MIXED WASTE TREATMENT AND DISPOSAL USING MACRO VAULTS: AN INNOVATIVE APPROACH TO MACROENCAPSULATION OF MIXED WASTE DEBRIS AND RADIOACTIVE LEAD SOLIDS

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ABSTRACT

Envirocare of Utah, Inc. (Envirocare) has developed, permitted, and implemented an innovative approach to macroencapsulation of mixed waste debris and radioactive lead solids. The engineered Macro Vault is a modular monolithic vault cast in place in Envirocare's Mixed Waste Disposal Cell. Envirocare uses Macro Mix, a proprietary cement-based encapsulant, to treat mixed waste debris and radioactive lead solids to meet Land Disposal Restrictions. Macro Vaults can be constructed to accommodate essentially any waste form geometry, weight, or other considerations. Regulatory approval to begin treatment with Macro Vaults was received in March, 2004. After a short operational implementation period, Envirocare has shifted essentially all macroencapsulation treatment operations to Macro Vaults. Macro Vaults provide a cost-effective solution for treatment of large and unique waste forms while ensuring compliance with Land Disposal Restrictions.

INTRODUCTION

Envirocare has developed, permitted, and implemented an innovative approach to macroencapsulation of mixed waste debris and radioactive lead solids. This paper presents an overview of Envirocare's work in Macro Vault permitting, research and development, and treatment operations, as well as a summary of Macro Vault treatment capabilities.

The engineered Macro Vault is a modular monolithic vault cast in place in Envirocare's Mixed Waste Disposal Cell. Envirocare uses Macro Mix, a proprietary cement-based encapsulant, to treat mixed waste debris and radioactive lead solids to meet Land Disposal Restrictions. Macro Vaults can be constructed to accommodate essentially any waste form geometry, weight, or other considerations. Envirocare has received regulatory approval for construction of Macro Vaults up to 25' x 25' x 16' tall. Other Macro Vault geometries can be developed to accommodate waste forms outside these dimensions. Because the Macro Vault is constructed within the Mixed Waste Disposal Cell, the resulting waste form does not need to be moved for final disposal.

EVOLUTION OF MACROENCAPSULATION AT ENVIROCARE

Envirocare received initial approval for macroencapsulation using low-density polyethylene (LDPE Macro) in 1996. Since that time, LDPE Macro has been used to successfully treat a wide variety of mixed wastes. Macro Capsules were added to Envirocare's permit in 1999 and have been used sparingly in macroencapsulation treatment. The basic requirements for Macro Vaults were approved in June, 2003 [1]; the specific process, materials, and operation requirements were approved in March, 2004. Envirocare has now shifted essentially all macroencapsulation treatment operations to Macro Vaults.

LDPE Macro

LDPE Macro is a time-consuming, resource-intensive treatment process that produces a rigorous final waste form. Treatment is accomplished by pouring molten LDPE around hazardous debris and/or radioactive lead solids. The waste may be a single piece, or multiple pieces in an open container. LDPE must be poured to a minimum of 1 inch of cover on all sides of the waste for waste forms up to 4 cubic feet (cf). For larger waste forms, LDPE must be poured to a minimum cover of 2 inches on all sides. If void spaces within the waste or container have not been filled, LDPE may also function as void filler, producing a final waste form that is a matrix of waste and LDPE. Figure 1 illustrates a complete LDPE Macro waste form.

Fig. 1. LDPE Macro Waste Form.

The LDPE Macro treatment process is time-consuming and resource-intensive because virgin polymers are heated until molten using conventional plastic extruders. It takes several hours to treat a standard B-25 container of waste. The polymer is heated, creating a potential hot work safety hazard. Envirocare has attempted to use recycled polymers for LDPE Macro treatment. The use of recycled polymers was not successful due to concerns with product quality and consistency, as well as reliable availability.

Initially, LDPE Macro was applied to single pieces of radioactive lead solids one at a time. Over time, Envirocare has developed the ability to perform LDPE Macro on larger and larger waste forms. However, LDPE Macro cannot practically be used to treat waste forms larger than 4' x 6' x 4' tall. Envirocare has successfully treated larger waste forms using LDPE Macro; however, above this size forms quickly become too heavy to move without time-consuming, expensive special equipment. Oversized LDPE Macro waste forms increase the cost of treatment and disposal as well as the potential for damage during handling, leading to a need for re-work of the macroencapsulant.

Macro Capsules

In permit modifications approved between July 1999 and November 2002, Envirocare received approval for use of Macro Capsules for the treatment and disposal of mixed waste debris. Macro Capsules are essentially closed containers made of inert materials. Because the Macro Capsule is a container, this technology is not approved for treatment of radioactive lead solids. Macro Capsule technologies that have been successfully applied at Envirocare include the Arrow-Pak™ HDPE tubes produced by Boh Environmental and Enduropak© HDPE high integrity containers produced by GTS Duratek. Figure 2 illustrates a typical Macro Capsule treated at Envirocare.

Fig. 2. Macro Capsule.

Macroencapsulation using a Macro Capsule is accomplished by loading waste into the capsule, filling void spaces, and securing the capsule lid or endcap. Macro Capsules used at Envirocare to date are also limited to accepting 55-gallon or 85-gallon drums only. The Arrow-Pak capsules

are long enough to accept up to seven 85-gallon drums, and could therefore be appropriate for some unique waste shapes. However, extremely large items such as gloveboxes and other large components would need to be size-reduced to fit into Macro Capsules.

Macro Permitted at Other Treatment Facilities and Hazardous Waste Sites

By 2003, the limitations of existing approved macroencapsulation technologies became apparent. Extremely large items such as gloveboxes required treatment due to the presence of radioactive lead solids; however, size reduction to accommodate LDPE Macro limitations was not always feasible due to contamination control and ALARA concerns.

Envirocare responded to this problem by researching macroencapsulation technologies permitted at Resource Conservation and Recovery Act (RCRA) treatment facilities, Department of Energy (DOE) sites, and cleanup projects around the country.

The regulatory definition of macroencapsulation [2] provides for wide flexibility in meeting this treatment technology. The chief design criteria is for the macroencapsulating media to "…substantially reduce surface exposure to potential leaching media." This definition applies to both radioactive lead solids (at 40 CFR 268.42, Table 1) and to hazardous debris (at 40 CFR 268.45, Table 1). For treatment of radioactive lead solids, "Macroencapsulation specifically does not include any material that would be classified as a tank or container…" It is not difficult to imagine a wide variety of materials and approaches that could be argued to meet these requirements.

In fact, in the preamble to the final rule establishing macroencapsulation as an acceptable treatment technology for hazardous debris, the Environmental Protection Agency (EPA) introduces the concept that hazardous debris bagged in accordance with requirements for asbestos management might be acceptable macroencapsulation: "The Agency agrees… that, if bagging meets the performance standard for macroencapsulation, such debris may then be disposed in a subtitle C facility."[2 at p. 37328]

In other guidance, EPA documents an interpretation that "…plastic coated, lead lined gloves… would be considered to comply with the standard identified as 'MACRO' provided that none of the lead is exposed… and provided that the coating provides a substantial reduction in surface exposure to potential leaching media…."[3]

An informal survey of commercial hazardous waste treatment, storage, and disposal facilities (TSDFs) indicates that permitted approaches to macroencapsulation include bagging, surface coatings, shrink wraps, HDPE containers, stainless steel containers, flowable concrete mixes, and molten LDPE. For example, Waste Management, Inc. describes their macroencapsulation process as a one-piece HDPE containment unit, in which waste is placed, voids are filled with flowable pozzolanic material, and a lid is welded on.[4]

Of particular relevance to the flowable concrete mix approach ultimately applied at Envirocare is the Weldon Spring Site Remedial Action Project, completed by the U.S. Department of Energy (DOE) in 2002. As part of that cleanup project, over 50,000 cf of regulated hazardous debris was

treated by macroencapsulation. The majority of the regulated debris consisted of process piping packaged in 20 cubic yard (cy) rolloff boxes. For this project, macroencapsulation was performed in the disposal cell by first pouring a cement/bentonite slurry beneath each box. The box contents were secured with ballast as needed, then the cement/bentonite slurry was added to the box to cover all exposed waste to a minimum of 2 inches. This waste form was considered to meet the technology standard of macroencapsulation. Disposal operations were completed with the addition of a second grout recipe, using contaminated sludges as an aggregate ingredient, to surround the macroencapsulated waste forms.[5,6]

It appears that DOE may be contemplating a similar approach to that applied at Weldon Spring for large items to be treated and disposed of at the Hanford site.[7]

Clearly, there is a broad scope of treatment approaches that can, and have been, argued to meet the regulatory definition of macroencapsulation. In selecting the criteria to apply in developing a new approach to macroencapsulation at Envirocare, a conscious decision was made to keep the quality, long-term integrity, and durability of the treated waste form consistent with the high standard established by LDPE Macro.

Macro Vaults

A modification to Envirocare's RCRA Permit outlining minimum acceptable Macro Vault requirements was approved in June, 2003.[1] These requirements include:

- Chemical stability with the waste to be encapsulated;
- Chemical stability with the disposal environment;
- Physical stability;
- Void filling procedures;
- Operating procedures; and
- Inspection requirements.

The primary concern in the regulatory permitting process was to define the Macro Vault in a way that would meet the minimum requirements of RCRA at a standard comparable to the existing approaches of LDPE Macro and Macro Capsules. Although a literal reading of RCRA could be used to support a less rigorous macroencapsulation technology, neither Envirocare nor its regulators would be supportive of a treatment technology of questionable durability.

A number of engineering approaches can meet the minimum acceptable Macro Vault requirements, as written in Envirocare's permit. These approaches include pre-fabricated concrete vaults, pre-fabricated HDPE or PVC vaults, pre-fabricated fiberglass vaults, and cast-in-place concrete vaults. All were evaluated in Envirocare's development process.

After detailed research, consideration of Envirocare's operational capabilities, and evaluation of the regulatory basis for macroencapsulation, Envirocare selected the cast in place vault approach. The cast in place vault best meets the regulatory requirements for both radioactive lead solids and hazardous debris. The cast in place vault also maximizes operational flexibility and efficiency. Envirocare then initiated field testing of potential Macro Mix formulations.

The primary design criteria for Macro Mix is coating effectiveness and reduced permeability, so as to comply with RCRA requirements for macroencapsulation to a standard comparable with LDPE Macro. A secondary design criteria is flowability of Macro Mix, to ensure that voids within and surrounding the waste form would be filled to the maximum extent practical. Other design criteria include operational flexibility, cost, and incorporation of the macroencapsulated waste form into the overall disposal embankment.

After several test pours on non-contaminated material, an acceptable Macro Mix formula was derived. Test pours consisted of 96 cf steel boxes, filled with non-contaminated debris as a simulated waste form. The simulated waste form was placed in forms constructed using standard concrete forming technology. Test Macro Mix formulation was then used to fill voids within the simulated waste form and to encapsulate the overall mass. The test pours were evaluated for evidence of settling, excessive cracking, and mix flowability. As a result of these tests, Envirocare derived a Macro Mix formula that met our design criteria.

Permeability was evaluated by comparing Macro Mix with controlled low-strength material (CLSM). CLSM is a concrete-based, very flowable grout used as void filler in embankment construction. The challenge was to maintain flowability in Macro Mix while reducing permeability. The final approved mix succeeds in meeting this challenge.

Compressive strength was not a design consideration, beyond ensuring that the completed Macro Vault had the minimum strength needed to resist embankment loading. Macro Mix was found to have more than three times the compressive strength of conventional CLSM, far exceeding that needed to remain structurally stable under the fully loaded embankment.

The proprietary Macro Mix formula was submitted together with operating and inspection procedures for regulatory approval in October, 2003. Regulatory approval to begin treatment with Macro Vaults was received in March, 2004. In all, Envirocare has invested over 18 months of development work into research, development, and regulatory approval of the Macro Vault.

After a short operational implementation period, Envirocare has shifted essentially all Macro treatment operations from LDPE Macro or Macro Capsules to Macro Vaults. Macro Vaults provide a cost-effective solution for macroencapsulation treatment of large and unique waste forms while ensuring compliance with Land Disposal Restrictions. In addition, Macro Vaults offer operational and economic advantages over LDPE Macro or Macro Capsules, since a larger volume of waste can be treated at once in a Macro Vault.

MACRO VAULT TREATMENT AT ENVIROCARE

The Macro Vault treatment process has many similarities to performance of LDPE Macro. Waste is staged either as single, generally large, pieces; or open containers are arranged together within a multi-container pour. Voids may be filled prior to placement within the pour, using approved void filling materials; or Macro Mix may be poured in a manner to fill any voids within the waste at the same time that it surrounds the waste. Figure 3 illustrates staging of containers awaiting the Macro Mix pour.

Fig. 3. Containers Staged Awaiting Macro Mix.

Fig. 4. Completed Macro Vault.

Figure 4 illustrates completed Macro Vaults after the forms have been stripped.

The completed Macro Vault is inspected for encapsulant integrity at least once a week until the vault is covered as part of final disposal. If observed, shrinkage cracks in the surface of the vault are evaluated for width, depth, and location to assess whether the crack is significant enough to potentially affect the vault's ability to isolate the waste within from potential leaching media in the landfill. All cracks are sealed with a commercial concrete sealant product. Cracks with the potential to affect the vault's ability to isolate the waste are evaluated by Envirocare's Director of Engineering and Mixed Waste Operations Manager to determine corrective action. In addition, regulatory notification is required when a crack is identified as having the potential to affect the vault's integrity. Utah regulators then have the opportunity to inspect the repair to confirm its effectiveness.

Envirocare's initial Macro Vault design approval restricts each vault to an outside dimension of 25' x 25' x 6' tall. Envirocare later received a second regulatory approval to construct Macro Vaults up to 25' x 25' x 16' tall. Other vault dimensions are under evaluation and may be approved at a future date. It is anticipated that a Macro Vault could be designed and constructed to accommodate virtually any waste form.

CONCLUSION

Macro Vault treatment has been very successful to date. Since beginning Macro Vault treatment operations, Envirocare has more than doubled macroencapsulation treatment and capacity. This improvement comes with no reduction in treatment or disposal effectiveness. Furthermore, construction of the Macro Vault within the disposal cell reduces the amount of waste handling required, reducing personnel exposure to hazardous and radioactive materials. Macro Vaults provide a cost-effective solution for treatment of large and unique waste forms while ensuring compliance with Land Disposal Restrictions.

REFERENCES

1. Envirocare of Utah, Inc. 2004. State-issued Part B Permit. Attachment II-1-5, "Macroencapsulation Plan."
2. U.S. Environmental Protection Agency. 1992. "Land Disposal Restrictions for Newly Listed Wastes and Hazardous Debris; Rule," 57 FR 160, 40 CFR 268.42 and 268.45.
3. U.S. Environmental Protection Agency. 1990. "Treatment Standards for Certain Mixed Radioactive Wastes." Faxback 13437.
4. Waste Management, Inc. 2004. "Hazardous Waste Services." www.wm.com/WM/services/WMXtra/Hazardous_waste.pdf
5. U.S. Department of Energy. 2003. "WSSRAP Becomes First Major U.S. DOE Site to Complete Mixed Waste Inventory Treatment." http://www.wssrap.com/mixed%20waste%20FS.html.
6. U.S. Department of Energy. 1999. "Developing Grout for Macroencapsulation of Heterogeneous Waste."
7. U.S. Department of Energy. 2004. "Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement." DOE/EIS-0286F, section 2.2.2.6