Waste Management Attendant Mercury Issues Involving Mercury-Contaminated Debris at the Y-12 Site, Oak Ridge, Tennessee – 15573

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ABSTRACT

The purpose of this evaluation is to gain a better understanding of the extent of mercury contamination within the four Y-12 major mercury contaminated complexes, to identify strategies to reduce the quantity and concentration of mercury in the D&D debris prior to disposal, and to evaluate disposition options for the mercury-contaminated debris that are protective of human health and the environment. Although the focus of this evaluation is on the mercury-contaminated debris that exceeds regulatory requirements for direct land disposal, other media contaminated with mercury are noted when relevant to the discussions. The information presented in this report can be used to plan future D&D and remedial actions (RA) within Y-12 mercury-contaminated zones.

INTRODUCTION

The Y-12 National Security Complex (Y-12) contains approximately 100 facilities requiring deactivation and demolition (D&D). Out of these 100 facilities, four large, former processing buildings are known to be contaminated with mercury: Building 9201-2 (Alpha-2), Building 9201-4 (Alpha-4), Building 9201-5 (Alpha-5), and Building 9204-4 (Beta-4). These four buildings and their ancillary facilities encompass over 1.8M ft^2 of floor space with a footprint of over 600,000 ft^2. Alpha-2 is managed by the Oak Ridge National Laboratory (ORNL), Alpha-4 is managed by URS | CH2M Oak Ridge LLC (UCOR) under the U.S. Department of Energy's (DOE's) Environmental Management (EM) program; Alpha-5 and Beta-4 are managed by Consolidated Nuclear Security, LLC (CNS).

D&D activities for these facilities are anticipated to begin in Fiscal Year (FY) 2021 (DOE/OR/01-2605&D2, *Strategic Plan for Mercury Remediation at the Y-12 National Security Complex, Oak Ridge, Tennessee*). Approximately 381,000 yd^3 of debris[1] is estimated to be generated during D&D. The forms of debris include process equipment and piping, structural and non-structural steel and other metals, concrete, clay block and tile, brick, and roofing material. Based on available survey and analytical data, it has been assumed that over 100,000 yd^3 of this debris will exceed mercury contamination concentrations for direct land disposal and will require treatment.

DISCUSSION

Mercury is present within the four complexes primarily in the form of liquid mercury held up in piping and equipment, as well as in contamination of the structure, porous surfaces, such as concrete floors and tile or transite walls. Some mercury may be in other forms from weathering due to chemical interaction or chemical reaction with sulfur during spill cleanup to form mercury sulfide. Subsequent operations also contaminated some areas, primarily in Alpha-5, with beryllium.

Numerous documents and databases were reviewed to assess the extent of mercury contamination within the four complexes. Their references are included in Appendix A. The draft *Data Gap Assessment Report for Alpha-5, Alpha-4, and Beta-4 at the Y-12 National Security Complex, Oak Ridge, Tennessee*, 5205-TR-01, was also reviewed and the conclusions verified to assist in developing the data gaps presented in the following subsections.

Much of the characterization data is compared to Resource Conservation and Recovery Act (RCRA) criteria. The RCRA hazardous waste limit for mercury from Toxicity Characteristic Leaching Procedure (TCLP) extract is 0.2 mg/L. RCRA provides a 20-times rule (referred to as "20×") for comparing total mercury to the hazardous waste limit where the TCLP limit is multiplied by 20 to produce units of mg/kg. Units of mg/kg are equivalent to µg/g or ppm; each of these units is used in this document based on the units in the original report. For mercury, 20 times 0.2 mg/L gives a limit of 4 mg/kg—or 4 µg/g—when reviewing results for total mercury. From a practical perspective, if the mercury is in the form of liquid mercury, which is not very soluble in the mildly acidic TCLP extraction solution, total mercury results may be significantly higher than 4 mg/kg before the TCLP mercury analysis will exceed the RCRA limit .

Alpha-2

No characterization information was located regarding the Alpha-2 structure, process piping, or equipment. Mercury is known to be in the building structural materials. When the first floor was converted to office space and the blocks and walls were removed, mercury seeped out from the walls (Y/EX-24. *Mercury at Y-12, A Study of Mercury Use at the Y-12 Plant, Accountability, and Impacts on Y-12 Workers and the Environment - 1950 to 1983*). Mercury is also known to be present within inactive pipelines at their joints.

Characterization has been performed for the Alpha-2 basement soil. Mercury contamination was identified in the northeast and southeast corners of the basement soil and is likely a continuous contamination area, also including the concrete on the east side. Although soil results are for total mercury, samples in this area are also likely to exceed the TCLP mercury limit. Those samples that may potentially pass TCLP, although total mercury results are > 20× the TCLP limit, are found in the center and north central areas. Based on this evaluation, approximately a third of the basement area may exceed RCRA land disposal restrictions (LDR) limits for mercury. This information and spill descriptions provide information for a biased sampling approach where, if mercury results from the highest expected mercury contamination areas (center to east side) are acceptable under RCRA and for visible mercury, then the entire facility would only require limited confirmation sampling (west side). It should be noted that the majority of samples collected in the soil study were from central to the east side with fewer samples toward the west due to access limitations.

Elemental mercury, mercury sulfide (HgS), and other inorganic salt forms of mercury are not very soluble in the weakly acidic TCLP leachate solution. These are the dominant forms of mercury found in Alpha-2 soil. There is some indication that mercury contamination in the basement of Alpha-2 is a result of leaks from piping in the basement; however, three large spills documented were in the operations areas suggesting that the upstairs may be more contaminated from operations. The extent of building remodeling was not observed for this evaluation and associated documents were not available for review. Confirmation of no mercury contamination would be proposed for the remodeled areas of the building and comprehensive characterization of walls and floors would be required for original areas.

Alpha-4

There are many similarities between the structure and processes that were conducted in Alpha-5 and Alpha-4 and some assumptions concerning the conditions in Alpha-4 may be made based on the more complete characterization information from Alpha-5. Although the original design and construction of Alpha-5 and Alpha-4 were identical, during the installation of the COLEX process Alpha-4 was modified to include diking and curbing in the COLEX process areas to contain mercury releases in the building based on knowledge gained during the Alpha-5 start-up and operation. There are limited data gaps for Alpha-4 primarily due to changes in regulatory oversight expectations, disposal facility waste acceptance criteria (WAC) and the expected demolition approach from the 1994-95 characterization. All areas of Alpha-4 remain accessible for further characterization, as needed.

Use of Roof Duct and Equipment Sampling

In 1987, a number of samples for total mercury were collected for the tanks, general ventilation motors and duct, the hydrogen vent system on the roof, and some piping. It is implied, but not always specifically stated, that the samples collected were cut metal coupons from the respective items for sampling. The low total mercury results suggest that this waste form would likely pass TCLP if performed as part of a hazardous waste determination. Without supporting documentation on the data quality, this 1987 data can be used for informational purposes to limit the number of additional (confirmation) samples required for the duct and vent inside Alpha-4, based on the expectation that these materials are suitable for on-site disposal without treatment.

Use of Radian Building Characterization Sampling

The purpose of the Radian Characterization project in 1994 and 1995 was to identify hazards that would be encountered during the D&D of Alpha-4 and not necessarily to provide characterization data for the disposition of waste. The approach used for the previous characterization does not always completely fulfill the requirements for waste characterization, which results in limited data gaps.

Both field methods, immunoassay and X-ray fluorescence (XRF), employed in the Radian study have significant uncertainty associated with the quality of the results and were only applicable to surface contamination, which would not be representative of the total waste form. Field measurements from the previous characterization efforts would not be used for waste characterization except qualitatively when confirmed by laboratory analysis, e.g. to determine areas for comprehensive vs. confirmation characterization.

Additional cleanup of Alpha-4 has been performed since the Radian characterization; however, the structural conditions are expected to be similar to those found at the time of the Radian characterization. The proposed characterization approach would be new sampling and analysis based on areas identified from the 1994–95 characterization, followed by an evaluation of whether to use the existing Radian data set (additional data and historic data are statistically similar), or perform more extensive new sampling and analysis (additional data are statistically different from historic data).

Data Gaps

The concrete under the new roof may be contaminated with mercury. The roof was not included in surveys and characterization by Radian in 1994–1995. Characterization of ceilings and roofs remains to be performed. Characterization of the rock wool insulation has not been performed;

analysis for heavy metals, including mercury, should be performed. Asbestos removed was found to have significant levels of mercury.

Alpha-5

Alpha-5 was characterized in 2011 and has the most recent data set. Alpha-5 has extensive access issues due to the poor structural condition of the building. The discussion of data gaps below does not consider whether access will prevent collection of additional data.

Beta-4

Systematic characterization of Beta-4 has not been performed. Characterization would begin with process knowledge (PK) assessments and a facility walkdown. The operational process in Beta-4 was different than in Alpha-4 and Alpha-5, so there is not a direct correlation to similar operational areas, although some comparison may be able to be made. A decision on cost and schedule will be needed to determine whether to perform a targeted characterization that might confirm compatibility with a waste profile for the Alpha facilities, or whether to perform a more in depth characterization for a potential stand-alone profile that may require less deactivation or treatment.

DISPOSITION OPTIONS FOR Y-12 MERCURY-CONTAMINATED DEBRIS EXCEEDING LAND DISPOSAL RESTRICTIONS

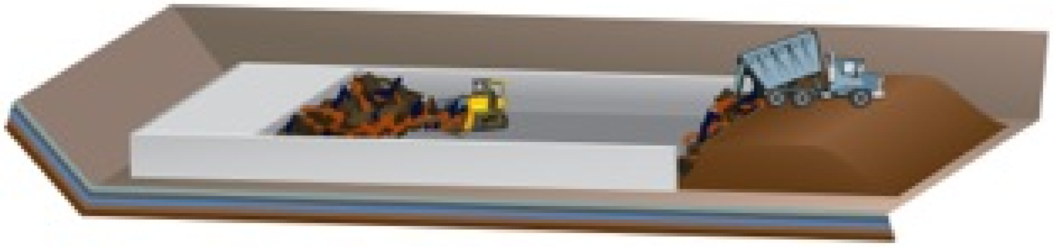
Options for disposition of the Y-12 mercury-contaminated debris that exceed LDRs are described below. These options include six on-site macroencapsulation and disposal options and an option for off-site transportation and disposal. Rough-order-of-magnitude (ROM) life cycle estimates were developed by UCOR for the on-site options. The on-site estimates include a 15% contingency, along with a 50% plus up for accuracy. Based on the conceptual nature of these options, the 50% plus up estimates are used for cost comparisons. ROM or budgetary estimates were also requested from three commercial facilities for off-site transportation, treatment and disposal. All cost estimates assume that demolition of the Y-12 mercury-use buildings begin in FY 2021 and continue for approximately 7 years. The estimates also assume that approximately 100,000 yd^3 of mercury-contaminated debris will exceed RCRA LDR requirements thus requiring treatment. Table 5.2 shows a comparison of the ROM cost estimates for the on-site and off-site options. The Basis of Estimates and build-up for the on-site cost estimates are contained in Appendix B.

Option 1 - Large scale in-cell macroencapsulation

This option involves constructing a large (550-ft-long, 100-ft-wide, 10-ft-high walls), open-ended, concrete vault on top of a new disposal facility liner system. Demolition debris would be placed into the vault in lifts and compacted using a dozer. After waste placement the vault would be filled periodically with controlled low-strength material (CLSM) to eliminate void spaces. Water collected within the vault during waste placement would be removed and treated appropriately. Seven vaults will be required to accommodate the anticipated 100,000 yd^3 of waste requiring treatment.

With Option 1, debris would be loaded at the generator site, transported to the on-site disposal facility, and dumped at the open of the large concrete vault. A dozer would be used to place and compact the waste within the vault. This option offers minimal requirements for size reduction at the generator site and the most compaction within the disposal facility.

Large scale in-cell macroencapsulation is estimated at $42M.

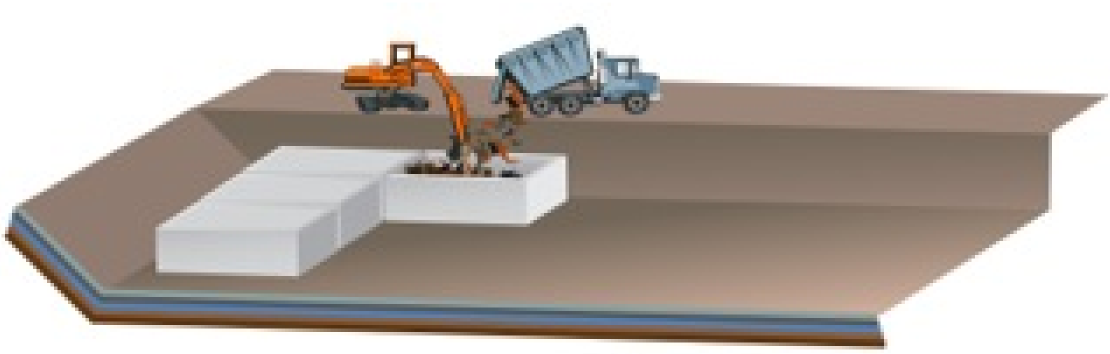


Option 2 - Medium scale in-cell macroencapsulation

This option is similar to Option 1, except the waste would be placed and compacted in smaller concrete cells, approximately 30-ft-long by 30-ft-wide, with 10-ft-high walls. Eighteen cells would make one concrete vault. Demolition debris would be placed into the cell in lifts. After each cell is full of debris, CLSM would be placed around the debris to fill void space. Water collected within the vault during waste placement would be removed and treated appropriately. Thirty-three concrete vaults, sectioned into eighteen 30-ft by 30-ft cells, would be required.

With Option 2, debris would be loaded at the generator site, transported to the on-site disposal facility, and dumped into the medium scale concrete vaults from the side of the disposal facility. A trackhoe, working outside the cell would move and arrange the waste. This option offers minimal size reduction at the generator site (similar to Option 1), however the debris would not be compacted as efficiently as in Option 1. This option minimizes the footprint and length of time that any given cell is open compared with Option 1.

Medium scale in-cell macroencapsulation is estimated at $77M.



Option 3 – Large containers filled with CLSM and placed in macro-bags in-cell

This option involves loading debris into top-loaded Sealand containers at the generator site and shipping the containers to the on-site disposal facility. A macro-bag would be placed on the disposal facility cell floor. The container would be placed on the bag, voids in the container would be filled with CLSM or a lighter material, and the macro-bag would be closed around the container.

With Option 3, debris would be sized-reduced at the generator size to dimensions that would fit into Sealand containers. The Sealand containers would be protected by lining the containers with plywood. Equipment would be needed at the generator site to load the Sealands on the transport vehicle and at the disposal facility to unload the Sealands. Over 4600 Sealand containers and macro-bags would be required. This option minimizes the opportunities for macro-bags to be torn or damaged during handling.

Large containers filled with CLSM and placed in macro-bags in-cell is estimated at $171M.

Option 4 – Large containers filled with CSLM and placed in macro-bags out of cell

This option involves loading debris into top-loaded Sealand containers at the generator site and shipping the containers to the on-site disposal facility. A macro-bag would be placed in a designated area outside of the disposal facility cell. The container would be placed on the bag, voids in the container would be filled with CLSM or a lighter material, and the macro-bag would be closed around the container. The container would then be placed in the disposal facility cell.

This option is similar to Option 3, except that filling the container with CLSM and adding the macro-bag enclosure would be performed outside of the disposal facility cell. This option would require construction of a staging area outside of the disposal cell for the Sealands while they are filled with CLSM and allowed to cure. Extra care would be needed to ensure that the integrity of the macro-bags are maintained when the bagged Sealands are moved from the staging area into the disposal cell. Compared with Option 3, more robust equipment (such as cranes) would be needed at the disposal facility to lift and move the heavier Sealands filled with CLSM onto transport vehicles and place the Sealands in the disposal cell.

Large containers filled with CSLM and placed in macro-bags out of cell is estimated at $202M.

Option 5 - Large containers filled with CLSM out of cell

This option involves loading debris into top loaded Sealand containers at the generator site. These Sealands would be modified with plastic pallets around the edge prior to loading to allow the CLSM to flow around the debris. This mimics the current practice at ERDF at DOE's Hanford site. The plywood lining used in Options 3 and 4 would not be required in Option 5. The loaded containers would be shipped to the disposal facility and filled with CLSM outside of the disposal cell. After the CLSM has cured, the containers would be placed in the disposal facility cell.

This option is similar to Option 4. However, lining the Sealands with plastic pallets would allow the CLSM to completely encapsulate the debris and eliminates the need for the macro-bag. The addition of the plastic pallets reduces the usable volume of the Sealand. Option 5 would require the purchase of approximately 5405 Sealand containers.

Large containers filled with CLSM out of cell is estimated at $251M.

Option 6 – Small containers filled with CLSM and placed in macro-bags at generator site

Option 6 was the only on-site option evaluated that meets the current limitations of the EMWMF Record of Decision (ROD) (i.e., treatment is performed by the generator). In Option 6, the debris is size-reduced at the generator to fit into a B-25 container. The container is filled with CLSM and enclosed with a macro-bag at the generator site. Once the CLSM has cured the container is transported to the disposal facility and placed in the disposal cell.

With Option 6, significant waste handling and size reduction would be required at the generator site. The generator site would also need to be equipped with a batch plant to produce the CLSM and a staging area for the B-25s while curing. This option significantly increases the waste disposal volume due to the size reduction required for the debris to fit into the B-25 and the lack of compaction. Option 6 would require the purchase of approximately 60,600 B-25 boxes.

Small containers filled with CLSM and placed in macro-bags at the generator site is estimated at $286M. The cost estimate for this option only includes costs for the containers, macro-bags, and CLSM. Costs associated with the additional size-reduction equipment and personnel that would be required, as well as transportation of the containers to the disposal facility would substantially increase this estimate.

Option 7 - Off-site transportation and disposal

Several commercial facilities have the capability and regulatory authority to treat mercury debris exceeding LDRs. As a part of this evaluation, UCOR developed a statement of work (SOW) requesting budgetary estimates from three commercial vendors for the transportation, treatment and disposal of 100,000 yd^3 of mercury-contaminated demolition debris. The SOW identified that the waste would be generated over 4 to 7 years and would be sized in 6-ft-lengths (which is similar to the current EMWMF WAC). In addition, the SOW identified three disposal options—the on-site Oak Ridge CERCLA landfill, NNSS, or an off-site approved commercial landfill.

Because of the different transportation, receipt, treatment and disposal capabilities of each vendor, the responses had very different implementation approaches. These approaches are:

(a) Building a temporary structure near the demolition site to size and package the debris in boxes followed by disposal at the on-site DOE CERCLA landfill. This scenario minimizes transportation costs, but relies on disposal at the on-site CERCLA landfill.

(b) Providing transportation by rail and commercial disposal with treatment to be performed by the generator in macro-bags. This scenario includes use of larger containers for transport by rail, which is inherently less expensive than truck transportation and does not require disposal at the on-site CERCLA landfill. However, it would require the D&D project to provide treatment (in macro-bags) prior to transportation. There are concerns with macro-bags being damaged by sharp edges associated with demolition debris during transport, which would need to be addressed.

(c) Providing turnkey services for transportation by rail, followed by treatment and disposal at an approved commercial facility. This option allows for the use of larger containers for transport by rail, does not require disposal at the on-site CERCLA landfill, and does not require the D&D project to perform “treatment” prior to transport.

None of the options proposed by the vendors included disposal at NNSS.

Discounting the first approach of building a temporary on-site processing facility and disposal in the on-site CERCLA landfill (similar to Option 6 above) and accounting for costs for the generator to provide treatment of the debris prior to transport in the second approach, the average ROM costs (including project management and contingencies) of the two off-site options are approximately $274M.

One of the off-site options included use of large freight cars for direct containerization and rail transport. This would require rehabilitation of existing or construction of a new rail spur within the Y-12 Plant. The cost for this rail spur has not been included in this ROM estimate, but the freight cars are significantly larger than macro-bags, boxes, or other intermodals, and as such, would not require nearly as much sizing of demolition debris during D&D as would be required, otherwise. Thus, there would be a significant reduction in demolition costs and life-cycle project costs.

Table 5.2. Comparison of rough order of magnitude cost estimates for disposition of Y-12 mercury debris exceeding land disposal restrictions

Disposition option for mercury debris > LDR	Rough order of magnitude point estimate	Point estimate with 15% contingency	Point estimate with 15% contingency plus 50%
On-site options			
Option 1 - Large scale in-cell macroencapsulation	$24M	$28M	$42M
Option 2 - Medium scale in-cell macroencapsulation	$45M	$51M	$77M
Option 3 – Large containers filled with CLSM and placed in macro-bags in-cell	$99M	$114M	$171M
Option 4 – Large containers filled with CSLM and placed in macro-bags out of cell	$117M	$135M	$202M
Option 5 – Large containers filled with CLSM out of cell	$146M	$168M	$251M
Option 6 – Small containers filled with CLSM and placed in macro-bag at generator site	$166M	$191M	$286M
Off-site option			
Option 7 - Off-site transportation and disposal	$159M	$183M	$274M

LDR = land disposal restriction

CONCLUSIONS

Characterization

Previous volume estimates assume that up to 100,000 yd^3 of mercury-contaminated debris, generated from D&D of the Y-12 mercury-use complexes, may require treatment to meet LDRs prior to land disposal. Based on preliminary correlations between total and TCLP mercury concentrations, there may less debris requiring treatment than originally assumed. Significant data gaps exist for the four mercury-use complexes regarding the presence and concentration of mercury (and beryllium) in the various media. Additional characterization, particularly TCLP testing, will be needed to accurately estimate the volume of mercury-contaminated debris requiring treatment, to delineate highly-contaminated areas, and to determine health and safety requirements for D&D.

Pre-demolition

Actions should be taken prior to D&D to aggressively remove accessible elemental mercury from equipment, piping, and within the building structures. Highly-contaminated materials and other select items (classified materials and potentially recyclable metals) may be identified for targeted removal prior to building demolition. These pre-demolition actions combined with strategic waste segregation should reduce the quantity of mercury-contaminated debris requiring treatment to meet LDRs.

Disposition

The most cost-effective disposition for Y-12 D&D debris is disposal at an on-site disposal facility, provided the WAC are met. Some of the debris will require treatment to meet LDRs prior to land disposal. EPA's alternative treatment technology of macroencapsulation is the most applicable technology for treating Y-12 mercury-contaminated debris exceeding LDRs. Macroencapsulation is a proven technology and is successfully used at several commercial facilities. Large scale, in-cell, macroencapsulation is the most cost effective macroencapsulation option for the Y-12 debris and provides for maximum compaction and minimum disposal volume. Regulatory compliant approaches are available to allow macroencapsulation in a new on-site disposal facility if on-site disposal is the remedy selected during the CERCLA process.