An Exploration of Mercury Soils Treatment Technologies for the Y-12 Plant – 13217

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ABSTRACT

There are a number of areas at the Y-12 National Security Complex (Y-12) that have been contaminated with mercury due to historical mercury use and storage. Remediation of these areas is expected to generate large volumes of waste that are Resource Conservation and Recovery Act (RCRA) characteristically hazardous. These soils will require treatment to meet RCRA Land Disposal Restrictions (LDR) prior to disposal. URS | CH2M Oak Ridge LLC (UCOR) performed a feasibility assessment to evaluate on-site and off-site options for the treatment and disposal of mercury-contaminated soil from the Y-12 Site. The focus of the feasibility assessment was on treatment for disposal at the Environmental Management Waste Management Facility (EMWMF) located on the Oak Ridge Reservation. A two-phase approach was used in the evaluation process of treatment technologies. Phase 1 involved the selection of three vendors to perform treatability studies using their stabilization treatment technology on actual Y-12 soil. Phase II involved a team of waste management specialists performing an in-depth literature review of all available treatment technologies for treating mercury contaminated soil using the following evaluation criteria: effectiveness, feasibility of implementation, and cost. The result of the treatability study and the literature review revealed several viable on-site and off-site treatment options. This paper presents the methodology used by the team in the evaluation of technologies especially as related to EMWMF waste acceptance criteria, the results of the physical treatability studies, and a regulatory analysis for obtaining regulator approval for the treatment/disposal at the EMWMF.

INTRODUCTION

Releases of mercury during operations at the Y-12 National Security Complex (Y-12) between 1950 and 1963 have resulted in contamination of soil and other media in the Upper East Fork Poplar Creek (UEFPC) area. Remediation efforts which began in the 1980s have eliminated or reduced point sources of mercury contamination but elevated levels of mercury remain in the soil. The UEFPC Phase II Record of Decision (ROD) preferred remedial action is excavation and

disposal of contaminated soil at the Environmental Management Waste Management Facility (EMWMF) (DOE/OR/01-2229&D3). It is anticipated that some of the waste generated under the Phase II ROD remedial action will be Resource Conservation and Recovery Act (RCRA) characteristically hazardous and contaminated with radionuclides. These soils will require treatment to meet RCRA Land Disposal Restrictions (LDR) prior to disposal.

URS | CH2M Oak Ridge LLC (UCOR) performed a feasibility assessment to evaluate on-site and off-site options for the treatment and disposal of mercury contaminated soil from the Y-12 Site that is classified as mixed waste. This paper summarizes results of the feasibility assessment and includes the proposed regulatory approach for treatment operations, the results of a literature evaluation of available treatment technologies for mercury contaminated soil, summary results of three treatability studies performed on Y-12 soils, and the proposed regulatory approach for disposal options.

REGULATORY APPROACH FOR TREATMENT

Mercury characteristic mixed waste soil (D009) generated during Y-12 Site remedial actions will likely require treatment to meet RCRA LDRs and disposal facility waste acceptance criteria (WAC) prior to disposal. RCRA LDRs are regulations contained in 40 *Code of Federal Regulations* (*CFR*) 268 that restrict the land disposal of prohibited hazardous (and mixed) waste and specify treatment standards. LDRs are either numerical standards, or technology-based standards that require the use of specific technologies. The selection of the treatment technology used for the D009 soil will, in part, be determined by the approach chosen to meet LDRs. RCRA LDRs applicable to D009 waste are specified in 40 *CFR* 268 Subpart D and summarized in Table I.

Table I. Summary of RCRA land disposal restrictions for non-wastewater D009 waste

Waste Type	Regulatory Reference	Concentration or Technology
Nonwastewaters ≥ 260 mg/kg total mercury that also contain organics (referred to as the High Mercury-Organic Subcategory)	40 *CFR* 268.40, "Treatment Standards for Hazardous Wastes" Table	IMERC or RMERC
Nonwastewaters ≥ 260 mg/kg total mercury that are inorganic (referred to as the High Mercury-Inorganic Subcategory)	40 *CFR* 268.40, "Treatment Standards for Hazardous Wastes" Table	RMERC
All other nonwastewaters < 260 mg/kg total mercury (referred to as the Low	40 *CFR* 268.40, "Treatment Standards for Hazardous Wastes" Table	0.025 mg/L TCLP and meet 40 *CFR* 268.48 standards

Mercury Subcategory)		
Nonwastewaters ≥ 260 mg/kg total mercury and are residues from RMERC only	40 *CFR* 268.40, "Treatment Standards for Hazardous Wastes" Table	0.20 mg/L TCLP and meet 40 *CFR* 268.48 standards
Elemental mercury contaminated with radioactive materials	40 *CFR* 268.40, "Treatment Standards for Hazardous Wastes" Table	AMLGM
Contaminated soils[1] containing elevated levels of mercury	268.49(c) (1). Alternative LDR treatment standards for contaminated soil	Reduce concentrations of constituents subject to treatment by 90 percent or meet hazardous constituent concentrations that are 10 times the UTS, whichever is greater (for mercury 10 x 0.025 = 0.25 mg/L)

[1]Soil is defined in 40 *CFR* 268.2 (k) to mean "unconsolidated earth material composing the superficial geologic strata (material overlying bedrock), consisting of clay, silt, sand, or gravel size particles as classified by the U.S. Natural Resources Conservation Service, or a mixture of such materials with liquids, sludges, or solids which is inseparable by simple mechanical removal processes and is made up primarily of soil by volume based on visual inspection. Any deliberate mixing of prohibited hazardous waste with soil that changes its treatment classification (i.e., from waste to contaminated soil) is not allowed under the dilution prohibition in 40 *CFR* 268.3".

IMERC – Incineration

RMERC – Retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery.

AMLGM – Amalgamation of liquid, elemental mercury contaminated with radioactive materials utilizing inorganic reagents such as copper, zinc, nickel, gold, and sulfur that result in a nonliquid, semi-solid amalgam and thereby reducing potential emissions of elemental mercury vapors to the air.

TCLP – Toxicity Characteristic Leaching Procedure

UTS – Universal Treatment Standard

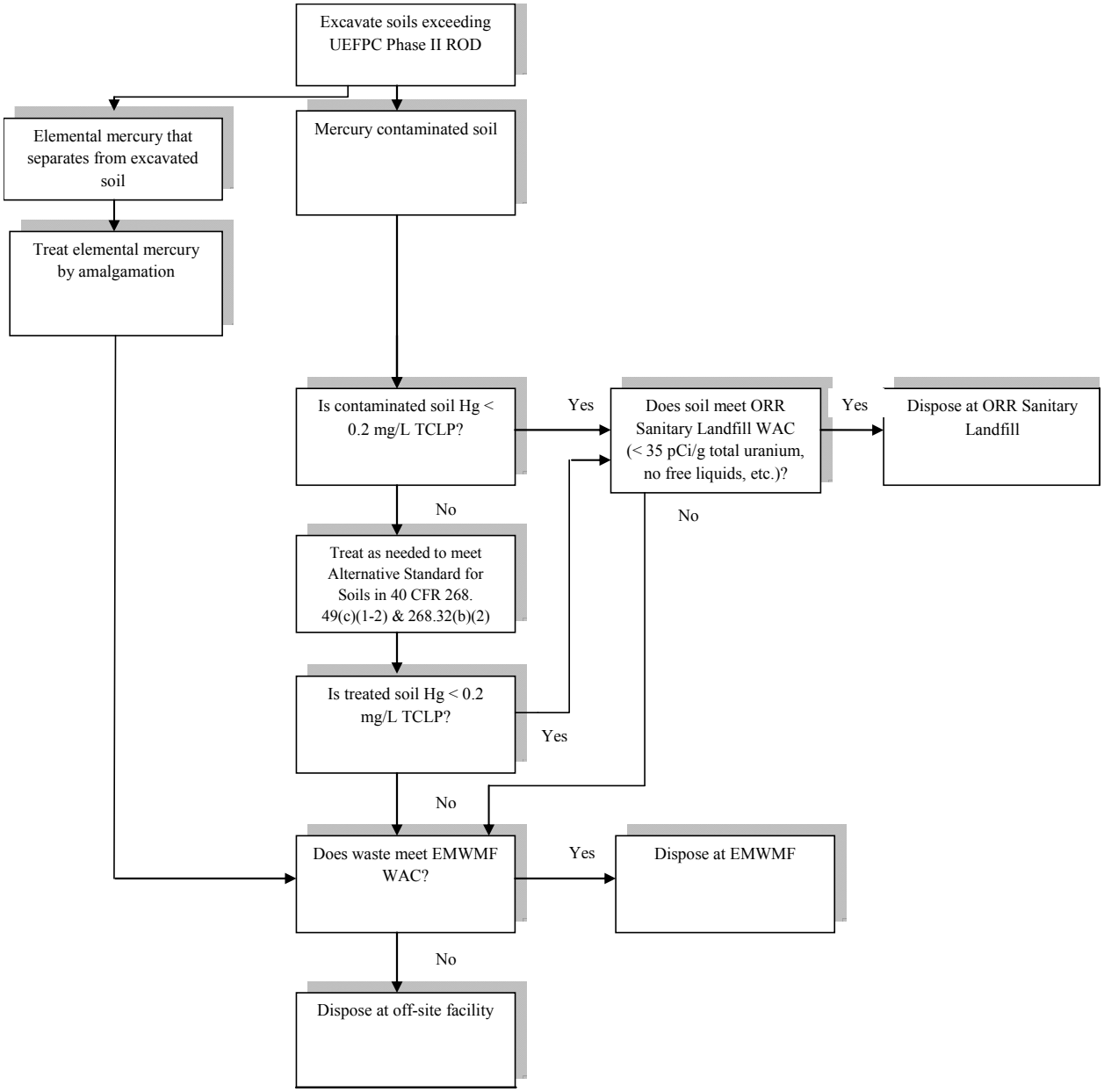
LDR – Land Disposal Restrictions

LDRs specified for high concentration mercury waste are technology based standards dependent upon the presence of organic materials. Incineration and Retorting/Roasting are specified for high concentration mercury waste containing organics. Retorting/Roasting is specified for high concentration mercury that is inorganic. The LDR for low concentration mercury waste is a concentration based standard of 0.025 mg/L TCLP and compliance with the universal treatment standards (UTS) in 40 CFR 268.48. Compliance with the generic treatment standards that apply to all hazardous wastes or the Alternative Treatment Standards for Contaminated Soil contained in 40 CFR 268.49 (EPA530-R-02-003) can be selected for contaminated soil. Other options for obtaining alternative treatment standards include obtaining a site specific variance under 40 CFR

268.44(h)(3) and 268.44(h)(4), or obtaining a Determination of Equivalent Treatment (DET) Variance under 40 CFR 268.42(b). Site specific variances apply to numerical LDR standards. DETs apply to LDR standards expressed as a specific technology. Both site specific variances and DETs require submittal of a petition to the Environmental Protection Agency (EPA) and EPA approval.

UCOR recommended using the Alternative Treatment Standards (40 CFR 268.49) to achieve LDR compliance for contaminated soil and Amalgamation for elemental mercury that separates from contaminated soil during the excavation and soil movement processes. Use of the Alternative Treatment Standards provides flexibility to use a variety of treatment technologies that meet the specified concentration standards. Figure 1 shows a flow chart of how these two LDRs could be used in the treatment and disposal process.

Figure. 1. Flowchart for treatment and disposal decisions for mercury-contaminated soils.



Compliance with the Alternative LDR Treatment Standards for Contaminated Soil

Two approaches can be used to achieve compliance under the alternative treatment standards for contaminated soil:

- Hazardous constituents must be reduced by at least 90 percent through treatment so that no more than 10 percent of their initial concentration remains or comparable reductions in mobility for metals, OR
- Hazardous constituents must not exceed 10 times the UTS contained in 40 CFR 268.48 (10 times the UTS for mercury is 0.25 mg/L).

Constituents subject to treatment include those present at characteristic levels and any additional constituents from the 40 CFR 268.48 UTS table which could reasonably be expected to be present at concentrations greater than ten times the UTS limits. The additional constituents are referred to as underlying hazardous constituents (UHCs), as defined in 40 CFR 268.2(I). For soils that are characteristic due to metals and halogenated organic compounds in total concentrations less than 1,000 mg/kg [40 CFR 268.32(b)(c)], polychlorinated biphenyls (PCBs) are not considered an UHC. The generator can use knowledge of their waste to identify the UHCs reasonably expected to be present when the hazardous soils are generated.

Treatment on the Oak Ridge Reservation

In-situ treatment was evaluated as a part of the feasibility assessment and determined not to be sufficiently proven to recommend as a near term treatment option. If future development of this technology makes in-situ treatment a viable option, the UEFPC II ROD could be amended or An Explanation of Significant Difference under the Comprehensive, Environmental, Response, Compensation, and Liability Act (CERCLA) could be prepared to evaluate its use.

Ex-situ treatment could be performed at the area of contamination, adjacent to the EMWMF, or at an off-site vendor location. Treatment operations performed on ORR, whether at the area of contamination or adjacent to EMWMF, would be performed in accordance with CERCLA. Under CERCLA Section 121(e), no federal, state or local permit is required for on-site CERCLA response actions. EPA has interpreted CERCLA Section 121(e) to waive the requirement to obtain a permit and associated administrative and procedural requirements of permits however; the substantive requirements that would be applied through permits must be met. Compliance with these substantive requirements could be documented in a Remedial Design Work Plan/Remedial Design Report prepared in accordance with the ORR Federal Facilities Agreement (FFA). Figure 2 shows the regulatory process that would be used to accomplish the various treatment options.

Treatment at an Off-site Facility

There are a limited number of off-site facilities that have the capabilities and required permits/licenses to treat mixed waste (see Table II). Prior to sending D009 mixed waste soil to an off-site facility, verification checks would ensure that the facility is operating in compliance with RCRA or other applicable federal or state requirements as specified in 40 CFR 300.440 (commonly referred to as the Off-Site Rule) and in compliance with the Department of Energy's (DOE's) Consolidated Audit Program.

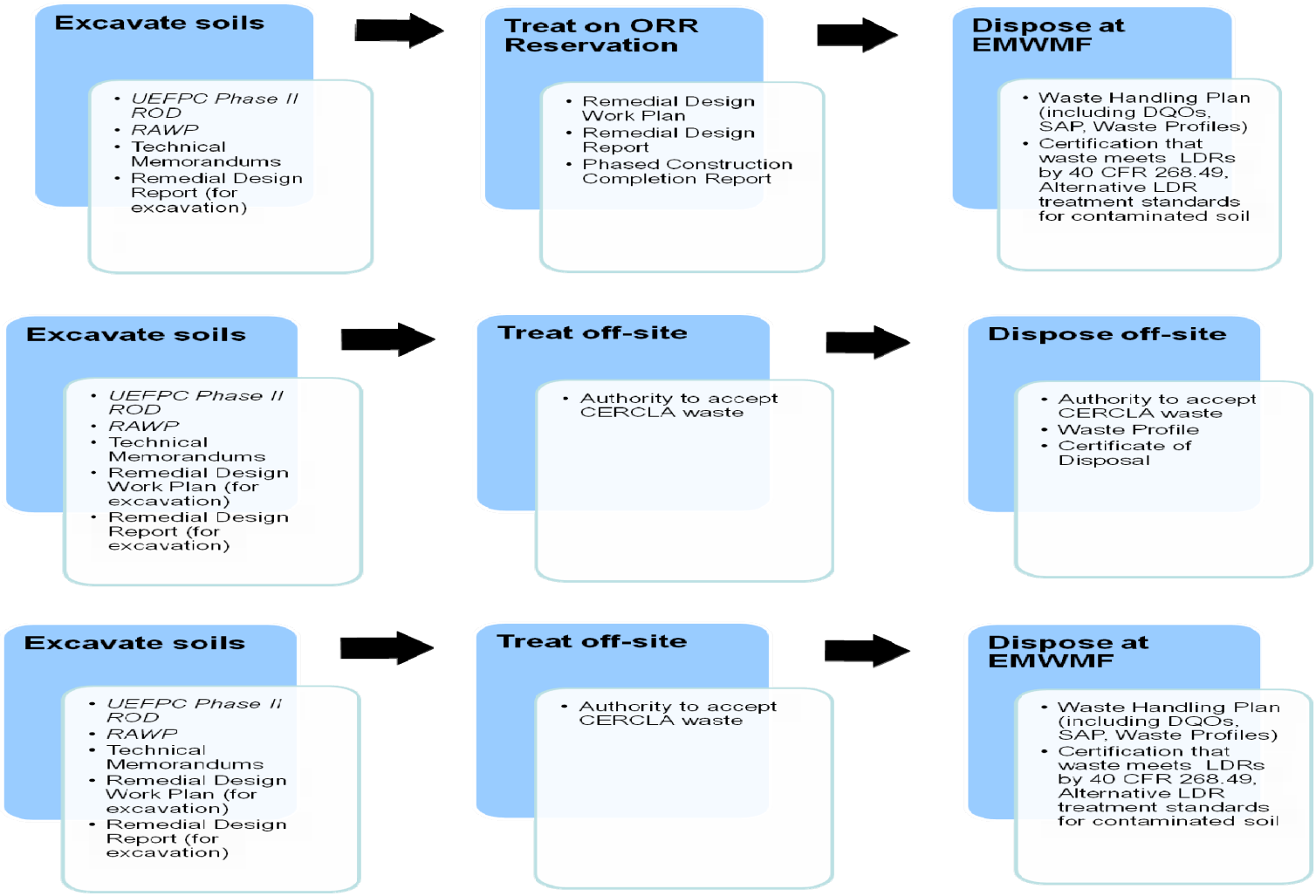


Figure 2. Regulatory process for treatment and disposal

Table II. Disposal facility waste acceptance criteria related to D009 mixed waste

Disposal Facility	Waste Acceptance Criteria Reference	Current Treatment Capabilities for D009 LLMW	Requirements for D009 LLMW
Environmental Management Waste Management Facility, Tennessee	Attainment Plan for Risk/Toxicity-Based Waste Acceptance Criteria, DOE/OR/01-1909&D3	No treatment capabilities	Can accept LLMW that meets LDRs
Energy Solutions, Utah	Bulk Waste Disposal and Treatment Facilities Waste Acceptance Criteria, Rev. 9	Can treat elemental mercury by amalgamation Can treat low concentration mercury waste (< 260 mg/kg Hg) by stabilization Can treat high concentration mercury waste (> 260 mg/kg Hg) by stabilization through a Site Specific Treatment Variance	Radioactive elemental mercury must be treated by amalgamation and be < 0.2 mg/L TCLP Treated low concentration mercury waste must be < 0.025mg/L TCLP Treated high concentration mercury waste must be < 0.2 mg/L TCLP
Nevada National Security Site, Nevada	Waste Acceptance Criteria, DOE/NV--325-Rev. 9, February 2012	No treatment capabilities	D009 mixed waste must meet LDRs, alternate LDR for contaminated soils, or have an approved Determination of Equivalent Treatment
Waste Control Specialists, Texas	Appendix 5.2-1, Waste Acceptance Plan, Rev. 4 Waste Acceptance Criteria (for RCRA/TSCA permitted landfill and adjacent processing facility), Rev. 3	Can treat low concentration mercury waste (< 260 mg/kg Hg) by stabilization	Can accept LLMW that meets LDRs

Note: This table focuses on disposal facility waste acceptance criteria. There are other vendors capable of treating D009 mixed waste.

TREATMENT TECHNOLOGY EVALUATION

To supplement information gathered from the three treatability studies described later in this paper, other technologies that could be used to treat mercury contaminated soils were also evaluated. Other potentially applicable technologies were identified through internet and literature searches, and through discussions with B&W Y-12 representatives and nationally recognized experts on the treatment of mercury contaminated soils. The following paragraphs of this section discuss other technologies identified during this evaluation, technology evaluation criteria, and the results of the technology evaluations.

Technology Identification

Fifteen potentially applicable treatment technologies were identified for EPA Waste Code D009 mixed waste soil. Some of these technologies also have the capability to treatment elemental mercury. The technologies fall into three technology types: In-Situ Treatment, Miscellaneous, and Stabilization (see Table III). Reactive media technologies were reviewed but not fully evaluated as they were more suited for treatment of aqueous wastes or as isolation techniques, and have not been demonstrated to treat mercury contaminated soil to meet LDR standards.

Table III. Technologies identified for D009 mixed waste soil

In-Situ Treatment	*Stabilization*
• Electro Chemical Remediation Technologies Induced Complexation • In-situ Mercury Stabilization • In-situ Nanotechnology • In-situ Phytoremediation • In-situ Electrokinetics	• Conventional Phosphate Treatment • Mercury Amalgamation Stabilization/Solidification • Klean Earth Environmental Company – Silica Micro Encapsulation • ENTHRALL – Inorganic Sulfide Stabilization • Nuclear Fuels Services DeHg™ Process • Allied Technology Group Chemical Stabilization • SepraDyne – Vacuum Thermal Desorption and Stabilization • M2 Polymer Technology Molecular Bonding System • Phoenix Ash Technology
Miscellaneous	
• Soil washing	

Technology Evaluation Criteria

The technologies were evaluated by a team of engineers and scientists using CERCLA criteria of effectiveness, implementability, and cost (EPA/540/G-89/004). Effectiveness focused on the potential of the technology to meet RCRA LDRs, disposal facility WAC, potential impacts to human health and the environment during construction and operation, and whether the technology is proven for treating soil similar to Y-12 soils. Implementability focused on the technical and administrative feasibility of implementing the technology. Three of the effectiveness criteria were considered Go/No-Go criteria:

1. Is the technology proven (has it been used on mercury contaminated soils)?
2. Does the technology achieve RCRA LDR requirements?
3. Can the final waste form meet the EMWMF physical WAC?

If the technology did not pass these three effectiveness criteria the technology was not retained for future consideration. After evaluating the specific technologies, a collective determination was made by the team as to whether the technology should be considered further in the near future. The draft technology evaluations were reviewed by a national expert on mercury treatment and his comments were incorporated. Technologies were evaluated based on the assumptions that: 1) mercury contamination in the soil could be present in three forms (elemental, methylmercury, mercury oxide), 2) the total mercury concentrations could range from 325 mg/kg to 9,000 mg/kg, and 3) the soil requiring treatment could contain up to 53% clay.

Results of Technology Literature Review

Of the fifteen technologies evaluated in the feasibility assessment, three stabilization technologies were determined to be effective and implementable for treatment of Y-12 Site D009 mixed waste soil to meet LDRs. The stabilization technologies retained for further evaluation include:

- Nuclear Fuels Services DeHg^{TM} Process
- Allied Technology Group Chemical Stabilization
- M2 Polymer Technology Molecular Bonding System

These three technologies have been demonstrated to achieve the 0.25 mg/L TCLP (and lower in many cases) mercury LDR standard for a range of mercury concentrations, can effectively treat mercury in high clay content soils, and have been demonstrated in the field. The Nuclear Fuels Services DeHg^{TM} Process and the M2 Polymer Technology Molecular Bonding System Process are also effective for treating elemental mercury. Although some cost information was available for these retained technologies, the details and basis of the cost estimates were not sufficient to make an accurate cost comparison.

In-situ technologies evaluated have not been demonstrated to treat the potentially high concentrations of mercury present in Y-12 Site soils and have not been sufficiently proven in full-scale operations. Soil washing is not effective at treating high clay content soils and generates significant quantities of secondary waste that requires further treatment.

TREATABILITY STUDIES

Treatability Samples and Performance Objectives

Samples of Y-12 soil were spiked to represent nominally 2,000 mg/kg and 10,000 mg/kg of total mercury. These spiked sampled were provided to Brookhaven National Laboratory (BNL), East Tennessee Materials & Energy Corporation (M&EC), and EnergySolutions for treatability studies.

The performance objectives of the study were:

- Meet a mercury concentration of < 0.2 mg/L as demonstrated by the Toxicity Characterization Leaching Procedure (TCLP)
- Do not exhibit the EPA D003 reactivity characteristic for sulfides; and,
- Optimize the volumetric waste loading while meeting the above criteria.

M&EC Treatability Study

The M&EC treatment process consisted of amalgamation followed by solidification/stabilization using proprietary formulations and process parameters. The M&EC optimum formulation produced a treated waste < 0.2 mg/L that did not exhibit reactive characteristics. The treated waste form was a low-strength monolith and showed only a slight increase in volume. Summary results of the best performing stabilization formulations are shown in Table IV.

Treatment cost estimates were prepared by M&EC however, are not included in this paper due to the business sensitive nature of the estimates.

Table IV. Summary Treatability Study Results

Nominal Total Initial Mercury Concentration (mg/kg)	M&EC Treatment Study Results (TCLP mg/L)	EnergySolutions Treatment Study Results (TCLP mg/L)	BNL Treatment Study Results (TCLP mg/L)
2,000	0.00122	0.00067	0.00083
10,000	0.00067	0.00067	0.0009

EnergySolutions Treatability Study

The EnergySolutions treatment process consisted of stabilization using proprietary formulations and process parameters. The EnergySolutions optimum formulation produced a treated waste resulting in <0.2 mg/L for mercury that did not exhibit reactive characteristics. The treated waste showed only a slight increase in volume. Summary results are shown in Table IV

Treatment cost estimates were prepared by EnergySolutions however, are not included in this paper due to the business sensitive nature of the estimates.

Brookhaven National Laboratory Treatability Study

The BNL patented Sulfur Polymer Stabilization/Solidification (SPSS) process is a two stage treatment process that chemically stabilizes mercury to form HgS powder and then physically

encapsulates it into a solid form that resembles cinnabar for long-term disposal. The BNL optimum formulation produced a treated waste < 0.2 mg/L that did not exhibit reactive characteristics. The treated waste form was a solid monolith. Summary results of the best performing formulations are shown in Table IV.

Treatment cost estimates were prepared by UCOR using parameters obtained from BNL however, are not included in this paper due to the business sensitive nature of the estimates.

REGULATORY APPROACH FOR DISPOSAL

Remediation waste from the Y-12 Site meeting WAC could be disposed at the Y-12 landfills (referred to as the ORR Landfills), EMWMF, the area of contamination, or at an off-site disposal facility. Regulatory approaches for each disposal option are discussed below.

Disposal at the ORR Landfills

The ORR landfills (Industrial Landfill V and Construction/Demolition Landfill VII) WAC prohibits the disposal of hazardous waste regulated under RCRA, radioactive waste, and most PCB waste regulated under the Toxic Substances Control Act of 1976 (TSCA). Special waste permits approved by TDEC's Division of Solid Waste Management are required for certain "special wastes," as defined by TDEC's standard operating procedure (TDEC SOP, Special Waste Approval). Special wastes include most wastes generated by remediation projects regulated under the CERCLA. If the waste is determined to be a special waste and meets the WAC for the Y-12 landfills, it will require TDEC-approved special waste permits prior to disposal in the Y-12 landfills. If the waste is not determined to be a special waste and meets the WAC for the Y-12 landfills, it will be disposed in the appropriate Y-12 landfill. Highlights of the Y-12 landfill WAC applicable to mercury contaminated soil are as follows:

- Waste shall not exhibit characteristics of or be RCRA-listed or be subject to any RCRA LDR.
- Radioactivity concentrations must be < 35 pCi of total uranium per gram of waste or must conform to the requirements of DOE Order 5400.5, Radiation Protection of the Public and the Environment.
- Waste must contain no free liquids.
- Mixing of waste streams shall be minimized.

The Alternative LDR Treatment Standard for Contaminated Soil requires that D009 mixed waste soil be treated to a TCLP mercury concentration of <0.25 mg/L TCLP. This LDR standard is higher than the mercury characteristic concentration of <0.2 mg/L TCLP. If the selected treatment technology achieves a TCLP mercury concentration of <0.2 mg/L disposal at the ORR landfill could be a disposal option. The majority of the mercury contaminated soil generated from remedial action taken under the UEFPC Phase II ROD is anticipated to contain > 35 pCi of total uranium per gram of waste. However, it is feasible that some of the soil may be less than the radioactivity concentration WAC and be non-hazardous, either as generated or as a result of treatment.

Disposal at EMWMF

The EMWMF can accept waste containing low-level radioactive substances, RCRA characteristically hazardous waste that meets LDR criteria, TSCA toxic constituents, asbestos-containing materials, and combinations of these materials. Details of the four sets of requirements that make up the EMWMF WAC (administrative, analytic, auditable safety analysis (ASA)-derived, and physical) are presented in the EMWMF WAC Attainment Plan for Risk/Toxicity-Based Waste Acceptance Criteria at the Oak Ridge Reservation (DOE/OR/01-1909&D3). The two primary evaluations performed as part of the feasibility assessment were how to achieve compliance with LDRs and whether the treated waste forms can meet the physical WAC requirements. The recommended approach for complying with LDRs is described above. It is anticipated that treated waste forms would meet the physical WAC.

A Waste Handling Plan would be prepared for Project Team (DOE, EPA, and TDEC) approval prior to the initiation of any excavation activities. Once the Waste Handling Plan is approved Waste Profiles would be prepared for submittal to the WAC Attainment Team. Treated waste shipped for disposal would be accompanied with a LDR Compliance Certification.

Disposal at the Area of Contamination

One unique disposal option is placing excavated soil back in the former area of contamination following treatment to meet LDRs. This option would only be attractive if the treatment operations were conducted at the area of contamination (using a mobile treatment unit) as it would eliminate the cost of transportation to an ORR disposal facility or an off-site disposal facility. It is recognized that this option would require considerable discussion with the Y-12 Site Project Team, and EPA Region 4, and TDEC approval.

Disposal at Off-site Facilities

As part of this feasibility assessment a survey was performed of off-site federal and commercial disposal facilities to determine their WAC for D009 mixed waste (see Table II). The EnergySolutions, Nevada National Security Site (NNSS), and Waste Control Specialist disposal facilities all accept D009 mixed waste that comply with LDRs. The EnergySolutions' WAC specifies TCLP concentrations that must be met based on the type of mercury waste or the original concentration of total mercury. The NNSS WAC acknowledges use of the alternative treatment standard for contaminated soil for LDR compliance. The Waste Control Specialist WAC requires LDR compliance but leaves the compliance method to the generator. All disposal facilities used must be operating in compliance with RCRA or other applicable Federal or State requirements and as such meet the CERCLA Off-Site Rule contained in 40 CFR 300.440, authorized by EPA Regions to accept CERCLA waste, and be operating in compliance with DOE's Consolidated Audit Program.

To send the D009 mixed waste to an off-site disposal facility, a waste profile, and LDR Compliance Certification would need to be prepared for approval by the disposal facility prior to shipment.

CONCLUSIONS

Several options exist for both the treatment and disposal of mercury contaminated soils generated at the Y-12 Plant. All three treatability studies were successful in meeting the 40 CFR, Part 268.49 "Alternative Treatment Standard for Contaminated Soils" by achieving a Toxicity Characterization Leaching Procedure (TCLP) concentration of <0.25 mg/kg for mercury (and in many cases lower concentrations). In addition, there are several other stabilization technologies that are field proven and viable options for treatment. Treatment on-site would be accomplishing using the existing CERCLA regulatory process defined in the ORR FFA.

Disposal options include on-site disposal at the Environmental Management Waste Management Facility (CERCLA disposal cell), and possibly the Oak Ridge Reservation Y-12 Sanitary or Industrial Landfills (ORR Landfill) if radiological waste acceptance criteria is met and the waste is no longer considered RCRA hazardous. Authorization for disposal on-site will be achieved via an approved Waste Handling Plan for the EMWMF or an approved Special Waste Profile for the ORR Landfill. Both of these authorizations require the Core Team (Department of Energy, TDEC, and EPA) approval. At this time, there are two off-site disposal options for this waste stream once LDR is met. These include the Nevada National Security Site and the Energy Solutions, Clive Facility. Waste Control Specialists (WCS) may become a third option in the near future once the Department of Energy (DOE) agrees to allow the disposal of DOE waste in WCS's Federal Cell.

At this time the actual quantity of soil requiring treatment and the available remediation funding are uncertain. These current uncertainties prevent selection of the most cost effective treatment and disposal options. Therefore, all treatment and disposal options should be preserved until these uncertainties are better defined.

REFERENCES

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