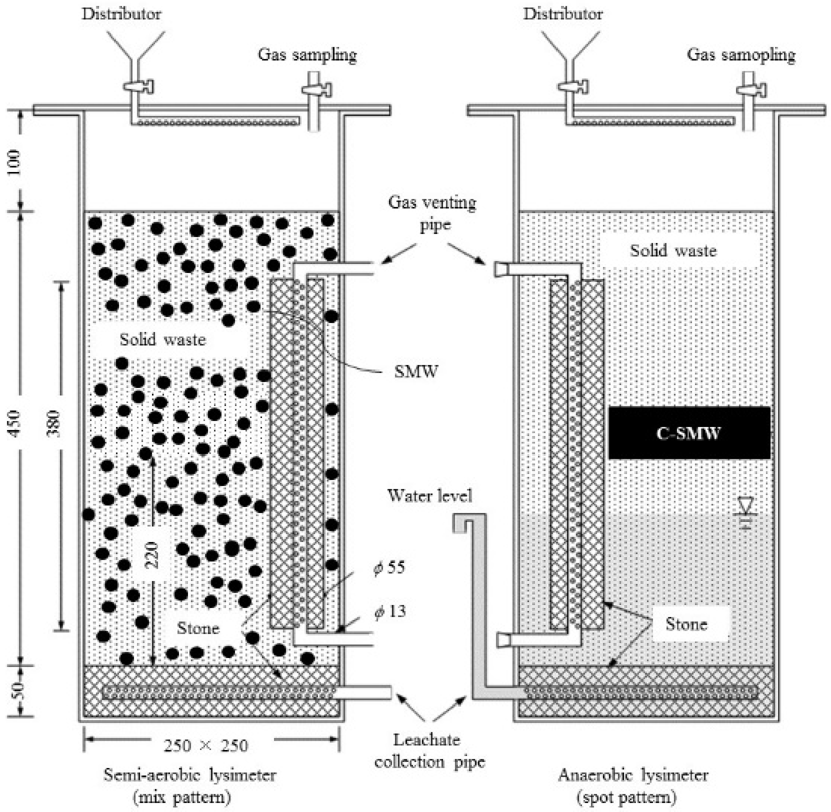

Fig. 1 Diagram of experimental lysimeters.
(SMW: sulfurized mercury waste, C-SMW: SMW solidified with cement)

The environmental risks of long-term mercury storage on the ground due to large earthquakes was assessed using a mercury environmental fate model. In this model, stochastic distributions of major model variables were included to embed large uncertainties of model variables. A component model for earthquake impact prediction showed good agreement with a geographical earthquake prediction model for peak ground velocity and with a Brownian-Passage-Time distribution model for earthqauake event probabity, respectively (Fig. 2). The model suggested that a large "class 7" earthquake might occur within 50 years with a 1.7% probability. On the other hand, the environmental risk of mercury leaching after the earthquake was very low. Unacceptable mercury exposure might happen with less than 0.01% probability (Fig. 2). Therefore, it is concluded that big earthquakes would cause negligible risks in long-term mercury storage on the ground. From a questionnaire survey, it was found that people had a strong perceptive aversion to mercury. Even when they accepted the social necessity of a mercury-disposal landfill site, they still felt a very strong aversion. The questionnaire survey suggested that 1000-year safe storage be proposed in accordance with cognitive safety of mercury final disposal.

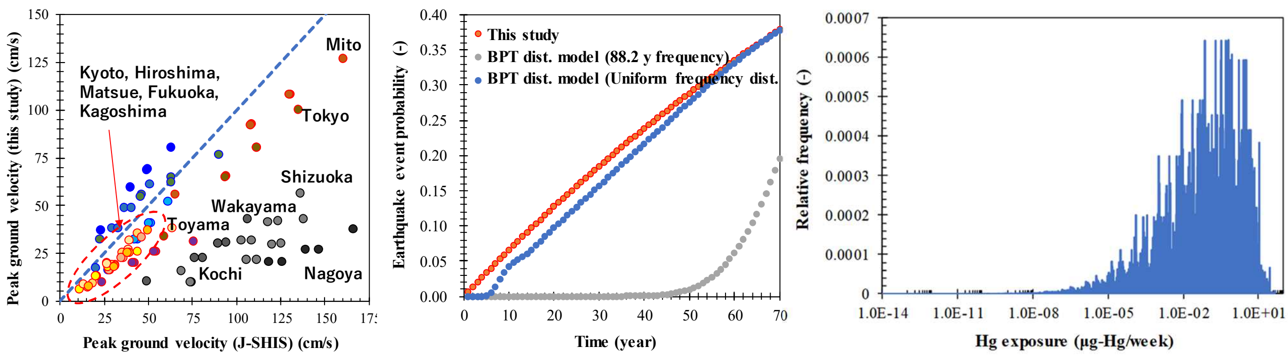

Fig. 2 Model verification in terms of peak ground velocity (left) and earthquake event probability (center), and predicted Hg exposure (right).