Treatment of Bottled Liquid Waste During Remediation of the Hanford 618-10 Burial Ground - 13001

Darrin E. Faulk, Chris M. Pearson, Barry L. Vedder, David W. Martin
Washington Closure Hanford, LLC, Richland, WA 99354

ABSTRACT

A problematic waste form encountered during remediation of the Hanford Site 618-10 burial ground consists of bottled aqueous waste potentially contaminated with regulated metals. The liquid waste requires stabilization prior to landfill disposal. Prior remediation activities at other Hanford burial grounds resulted in a standard process for sampling and analyzing liquid waste using manual methods. Due to the highly dispersible characteristics of alpha contamination, and the potential for shock sensitive chemicals, a different method for bottle processing was needed for the 618-10 burial ground. Discussions with the United States Department of Energy (DOE) and United States Environmental Protection Agency (EPA) led to development of a modified approach. The modified approach involves treatment of liquid waste in bottles, up to one gallon per bottle, in a tray or box within the excavation of the remediation site. Bottles are placed in the box, covered with soil and fixative, crushed, and mixed with a Portland cement grout. The potential hazards of the liquid waste preclude sampling prior to treatment. Post treatment verification sampling is performed to demonstrate compliance with land disposal restrictions and disposal facility acceptance criteria.

INTRODUCTION

Washington Closure Hanford, LLC, under contract to the United States Department of Energy, Richland Operations Office, is currently conducting deactivation, decontamination, decommissioning, and demolition of excess facilities; placing former production reactors in an interim, safe, and stable condition; and remediating waste sites and burial grounds in support of the closure of the Hanford Site River Corridor. The Hanford Site River Corridor consists of approximately 210 square miles of the Hanford Site along the Columbia River, in the State of Washington.

The remediation of Hanford Site River Corridor waste sites is authorized using interim action Records of Decision under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 [1]. The Record of Decision for the 618-10 Ground specifies removal, treatment, and disposal as the remedy for hazardous substances [2].

Burial Ground Description

The 618-10 Burial Ground (Figure 1) is located approximately 9.6 kilometers north of the city of Richland and approximately 400 meters upwind of the primary Hanford highway. It was activated in March 1954 and closed in September 1963. The 618-10 burial contains waste generated primarily from Hanford's 300 Area, where fuel metallurgical analysis was performed and new methods were developed to separate plutonium from nuclear fuel. These wastes consisted of metallurgical sample residues, samples from experiments, and other very highly radioactive wastes [3]. Also, there are records indicating that some of the waste disposed in
618-10 may be shock sensitive.

The burial ground includes 12 trenches of various sizes which are up to 23 meters wide and 92 meters long by up to 7.6 meters deep. It also contains 94 vertical pipe units (VPUs), which are bottomless 108 liter drums that were welded together and buried vertically. The VPUs are planned to be remediated at a later date. The burial ground received a broad spectrum of low- to high-activity, dry, radioactive waste. The waste was primarily fission products and some plutonium-contaminated waste from the 300 Area. The trenches received low level waste in cardboard boxes; concreted drums containing higher activity waste, including some liquids; and large miscellaneous items (i.e., laboratory hoods, vent filters, and glove box trays). Non-radioactive beryllium was also disposed in the trenches. Few records documenting solid waste burial activities were kept until 1960.

When waste was disposed, higher dose rate items were generally transported to the 618-10 burial ground in bottom-opening shielded casks and placed in vertical pipe units. Remaining waste was disposed in trenches. Some high-dose-rate waste was disposed in trenches by either loading cardboard boxes of waste into shielded load luggers or centering small quantities of waste in a drum and pouring either concrete or a combination of concrete and lead around the waste. While use of the concreted/lead-shielded drums resulted in a significant dose rate reduction for personnel disposing of the waste, they present characterization and handling challenges when the waste exhumed.

Figure 1. 618-10 Burial Ground Remediation, April 2012.

PROCESS BACKGROUND

Prior Bottle Anomaly Process

The past practice of handling bottle waste at WCH Field Remediation sites involved segregation of the bottles followed by individual characterization of bottle contents (Figure 2). During remediation of the 618-10 Burial Ground, hundreds of small laboratory-type containers have been encountered in the area of contamination during the initial months of excavation. It is not unreasonable to expect thousands of individual bottles could be encountered during the whole trench remediation activity (Figure 3). Process improvements are needed in the management of bottle waste from this burial ground, which contains highly radioactive, alpha containing waste. Standard remediation practices are adequate for handling soil and debris, however, there are records that indicate the potential for reactive chemical within bottles (e.g., picric acid).

Figure 2. Prior bottle handling process

Figure 3. Bottles unearthed during remediation of Hanford's 618-10 Burial Ground.

Challenges with Bottle Processing at 618-10

The problematic waste consists of glass and plastic bottles in varying dimensions and composition potentially contaminated with barium, cadmium, or lead, and possibly other regulated metals. All of these metals could be at levels rendering the waste above Toxicity Characteristic Leaching Procedure (TCLP) limits that are subject to Land Disposal Restrictions (LDRs) prior to disposal [4]. The waste requires stabilization of the TCLP metals prior to disposal in the Environmental Restoration Disposal Facility (ERDF). Due to the highly dispersible characteristics of alpha contamination, and the potential for shock sensitive chemicals, a different method for bottle processing was needed at the 618-10 Burial Ground.

Benchmarking with other DOE Sites

During August, 2007, several additional DOE sites were contacted to collect information regarding bottled waste handling practices at other cleanup projects. The sites that responded to this information request included Los Alamos National Lab (LANL), Savannah River Site (SRS), Oak Ridge Reservation (ORR), and the Idaho National Laboratory (INL).

The approach followed at INL was documented in a waste retrieval procedure and sampling guide approved by the EPA. Various bottles of containerized liquid were present within the sludge matrix being excavated at INL Pit 4. Per agreement with EPA, a representative number of bottles were selected and opened with heavy equipment in separate trays containing an engineered mixture of absorbents. In cases where the expected bottled liquid sample volume was small (i.e. less than 100-mL), care was taken to ensure that the contents were not diluted in the absorbent by limiting the amount of absorbent used for each evaluation. Operators filled 250-mL wide-mouth sample jars with the liquid filled absorbent using disposable sampling scoops. These sample jars were sent to the laboratory for screening of the material's hazardous materials characteristics. The laboratory used water to leach the absorbed liquids from the engineered absorbent. Following analysis, all of the absorbents and container materials were returned to Pit 4.

Contacts at ORR and LANL revealed encounters with small numbers of bottles during remediation activities. At LANL, the bottle contents were evaluated using field screening methods and disposed in labpacks. At ORR, the bottles and their contents were sent to laboratories for analysis and subsequent disposal. SRS determined that their burial ground contents were too difficult to remediate from a health and safety perspective, and they chose to cap the burial grounds without further characterization of the contents.

At DOE sites that evaluated the contents of bottles discovered during remediation, all of the sites addressed the characterization on a bottle-by-bottle basis. Although the waste disposal protocol varied somewhat, the method followed to characterize the contents of the bottles was similar.

Initial discussion with EPA for bottle management at 618-10 led to an attempt to duplicate the process employed during previous Hanford burial ground remedial actions. However, alpha radiological contamination and reactive chemical presence is a much higher risk at 618-10 than it was at other Hanford burial grounds.

Identification and Evaluation of Alternatives

Four alternatives were identified for consideration in management and disposal of bottled waste. A description of these alternatives, along with a discussion of potential regulatory options for implementation, is presented below.

- Option #1 - Individual bottle characterization/disposal

  Description: This alternative involves sampling and characterizing each bottle on an individual basis. Bottles are typically broken in a small container and then transferred to sample bottles for shipment to an offsite. Subsequent treatment (if necessary) and disposal of any remaining material would be pursued based on analytical results. However, based on experience to date, most of the individual bottles do not contain enough waste to have any remaining material; i.e., all of the bottle content is used in the limited characterization effort.

Regulatory evaluation: This option would facilitate compliance with all applicable or relevant and appropriate requirements (ARARs), including requirements to determine waste designation and provide required treatment.

- Option #2 - Visual evaluation/representative characterization/disposal

    Description: Based on a visual evaluation, bottles appearing to contain like materials would be segregated. A representative sample would be taken from the accumulated “like” bottle materials. Subsequent treatment (if necessary) and disposal of any remaining materials would be pursued based on analytical results.

    Regulatory evaluation: This option would facilitate compliance with all ARARs, including waste designation and treatment requirements. Representative sampling to characterize a waste stream is consistent with regulations and guidance [5,6,7]. However, the determination of what constitutes a “representative” subset of like bottles may not always be clear. For example, in some cases a variety of bottles may appear to contain the same material, but 100% certainty (not a regulatory requirement) may not be achievable without 100% sampling.

- Option #3 - Crush bottles in trench and sample soil matrix prior to disposal

    Description: Bottles would be crushed in place (without segregation) within the excavation area. The resulting soil matrix would be characterized, treated (if necessary) based on characterization results, and disposed of. (Note: full intact containers greater than an agreed upon volume would be segregated and managed separately in accordance with existing project procedures)

    Regulatory evaluation: Under the hazardous and dangerous waste regulations, crushing and absorbing bottled waste in soil *outside the excavation area* could be viewed as impermissible dilution, and thereby be prohibited. Such action could also be viewed as placement of waste on land prior to meeting LDR treatment standards, prohibited under 40 CFR 268.40 unless a corrective action management unit (CAMU) or other regulatory allowance or waiver was established. In the case of bottled waste originally disposed of prior to the LDR standards, and subsequently treated (e.g., crushed and absorbed in a soil matrix) *within the excavation area* (i.e., the area of contamination), these prohibitions would not apply.

- Option #4 - Visual evaluation/crush bottles in container/separate liquid/dispose

    Description: Visual evaluation would be performed to remove empty bottles, bottles containing visually identifiable materials (e.g., elemental mercury) and any materials that are deemed potentially incompatible based on visual observation. The remaining bottles would be crushed in a container, the resulting liquid sampled and characterized, with subsequent treatment (if necessary) and disposal based on characterization results.

    Regulatory evaluation: This alternative would be implemented in a manner that complies with regulatory requirements, with the possible exception of concerns regarding the land disposal restriction (LDR) dilution prohibition of 40 CFR 268.3. In other words, the crushing and combining of liquids from potentially dissimilar waste streams could arguably be considered dilution of the individual bottled waste components. EPA requires LDR determinations to be made at the point of initial generation rather than at a centralized point of aggregation [8].

    Under this bottle management alternative, the constituent concentration of the waste within each individual bottle would not be determined, only the resultant composite waste would be analyzed.

As a consequence, a determination of whether the original bottled waste exceeded an LDR standard would not be made. There are, however, extenuating circumstances that could preclude complete LDR characterization of the individual bottled waste at the initial point of generation in any event. Predominant among these is the limited quantity of waste present in most bottles. This factor makes a full characterization of bottle contents technically impracticable: There simply is not enough waste present to allow all the required analytical tests to be run. Crushing multiple bottles and collecting and analyzing the resultant liquid conceivably addresses this issue by creating a larger volume waste stream, albeit at the risk of diluting one or more of the individual waste streams in an indeterminable manner. Thus, a regulatory dilemma exists: The individual bottle contents are typically insufficient to allow a complete LDR analysis and determination, whereas combining the bottle contents could result in dilution of one or more of the contributing waste streams in an indiscernible manner.

Development of Evaluation Criteria

The four alternatives were assessed based on three evaluation criteria, as described below:

- Worker protection: This criterion assesses the ability of the alternative to provide worker protection during implementation. Alternatives that have the least risk of worker exposure to bottled waste are ranked higher than those representing more exposure potential.
- Regulatory pathway: A variety of regulatory mechanisms may be required to implement the different alternatives. Those alternatives with the most straightforward regulatory pathways (e.g., no special regulatory approvals required) are ranked higher than those needing special allowances (e.g., approval of variances or waivers).
- Cost effective and time efficient: This criterion considers the ability of an alternative to meet cleanup milestones in a timely and cost effective manner.

Comparison of Alternatives

Each of the four alternatives were ranked using best professional judgment against the evaluation criteria and assigned a numerical score. A score of “1” represents the most favorable option compared with a criterion, whereas a score of “5” was assigned to the least favorable alternative in each category. In cases where more alternatives were relatively equal in comparison with a criterion the same score was assigned to each. Table I presents a matrix showing the scoring for each alternative against the criteria.

Table I
Anomalous Waste Evaluation Matrix

Alternative	Worker Protection	Regulatory Pathway	Cost Effective/Time Efficient	TOTAL
Individual bottle characterization/dispose	5	1	5	11
Visual evaluation/representative characterization/dispose	4	1	4	9
Crush in trench/characterize soil matrix/dispose	1	2	1	4
Visual evaluation/crush in container/separate liquid/characterize/dispose	3	3	2	8

(Ranking Key: 1 – most advantageous; 5 – least advantageous)

Proposed Approach

Based on this review, the recommended alternative for streamlining the management of anomalous bottle waste was <u>Option #3, Crush in Trench/Characterize Soil Matrix/Dispose</u>. As noted in the matrix evaluation, Option #3 provided the greatest worker protection while capitalizing on available regulatory pathways.

This evaluation was used to initiate discussions with the EPA regarding alternative bottle handling and treatment methods during 618-10 remediation.

IN SITU PROCESSING

Regulatory Pathway

Planning with the Hanford Project Office of the EPA, Region 10, resulted in implementation of a method similar to Option #3 described previously. An Explanation of Significant Differences (ESD) to the Record of Decision for the 300 Area Remedial Action was approved on August 3, 2011 which authorized a modified approach for managing liquids in bottles at 618-10. The ESD modified the remedy for 618-10 to allow for necessary treatment of liquid waste in bottles, up to one gallon per bottle, to occur in a tray or box within the excavation area. Because of the unknown integrity of bottles, removing each bottle from the excavation for individual handling poses a safety challenge. Safety for both workers and the environment is greatly improved if the bottles are placed into a tray or box in the excavation for treatment within the remediation area [9].

Method Development

Prior to implementing the treatment process, it was necessary to evaluate specific methods for crushing bottles, mixing with grout, and demonstrating successful treatment results. In order to be successful, a series of mockup tests would need to be performed to show complete breakage or opening of all bottles and successful stabilization of heavy metals. For mixing bottles with grout, Operations personnel suggested use of a standard construction “bedding box”. In order to maintain personnel and environmental protection, it was necessary to ensure that bottles were breached beneath the grout mixture. A standard excavation bucket was fitted with a plate tamper to facilitate breaking of bottles. As mockup tests progressed, small plastic vials were the only bottles surviving the crushing process. Additional means of crushing/shearing were needed. The addition of angular gravel into the grout mix achieved complete breakage of all of the test bottles.

Acceptance Testing

In order to demonstrate that the crushing and mixing operations would meet the goals of 1) breaching all bottles; and 2) stabilizing any hazardous metals, the process underwent an acceptance process consisting of two elements.

The first acceptance element was to demonstrate that the process would breach all test bottles. Initially a sand/water/crushed rock slurry was mixed up to approximate the Portland cement slurry consistency that was ultimately implemented. This was done so that the degree of breaching could be easily evaluated before progressing to further tests using cement. The crushed rock was added to aid in shearing bottles. A surrogate waste mix of water filled bottles was run through the treatment process [10].

Parameters for surrogate batch:

- Each batch was less than 1 gallon of liquid (3.78 L)
- Plastic and glass bottles were used
- Bottles were filled with water
- The bottle distribution per batch was:

Number of bottles	Size of bottle (mL)
1	500
2	250
5	100
10	50
25	20

To determine that the breaching and grouting process would be successful, there were three planned test batch campaigns using a Portland cement based grout. The grout mix was approximately 12% to 15% Portland cement with sand/soil added to mimic the burial ground soil that will be added to the mixing box during implementation. No aggregate was planned or needed except for the addition of angular gravel to aid in shearing. For process acceptance testing, each batch was spread over the surface to prove that breakage was complete.

Stabilization Process

In testing, surrogate bottle parcels were used. In practice, bottles are collected as they are found and then when enough have been collected a bottle crushing campaign is initiated.

The grout mix is first added to a mix box and then bottles are added to the slurry. The excavator bucket is outfitted with a tamper plate. The tamper plate is positioned over the bottles and then lowered, crushing them (figure 4). The material is then mixed with the excavator bucket to reveal any unbroken bottles. If unbroken bottles are seen, the tamper is used to crush again. Mixing and crushing continues until no unbroken bottles are seen.
This process may be repeated many times per each batch of grout.

After all crushing and mixing is complete, a small sample of material is placed on a ply wood surface and smeared thinly for ease in obtaining a sample. This sample is analyzed for RCRA metals. Process knowledge has showed that organic constituents are not a concern.

During testing, the stabilized material was placed on the ground and raked out to facilitate examination for complete breakage (Figure 5). In practice, the remainder of the material is placed into a metal box to cure for later disposal (Figure 6). Reprocessing may be necessary if sample results show metals above land disposal restriction levels.

Figure 4. Crushing and mixing test bottles with grout within a mix box.

Figure 5. Examination of finished test batch.

Figure 6. Final treated test batch packaged “for disposal”.

RESULTS

Sand Slurry Test

For this test, approximately 1.5 cubic yards of sand slurry (sand and water) was created to approximate the physical characteristics of the grout mix. This was done to allow for examining the crushed contents without Portland cement being present.

After the sand slurry was added to the bedding box, the heavy equipment operator added a portion of angular rock to the slurry and began crushing operations. For crushing, the operator worked the bucket plate tamper side to side from one end of the box to the other end in a manner that ensured the tamper overlapped its previous footprint by approximately four inches. This process was repeated twice to ensure total breakage.

After crushing, the operator mixed the contents of the bedding box a minimum of three times in order to stabilize the contents. If the operator saw any intact bottles during mixing, he repeated crushing and mixing steps as necessary.

After thorough mixing, the operator transferred the slurry containing crushed bottles to a soil area to be examined. A laborer raked out the mixture looking for intact bottles.
The only intact bottles seen were 20 mL poly bottles with poly lids. Even these containers, though intact, had the lid seals broken and sand inside demonstrating mixing with the slurry occurred.

The 20 mL bottles represented the worst case for testing purposes. These brand new bottles are extremely pliable and the poly lids are very flexible and robust. Also, these bottles are not representative of what will be found in the burial ground. Poly bottles will be brittle from years in the ground and chemical/radiological exposure. Also, bottles from the time period when waste was disposed in 618-10 would not have had poly lids. Lids used in those days were hard plastic and would break rather than flex [11].

Other than the 20mL poly bottles, all other containers were broken or shredded by the crushing and mixing process. This test was declared successful.

Grout Test 1 (G1)

Test G1 was conducted in the same manner as S1, except a nominal 12%-15% Portland cement mixture (3 sack controlled density fill) was used. The results were very similar to the sand slurry test with only two 20mL poly bottles coming through unbroken. Here again, the degree of crushing with these still resulted in mixing of contents with cement.

This test was declared successful.

Grout Test 2 (G2)

G2 was conducted the same as G1 with a couple of exceptions. The grout ordered for this test was ordered at a drier mix, with the intent to further hydrate it at the job site, if necessary. The resultant grout mixture was not hydrated to the same degree as test. Also, the mixing time appeared to be significantly shorter during this test.

After mixing and raking out the contents, one 20 mL glass bottle was discovered to remain intact. It was not broken and it still held the water that was placed in it prior to processing. Because the success criterion is 100% breaching of the bottles, this test was not successful.

Upon examining the differences in G2 compared to G1, it was thought that the dryness of the grout was the primary reason for failure. The mixture was more difficult to process and since it did not flow as freely as in the other tests, it was more difficult to see if intact bottles remained. This also explains the reduced mixing time. The operator ended the processing when he could not see intact bottles. The problem was the dryness of the grout mix caused large clumps obscuring the ability to see finer details such as the smaller unbroken bottles.

Grout Test 3 (G3)

G3 was conducted with the same grout mix as G2, but with significantly more water added to test the theory that the flowability of the grout was a key factor for success. The resultant mixture was much more flowable than the previous mix. Also, more angular rock was added to aid in breaching containers and the mixing time was increased. No unbroken bottles were observed and thus this test was declared a success.

Grout Test 4 (G4)

Since G2 was not a success, the project incorporated lessons learned into the work process and conducted one more test. The process is described in detail so that the processing differences can be seen.

For G4, approximately 1.5 cubic yards of 12 – 15% Portland cement at a 3 sack controlled density fill (CDF) was added to the bedding box. The operator then added approximately one quarter cubic yard of angular rock to the mixture. Surrogate waste bottles were added and the operator began crushing operations. For crushing, the operator worked the bucket plate tamper side to side from one end of the box to the other end in a manner that ensured the tamper overlapped its previous footprint by approximately four inches. This process was repeated five times to ensure total breakage.

After crushing, the operator mixed the contents of the bedding box a minimum of fifteen times to stabilize the contents. If the operator saw any intact bottles during mixing, he repeated crushing and mixing steps as necessary.

After thorough mixing, the operator transferred the slurry containing crushed bottles to a prepared area on soil for examination. A laborer raked out the mixture looking for intact bottles.
No intact bottles were observed. This test was declared successful.

Testing

For implementation with actual waste bottles, each batch of processed bottle/grout mix is sampled and analyzed for RCRA metals to determine land disposal restriction status.

IMPLEMENTATION

The process described for the G4 test run was incorporated into a procedure for actual bottle processing. To date, two bottle treatment campaigns have been conducted with hundreds of bottles of waste treated and disposed. The process has resulted in quick and safe processing. All analytical results of the grouted matrix have been below RCRA standards for land disposal (40 CFR Part 268).

CONCLUSION

Due to the radiological and physical safety challenges associated with remediation of the Hanford 618-10 burial ground, an innovative approach for bottled waste treatment was needed. Planning with the lead regulatory agency resulted in the development of a bulk stabilization method that is easily implemented and extremely safe. By crushing bottles under a grout slurry and thoroughly mixing the waste materials with the grout, a stabilized waste form is produced which meets land disposal criteria for disposal in Hanford's radioactive waste landfill. To date, hundreds of bottles have been successfully treated with no safety incidents or environmental releases. The estimated cost saving over the life of the 2 year project is S14 million.

REFERENCES

1 Comprehensive Environmental Response, Compensation, and Liability. 42 U.S.C. §9601 (1980).

2 U.S. Environmental Protection Agency. (2001). *Interim Action Record of Decision for the 300-FF-2 Operable Unit, Benton County, Washington.*

3 Nolan, L.M. (2007). *600 Area Remediation Design Solution Waste Volume and Inventory,* Washington Closure Hanford LLC, WCH-125 Rev. 0.

4 40 CFR, Part 268. *Land Disposal Restrictions,* Code of Federal Regulations, as amended.

5 U.S. Environmental Protection Agency. (2011) *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* SW-846, Chapter 9.

6 40 CFR, Part 260. *Hazardous Waste Management System - General,* Code of Federal Regulations, as amended.

7 WAC 173-303. *Dangerous Waste Regulations*. Washington Administrative Code, as amended.

8 Land Disposal Restrictions for Certain “California List” Hazardous Wastes and Modification to the Framework. 52 Federal Register 25766. (1987).

9 U.S. Environmental Protection Agency. (2011) *Explanation of Significant Differences, Hanford 300 Area, 300-FF-2 Operable Unit, 618-10 Burial Ground*.

10 Faulk, D.E. (2012). *Acceptance and Treatment Plan for Liquid Anomalies in Bottles at the 618-10 Burial Ground*, Washington Closure Hanford LLC, WCH-532 Rev. 0.

11 Faulk, D.E., (2012). *Acceptance Testing Results for Treatment of Liquid Anomalies in Bottles at the 618-10 Burial Ground,* Washington Closure Hanford LLC, WCH-533 Rev. 0.