Using Advanced Mixed Waste Treatment Technology To Meet Accelerated Cleanup Program Milestones

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ABSTRACT

Some DOE Complex facilities are entering the late stages of facility closure. As waste management operations are completed at these sites, remaining inventories of legacy mixed wastes must be finally disposed. These wastes have unique physical, chemical and radiological properties that have made their management troublesome, and hence why they have remained on site until this late stage of closure. Some of these wastes have had no approved or practical treatment alternative until just recently. Results are provided from using advanced mixed waste treatment technology to perform two treatment campaigns on these legacy wastes. Combinations of macroencapsulation, vacuum thermal desorption (VTD), and chemical stabilization, with off-site incineration of the organic condensate, provided a complete solution to the problem wastes. One program included approximately 1,900 drums of material from the Fernald Environmental Management Project. Another included approximately 1,200 drums of material from the Accelerated Cleanup Program at the Oak Ridge Reservation. Both of these campaigns were conducted under tight time schedules and demanding specifications, and were performed in a matter of only a few months each. Coordinated rapid waste shipment, flexible permitting and waste acceptance criteria, adequate waste receiving and storage capacity, versatile feed preparation and sorting capability, robust treatment technology with a broad feed specification, and highly reliable operations were all valuable components to successful accomplishment of the project requirements. Descriptions of the waste are provided; material that was difficult or impossible to treat in earlier phases of site closure. These problem wastes included: 1) the combination of special nuclear materials mixed with high organic chemical content and/or mercury, 2) high toxic metal content mixed with high organic chemical content, and 3) very high organic chemical content mixed with debris, solids and sludge. The waste materials were extremely challenging; at times exceeding 85% total organic chemical content. Vacuum thermal desorption operations are described that resulted in waste processing rates as high as 376 drum equivalents per month, with an average over 300 drums/month for a four month period. During

this same time period, performance verification sampling demonstrated 99.2% successful VTD treatment, with only 10 drums failing out of 1,244 drums processed. These 10 drums were successfully treated upon reprocessing in the VTD unit. Condensate volume of 14,400 gallons was collected from the 1,244 drums, composed of approximately 2/3 organic liquid having high chlorine content from both solvents and PCBs. This condensate is being shipped for off-site incineration as it meets the acceptance criteria for that disposal method. With this combination of management initiative, permits, and technology, important Accelerated Cleanup Program milestones have been met.

INTRODUCTION

Two mixed waste treatment campaigns were conducted in 2005 at the Envirocare site that were essential to DOE sites achieving closure milestones. These campaigns were conducted on waste from the Fernald Environmental Management Project (FEMP) and the Oak Ridge Accelerated Cleanup Program (ACP). Advanced mixed waste treatment technology was used including macroencapsulation, vacuum thermal desorption and chemical stabilization as part of an integrated treatment train. Without these technologies, important closure milestones would not have been achieved for these sites.

WASTE POPULATIONS

Descriptions of the waste are provided. The waste was received as part of two treatment campaigns; one for the Fernald Environmental Management Project, and another as part of the Oak Ridge Accelerated Cleanup Program. These waste materials were all difficult or impossible to treat in earlier phases of site closure for both facilities. These problem wastes included: 1) the combination of special nuclear materials mixed with high organic chemical content and/or mercury, 2) high toxic metal content mixed with high organic chemical content, and 3) very high organic chemical content mixed with debris, solids and sludge. The waste materials were extremely challenging; at times exceeding 85% total organic chemical content.

Fernald Environmental Management Project

Fluor Fernald has been performing active closure of the FEMP since the early 1990s. During that time, waste materials were treated on site, landfilled onsite, shipped to DOE disposal facilities, and shipped to commercial processors and disposal facilities. However, it was identified in 1997 that there were numerous mixed waste materials that had no existing permitted treatment or disposal capacity. Fluor Fernald began a systematic program to assure that these materials could be treated and disposed as an essential element to final closure of the site. In 2002, Fluor Fernald contracted with Envirocare of Utah to deploy a VTD unit for these wastes as part of a treatment train that included VTD, macroencapsulation, chemical stabilization and secure landfilling.

The Fernald treatment campaign was a follow up to a successful System Operability Test (SOT) that was performed at Envirocare in 2003 [1]. During the SOT, 170 representative drums of a variety of difficult to treat organic contaminated wastes were processed using VTD. For the treatment campaign, a total of 1,900 drums of waste were treated. Wastes consisted of materials as itemized in Table I.

Table I. Fernald Mixed Wastes Treated in Campaign

Fernald ID	Description	Fernald ID	Description
10026	1,1,1 TCE Still Bottoms – PCB	30005	Oily Sludges
2626	Oily / Water / Sludge – PCB	60051	Solvents and Filter Material
10023	Non-Recoverable Trash – PCB	61003	Oily rags
1427	Mop Heads	1411	Contaminated Solvents from Paint Shop
2682	Soil Extract Waste	3171	Dry Contact Waste
2992	Non-Recoverable Trash	50014	Non-Recoverable Trash
30010	Sludge	742	Oily Sludges from Floor Drains
396	Paint Thinner Rags	3767	Oily Sludges from Building 12 D&D
60303	Flame Retardant Blankets	10012	PCB Contaminated Burnables
514	Paint Waste	2785	Sludge from Ignitable Liquid Tank
2085	Liquid Chlorinated Solvents	3170	PCB Trash

All of these wastes were contaminated by uranium; natural, depleted and enriched. About 25% of these drums had uranium composition such that the material was designated as special nuclear material (SNM). These various complex wastes were placed into six treatment groups as shown in Table II. Organic contaminants included solvents like perchloroethene, at times at concentrations over 50%, as well as mixtures of semivolatile organics used in paint products and present in sludges.

Table II. Fernald Mixed Waste Streams Treated

Waste Stream	Description	Drum Equivalents	
		Total	VTD
9026-01	RCRA Organic Chemicals		492
9026-02	PCBs and Metals		83
9026-03	PCBs and Mercury		40
9026-04	RCRA Organic Chemicals and Mercury		221
9026-05	RCRA Organic Chemicals and Metals		365
9026-06	PCBs		11
		1,500	1,215

Oak Ridge Accelerated Cleanup Program

The USDOE's Oak Ridge Reservation encompasses nuclear materials operations at three separate large installations: the X-10 Oak Ridge National Lab, the K-25 Oak Ridge Gaseous Diffusion Plant, and the Y-12 Weapons Production Complex. Oak Ridge accumulated a large inventory of untreated mixed waste materials from its historic operations. Oak Ridge has been evaluating and performing mixed waste treatment and disposal since the late 1980s. This includes the operation of the K-25 TSCA Incinerator (TSCAI), a permitted mixed waste treatment unit. Substantial progress has been made from these efforts. In 1997 Bechtel Jacobs Company, the Oak Ridge operating contractor, had also established commercial contracts for the treatment of mixed waste materials [2]. However, in 2001 Bechtel Jacobs entered into the Accelerated Cleanup Program (ACP) agreement with USDOE to increase the rate of waste treatment. The ACP was designed to realize large programmatic savings by achieving more rapid progress than was occurring using pre-existing programs. As of late 2004 an inventory of mixed wastes remained at Oak Ridge, and needed to be permanently disposed by September 30, 2005 to meet the ACP milestones.

Table III. Oak Ridge Mixed Wastes Treated in Campaign

Ash (1420 incinerator)	Oily sludge and diapers
Bulked wastes: uranium and PCB contaminated excess samples	Containerized chemical materials, formulations, oils and paints.
Flammable liquids	Sludges generated from the clean out of tanker
Floor debris and scabble from a fixed (painted) contamination area	Vacuum debris, paint chips, and floor/concrete powder
Tank waste, oil with solvents, and beryllium	Waste paint related material
Miscellaneous soil, sludges and liquids contaminated by organics and metals	Miscellaneous debris contaminated by organics and metals

All of these wastes were contaminated by uranium. A majority of these drums had uranium composition such that the material was designated as special nuclear material (SNM). Mixed fission product and activation product isotopes from the operation of nuclear reactors are also present in the Oak Ridge waste. These various complex wastes were placed into four treatment groups as shown in Table IV. Waste streams –03 and –04 were contaminated by RCRA waste codes such as mercury that may not be acceptable to the TSCAI. As such, the condensate from these wastes will have to be reviewed for approval for disposal at the K-25 TSCA incinerator, making this condensate a potentially problematic waste material. The organic chemical concentrations in the Oak Ridge waste was extremely high, because of the presence of essentially pure organic chemical products, as shown in Fig. 1. The "paint chips" were PCB based, and represented the highest PCB concentration levels ever managed at the Envirocare site, at times generating PCB levels in the VTD condensate over 10%.

Table IV. Oak Ridge Mixed Waste Streams Treated

Waste Stream	**Description**	**Drum Equivalents**	
		Total	VTD
9036-01	RCRA Organic Chemicals and Metals	475	299
9036-02	RCRA Organic Chemicals, PCBs and Metals	488	331
9036-03	RCRA Organic Chemicals with Mercury or other EPA Waste Codes Problematic for TSCAI and Metals	217	206
9036-04	RCRA Organic Chemicals with Mercury or other EPA Waste Codes Problematic for TSCAI, PCBs and Metals	64	75
		1,244	911

Fig. 1. Feeding VTD unit with organic sludge from Oak Ridge

ADVANCED TREATMENT TECHNOLOGIES

For both of these campaigns, the waste materials were heterogenous mixtures of solids, sludges and debris. High levels of numerous organic chemicals imposed demanding performance requirements on the treatment in order to achieve the RCRA Land Disposal Regulations (LDR) Universal Treatment Standards (UTS). It was not practical to segregate the waste into treatable material at the generating site. It was much more effective to ship the waste to a facility that had multiple treatment technologies capable of managing all of the physical and chemical constituents in the waste containers.

The Envirocare of Utah facility is permitted to receive and store hazardous mixed waste for up to one year before treatment and disposal. The permitted mixed waste storage areas are large, allowing for storage of thousands of drums and boxes. The practical limitation on storage therefore is the processing rate of the treatment technology to assure that waste can be treated and disposed before the anniversary of its receipt. The facility's radioactive materials license also allows for storage of the SNM constituents of the Fernald and Oak Ridge wastes such that there was no practical limitation on their receipt for these campaigns. The RCRA Part B permit of the Envirocare site includes:

- Storage of hazardous wastes for up to one year,
- feed preparation by sorting, screening and shredding
- macroencapsulation of hazardous waste debris,
- thermal desorption of hazardous waste solids, sludges and debris, including treatment of TSCA regulated PCBs under the TD*X National TSCA approval,
- chemical stabilization of hazardous wastes, and
- secure landfill disposal of LDR compliant mixed waste solids.

Coordinated use of all of these capabilities proved essential in the performance of the treatment campaigns. Not only to achieve the demanding technical requirements of the projects, but also to meet the treatment schedules imposed by site closure activities.

Feed Preparation and Sorting

Waste materials are received at the site and placed into permitted mixed waste storage. Detailed review of the disposal manifests as well as visual inspections are performed to establish the treatment requirements of the waste. For these projects, some of the wastes was amenable to macroencapsulation treatment directly. These wastes containers were segregated and directed to that technology. However, relatively little of the waste was amenable to direct macroencapsulation without sorting.

Waste mixtures that had significant quantity of debris were sorted so as to remove debris and place it into separate containers for macroencapsulation. The remaining soil and sludge was directed to thermal desorption treatment. Some of the waste contained free liquids and these were solidified using absorbents to facilitate further processing. A small number of the waste containers had high or low pH materials that required chemical neutralization prior to thermal desorption treatment.

All of these feed preparation operations are performed in the Mixed Waste Treatment Building. This permitted unit has a filtered general and local exhaust ventilation system to provide controlled negative pressure of the treatment operations. A concrete containment floor and various material handling equipment facilitate efficient handling of the solids and sludge materials. Prepared feed materials are placed into drums for transfer to the VTD unit.

Macroencapsulation

Hazardous waste debris materials are macroencapsulated using three different permitted technologies at the Envirocare site. The most suitable technology is selected based on cost and performance requirements of each waste material. Macroencapsulation involves completely surrounding the hazardous waste debris with a durable material, such as plastic, to render it suitable for landfill disposal. The combination of the macroencapsulation and VTD technologies proved essential to providing complete treatment of the heterogeneous waste materials. Oftentimes large debris items were mixed in with solids and sludges. These would damage or reduce efficiency of the VTD unit. However, by simply segregating this debris during feed preparation it was effectively treated by macroencapsulation. If this unit operation was not available at the site, logistical complications would have been presented impacting the ability to meet the project's technical and schedule requirements. There was simply not sufficient time to repackage and ship materials to another site for debris treatment. Even if there was time, this would have adversely impacted the cost of treatment. Envirocare's macroencapsulation technologies are implemented at a production scale that allows for cost effective performance of this treatment.

Vacuum Thermal Desorption

VTD employs a TD*X high performance thermal desorption unit to treat organic chemical and mercury contaminated solids and sludges. The VTD unit provides aggressive treatment conditions that can separate virtually any organic chemical and mercury compound from waste materials, and achieve residual contaminant concentrations in the treated product regularly well below 1 ppm. This broad capability was essential for these projects, because the waste included mixtures of volatile and semi volatile organic compounds, PCBs, and mercury. The chemical constituents were ever variable from one container to the next. Aggressive treatment conditions provide a robust unit operation that can meet the LDR UTS requirements with a high degree of reliability. This proved absolutely essential considering the high expense of performance verification sampling and certified offsite analysis of the treated material. Furthermore, the project schedule for both campaigns simply did not allow for frequent re-treatment of material that did not meet the landfill criteria. Finally, neither DOE site was capable of receiving "untreatable" waste back if the technology failed, therefore, aggressive performance was especially important to the DOE site closure program.

The TD*X unit uses heat to separate the organic chemicals, mercury and water from the mixed waste materials. These compounds evaporate, leaving the radioactive solids as treated product suitable for landfill disposal. The vapors are carefully condensed into a condensate for disposal as a separate process residual. Treated product is placed into waste containers, matched with the original waste feed information. This is important because some wastes require chemical stabilization of the toxic metals prior to landfill disposal.

Chemical Stabilization

The Envirocare site has a batch stabilization mixer. This unit is used to perform chemical stabilization treatment of toxic metals according to proven chemical formulations. A wide variety of stabilization

chemicals are approved for use at the site; both solid and liquid reagents. This allows for flexible treatment of almost any toxic metal. Simple chemistries with only one reagent are often used. However, multiple step formulas involving oxidation/reduction reactions followed by simple stabilization are routinely performed. All of these operations are performed in the same Treatment Building as was feed preparation, allowing for the positive control of the operations. Stabilization can be implemented within a few days of completion of the thermal desorption treatment in order to achieve project schedule requirements. The VTD unit generates a treated product that is very well suited to stabilization treatment. All interfering organic chemicals have been removed. Furthermore, the solid product is easily fed to the stabilization unit and requires minimal reagent mix ratios because excess free liquids have been eliminated.

Off-Site Incineration of Organic Condensate

The VTD unit generates a liquid condensate. This material is very concentrated in the organic chemical contaminants. At times the chlorinated chemical content is so high that the condensate is a dense phase, such as shown in the photo in Fig. 2. Incineration is the most effective management method for this condensate material. For both the Fernald and Oak Ridge project, the planned incineration facility for the VTD condensate is the Oak Ridge TSCA Incinerator.

Fig. 2. VTD condensate from Fernald waste treatment

TREATMENT CAMPAIGN RESULTS

Vacuum thermal desorption operations are described that resulted in VTD waste processing rates as high as 376 drum equivalents per month, with an average over 300 drums/month for a four month period. During this same time period, performance verification sampling demonstrated 99.2% successful VTD treatment, with only 10 drums failing out of 1,244 drums processed in a four month time segment in 2005 that overlapped both the Fernald and Oak Ridge campaigns. These 10 drums were successfully treated upon reprocessing in the VTD unit.

During the time period from mid-2003 through March 2005, numerous performance demonstration tests were performed as part of the RCRA and TSCA permitting of the VTD unit. Waste materials from both Fernald and Oak Ridge were used to conduct these performance tests. All requirements of both the RCRA and TSCA permits were satisfied, including the attainment of PCB DRE well in excess of "six nines" as well as essentially no radioactive air emissions from the VTD unit. In March 2005, the VTD unit received interim operations approval allowing for routine commercial operations. This approval allowed for VTD unit operations at essentially 75% of rated capacity. At that time, Envirocare began scheduling waste deliveries up to the projected annual capacity of the VTD unit of 2,000 to 4,000 drums per year.

Fernald Campaign

Fernald waste treatment was initiated on a 24/6 basis on March 9, 2005. The Interim Operations approval allowed for VTD operations at 75% of rated capacity, therefore, only six work days per week were scheduled because of this constraint. Full-scale VTD operations on Fernald waste continued until June 4, 2005, when the last drum of mixed waste from the Fernald site was processed. Chemical stabilization was required for 30% of the Fernald treated product from the VTD unit. This is because the product also contains toxic metals. Chemical stabilization was completed by June 25, 2005 and all of the material was placed into the Envirocare landfill by June 30, 2005. This extremely important milestone allowed Fluor Fernald to achieve final closure of the Fernald site on schedule. One to two truckloads of waste were received per week during the most active part of this campaign. A total of 18 truckload shipments of waste were received between March and June, having a total of 1,400 drum equivalents. A total of 945 drums were processed using VTD in this three month span for an average VTD processing rate of 334 drums/mo. This was with VTD plant operations scheduled around a 75% capacity restriction from the Interim Operations approval.

- Full-scale VTD operations March 9 – June 4, 2005
- 18 truckload shipments of waste totaling 1,400 drum equivalents
- 945 drums treated by VTD March 9 – June 4 → average 334 drum/mo at 75% VTD capacity
- 30% of treated product required chemical stabilization
- All waste placed in landfill by June 30, 2005

Oak Ridge Campaign

The Oak Ridge treatment campaign was performed under somewhat more demanding schedule constraints. Waste shipments did not begin until May 2005, with the first shipment being received at the site on May 17. Oak Ridge feed preparation was started immediately upon waste receipt, and the first VTD operations began on June 5, 2005, immediately following completion of the Fernald campaign. Waste shipments were made at essentially the maximum rate possible considering regulatory compliance framework for shipping paper preparation, container inspection and truck loading. Between May and September, 26 truckload shipments were performed. A total of 1,200 drum equivalents of waste was shipped in this time. VTD operations were performed from June 5 through September 22, with 926 drums processed by VTD. At times, VTD processing was being performed the same day that a shipment was received at the site so that progress could continue to be made. This required extreme coordination between the Oak Ridge shipping staff, Envirocare receiving, sampling and feed preparation, and the TD*X VTD operations. The final ACP waste was stabilized and placed into the Envirocare landfill prior

to September 30,2005. This allowed Bechtel Jacobs to achieve an extremely important ACP milestone related to treatment of 100% of the most troublesome waste at that site.

- Full-scale VTD operations June 5 – September 22, 2005
- 26 truckload shipments of waste totaling 1,200 drum equivalents
- 926 drums treated by VTD June 5 – Sept 22 → average 264 drum/mo at 75% VTD capacity
- 30% of treated product required chemical stabilization
- All waste placed in Envirocare landfill by September 30, 2005

Condensate Characterization

Condensate volume of 14,400 gallons was collected from the 1,244 drums that were processed in the VTD unit between March and June 2005. Average condensate yield from both the Fernald and Oak Ridge waste was about 40% of the original waste material. These wastes were extremely challenging from a thermal desorption perspective. Further validation of the robust capabilities of the TD*X high performance thermal desorption unit. The condensate was composed of approximately 2/3 organic liquid having high chlorine content from both chlorinated RCRA regulated hazardous chemicals and PCBs. This condensate is being shipped for off-site incineration as it meets the acceptance criteria for that disposal method.

Analytical characterization of the VTD organic condensate has shown the following values:

- pH 3.3 to 5.7
- Heating Value 16,500 to 13,100 btu/lb
- Density 0.9 g/cc
- Flash Point 80˚F
- Chlorine 55,000 to 79,400 ppm
- Sulfur 800 ppm
- Metals trace
- PCBs 40 to 157,000 ppm
- Benzene 1,770 to 2,620 ppm
- Trichloroethene 4,020 to 6,390 ppm
- Tetrachloroethene 18,700 to 57,700 ppm
- Xylene 20,300 to 68,700 ppm

CONCLUSION

As DOE sites enter the final stages of closure, sometimes the most complicated and challenging wastes remain to be treated and disposed. The successful disposition of these complex wastes requires advanced mixed waste treatment. Furthermore, performance of these projects under the tight schedules dictated by site closure emphasizes the value derived from having robust treatment capability at the same site. The treatment train of feed preparation, macroencapsulation, vacuum thermal desorption, chemical stabilization and secure landfilling at the Envirocare site allows truckload quantities of these complex wastes to be shipped, treated and disposed. This treatment train can treat essentially all hazardous organic chemicals and metals in solids, sludges, and debris. Projects can be executed with low risk that problems will occur. Broad permits and large on-site storage capacity further enhance project performance.

REFERENCES

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