359 pages

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January 9, 1995

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Re: Final Report

Enclosed is a copy of the final report entitled "Evaluation and Screening of Treatment and Disposal Options for the Solar Ponds Sludges at Rocky Flats". Many individuals and organizations contributed to this report which was delivered to DOE in December. I hope that you found the project interesting, if not enjoyable, and I would like to thank-you all of you for your time and participation in this endeavor.

Regards-

Kathryn

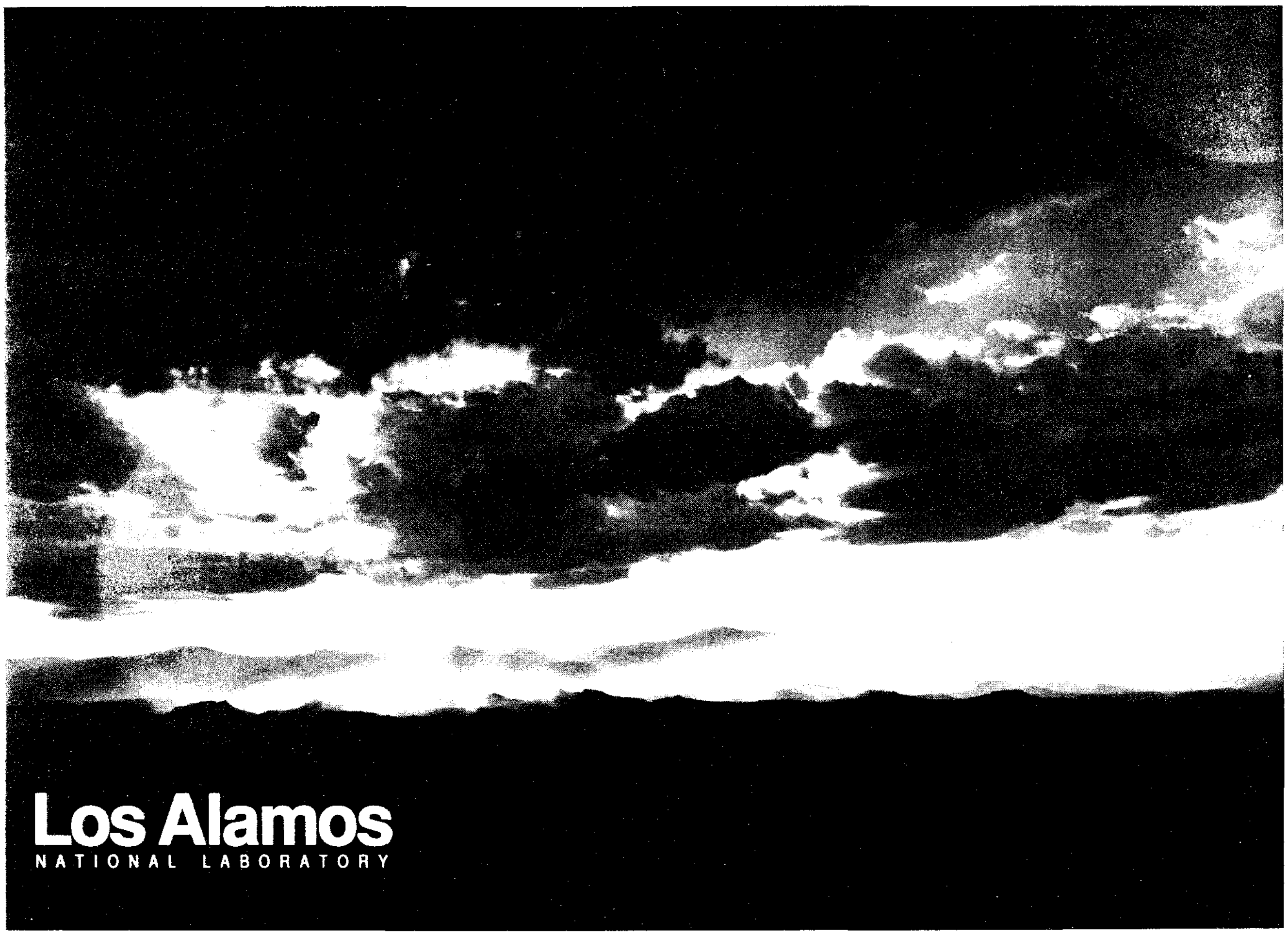
LA-UR-94-4414

Issued: December 1994

Evaluation and Screening of Treatment and Disposal Options for the Solar Pond Sludges at Rocky Flats

Prepared by

Los Alamos Technology Office at Rocky Flats,
an office of
Los Alamos National Laboratory



Photograph by Chris J. Lindberg

Final Report

49189

LA-UR-94-4414

Evaluation and Screening of Treatment and Disposal Options for the Solar Pond Sludges at Rocky Flats

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ACRONYMS AND ABBREVIATIONS

ARAR	-	applicable or relevant and appropriate requirement
ATTIC	-	Alternative Treatment Technology Information Center
BNL	-	Brookhaven National Laboratory
BWR	-	boiling water reactor
CAMU	-	corrective action management unit
CCW	-	constituent concentration in the waste
CCWE	-	constituent concentration in the waste extract
CDPHE	-	Colorado Department of Public Health and Environment
CERCLA	-	Comprehensive Environmental Response, Compensation and Liability Act
DOD	-	Department of Defense
DOE	-	Department of Energy
DOT	-	Department of Transportation
dpm/g	-	disintegrations per minute per gram
EPA	-	Environmental Protection Agency
FFCA	-	Federal Facilities Compliance Act
gal.	-	gallon
IAG	-	interagency agreement
IM/IRA	-	interim measure/interim remedial action
INEL	-	Idaho National Engineering Laboratory
ISV	-	in situ vitrification
ITS	-	interceptor trench system
LANL	-	Los Alamos National Laboratory
LATO/RF	-	Los Alamos Technology Office at Rocky Flats
LDR	-	land disposal restriction
LLMW	-	low-level mixed waste
μg/kg	-	microgram per kilogram
μg/L	-	microgram per liter
mg/kg	-	milligram per kilogram
mg/L	-	milligram per liter
nCi/g	-	nanocuries per gram
NEPA	-	National Environmental Policy Act
NTS	-	Nevada Test Site
ORNL	-	Oak Ridge National Laboratory
OU	-	operable unit
PAH	-	polyaromatic hydrocarbons
PCBs	-	polychlorinated biphenyls
PCE	-	perchloroethylene
pCi/g	-	picocuries per gram
pCi/L	-	picocuries per liter
PNL	-	Pacific Northwest Laboratory
psi	-	pounds per square inch
RA	-	remedial action
RCRA	-	Resource Conservation and Recovery Act
RFETS	-	Rocky Flats Environmental Technology Site
RFFO	-	Rocky Flats Field Office
RO	-	reverse osmosis
ROD	-	record of decision

PREFACE

This report describes the methods and results of a study to evaluate and screen options for treatment and disposal of low-level, mixed waste sludges at the U. S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (RFETS) near Denver, Colorado. During 1994, ~650,000 gal. of sludges were removed from a series of solar evaporation ponds and stored on the site in numerous 10,000-gal. tanks. To facilitate appropriate treatment and disposal of the containerized sludges, the DOE Rocky Flats Field Office requested that national laboratory staff affiliated with the Los Alamos Technology Office at Rocky Flats provide technical support to DOE during closure and remediation of the solar ponds. The work described herein was initiated during late fall 1993 and completed during the subsequent nine months. The evaluation and screening work was designed to be unbiased and independent of related activities of the managing and operating contractor, EG&G/Rocky Flats, Inc. However, the work was completed with knowledge of and participation by EG&G personnel, including EG&G membership on an ad hoc technology evaluation team. Independent peer review of the work was obtained through an ad hoc committee of nationally recognized scientists and engineers. In its current form, this report is a final document that has undergone review and comment by DOE project sponsors, ad hoc peer reviewers, and report authors.

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Many individuals and organizations have contributed to completion of the work described in this project report. The authors recognize the following individuals for their contributions to the project.

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Private Industries and other DOE sites

Numerous private industries and sites provided valuable input to project surveys.

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EXECUTIVE SUMMARY

Solar evaporation ponds referred to as Operable Unit 4 (OU4) have been used at the U. S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (RFETS) since the early 1950s for disposal of process wastewaters containing a variety of constituents, including radioactive and hazardous materials. The ponds were routinely used through the mid-1980s, after which RFETS began efforts to close them in accordance with regulatory requirements and DOE commitments. The original closure process for the solar ponds and OU4 involved evaporation of any remaining liquids, ex situ stabilization/solidification (S/S) of the sludges, and off-site disposal of the solidified blocks at the Nevada Test Site (NTS). RFETS began removal and treatment operations but terminated them in 1990 because of problems in the early S/S work and an inability to dispose of the final waste form. During spring 1994, the remaining sludges in the ponds were removed using a vacuum truck and then placed in temporary storage consisting of numerous 10,000-gal. double-wall polyethylene tanks located under a tent on the 750 pad. As of this writing, ponds 207A and 207B have been emptied, and pond 207C removal is ongoing.

The purpose of the work described in this report has been to identify, evaluate, and screen options for treatment and disposal of the containerized sludges, consistent with the overall OU4 closure strategy and current waste management options available and feasible for RFETS. This work examined potential treatment options in light of feasible options for final disposal (e.g., on-site disposal in OU4 or in a new RFETS disposal cell; off-site disposal at Envirocare of Utah, Inc.) and given that the sludges would be containerized in tanks.

To perform the initial aspects of this study, the authors acquired, reviewed, and assimilated relevant documents; met with DOE, EG&G/RF, and regulatory agency staff; searched databases and open literature sources, both manually and on-line; and telephoned and wrote technical experts and industry representatives. These efforts contributed to completion of the following principal work elements: problem definition, including compilation of available sludge characterization data and the relevant treatment and disposal criteria; unconstrained identification of sludge treatment technologies potentially applicable to OU4; a survey of sites with experience in treating and disposing of sludges similar to those of OU4; a survey of environmental technology developers and providers to determine potentially viable options and their commercial availability; and identification of a candidate list of potential viable treatment and disposal options. This information was then used by an interdisciplinary, multi-institutional team of scientists and engineers affiliated with RFETS to review, discuss, and rank each candidate system. This report describes the methods, results, and conclusions of this study.

Available sludge characterization information indicated that the sludges comprised low-level mixed waste of two different waste compositions, depending on the source of the sludges. Contents of ponds 207A and 207B were characterized as a brackish solution in equilibrium with a mixed chemical and mineral sediment sludge. In contrast, pond 207C sludges were characterized as a brine solution in equilibrium with a chemical sludge. Sludges from the 207A/B ponds exceed land disposal restrictions (LDRs) for cadmium, whereas sludges from pond 207C exceed LDRs for cadmium and nickel. Alpha and beta radionuclides are also present, but at low levels, typically below 10 nCi/g. Radionuclides present are plutonium-239, americium-241, uranium-234, uranium-235, and uranium-238.

A review of published literature and selected remedial action databases revealed that S/S with cement-based processes was the most common sludge treatment method used. Relatively few sites had chosen innovative technologies for sludge treatment, and where innovative technologies were originally chosen, they were often abandoned for more conventional approaches. Factors that led to changes in technology selection after an innovative technology was initially chosen included (1) demonstration of technology infeasibility during treatability studies, (2) discovery of new contaminants, (3) discovery of contaminants in higher concentrations than anticipated, (4) inability of the selected technology to handle variability of wastes, (5) community concern over the selected remedy, and (6) technology not becoming commercially available as anticipated.

A focused survey of sludge treatment projects at other DOE sites indicated that only a few technologies were used to treat most sludges and that, like Superfund sites in general, established technologies were chosen most frequently, specifically stabilization. Only four sites had undergone treatment and disposal, with the remaining sites currently in the evaluation or treatment phases. Approximately half of the sites with sludges had either used or are planning to use S/S by cementation or grout. Other options either under consideration or being implemented included in situ vitrification, flyash immobilization, dewatering, thermoplastic encapsulation, chemical stabilization, and denitrification.

Disposal options in use or being considered by DOE sites were also surveyed, and it was found that approximately 75% of the sites have or plan to dispose of the treated sludges off the site. Of the sites that have considered on-site disposal, about half of the disposal actions were completed prior to new stringent land disposal regulations (e.g., mid 1980s). DOE sites considering or currently operating on-site sludge disposal options include larger sites such as NTS, Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory (LANL), Savannah River, and Portsmouth.

DOE sites were also queried regarding consideration and implementation of the corrective action management unit (CAMU) concept. Of those questioned, most sites were familiar with the CAMU concept but were not pursuing it for sludge treatment and on-site disposal. Disposal planning was still focused on off-site disposal options. Reasons given included political constraints, space limitations, environmental setting, and/or regulatory considerations. Perhaps more importantly, many of the sludge waste streams identified at the other DOE sites were from current operations, and thus, CAMUs were not applicable. Hanford and Fernald were the only sites surveyed that had actual experience working with the CAMU permitting process. After reviewing a CAMU option at Hanford, the U. S. Environmental Protection Agency (EPA) denied the permit application because it felt that the proposed option could not be defended to the public and other stakeholders. Fernald has implemented CAMU for solid waste landfills only.

A formal survey of environmental technology developers and providers was designed to obtain detailed information regarding potentially applicable sludge treatment technologies and their operation and performance characteristics. Seventeen vendors (out of 86 queried) responded to the inquiry, proposing a total of 24 processes. These processes can be generalized into six types of treatment technologies (of varying development stages): S/S, chemical extraction/precipitation, polyethylene immobilization, vitrification, molten metal, and pyrolytic concentration.

Assimilation and integration of information obtained through literature reviews, the DOE site survey, and the environmental technology vendor survey led to development of a candidate list of treatment and disposal options. An ad hoc technology evaluation team composed of 11 scientists and engineers from Oak Ridge National Laboratory, LANL, and EG&G/RF was assembled to review, consider, and then score and rank different candidate treatment and disposal systems. Several working team meetings were held to discuss and concur on the candidate technology list and the methodology for evaluation and screening. A total of 22 different systems developed from 9 different treatment technologies and 3 different disposal options were considered in this analysis. Results from this team effort indicated that the treatment and disposal systems were ranked so that there were three different groupings; nonparametric statistical tests revealed that the groupings were significantly different. The top-ranked system was cement-based S/S. The middle-ranked systems were simple stabilization, biochemical stabilization, biodenitrification followed by cement S/S, pressure S/S, and polymer S/S. The lower-ranked systems were vitrification, microwave S/S, and plasma hearth S/S. Because the evaluation included treatment and disposal systems, each treatment technology was evaluated with different likely disposition options, including on-site burial in OU4 or a new disposal cell or off-site disposal at Envirocare of Utah, Inc. While on-site disposal was generally preferred, preferences for one disposal option over another were not as strong as those for the treatment processes.

The results of this work led to several general conclusions. In brief, the sludges were clearly low-level mixed waste of variable character and composition, and while numerous candidate treatment and disposal options appeared potentially applicable, S/S with burial in OU4 or a new disposal cell appeared most appropriate for further consideration. Prior to selection, design, and implementation of a full-scale treatment and disposal system, focused analysis and treatability testing should be completed.

Evaluation and Screening of Treatment and Disposal Options

for the Solar Pond Sludges at Rocky Flats

1.0 INTRODUCTION

Operable Unit 4 (OU4) solar evaporation ponds (SEPs) have been used at the Rocky Flats Environmental Technology Site (RFETS) since the early 1950s for disposal of process wastewaters containing a variety of constituents, including radioactive and hazardous materials (Rockwell International 1988b). The first pond was constructed in December 1953, and additional ponds were built over the next 17 years. During this period, five SEPs were routinely used, with a total surface area of 6.5 acres and a liquid volume of 14.5 million gal. These ponds were lined with impervious materials, and liquid treatment occurred by evaporation.

Since 1985, RFETS has attempted to close the ponds in accordance with regulatory requirements and U. S. Department of Energy (DOE) commitments (EG&G 1993a, ICF Kaiser Engineers 1993a). The original closure process involved evaporation of any remaining liquids, ex situ solidification/stabilization of the sludges, and off-site disposal of the solidified blocks at the Nevada Test Site (NTS). RFETS began removal and treatment operations at Pond 207A but terminated further activities in 1990 because of problems in the early stabilization/solidification (S/S) work and an inability to dispose of the final waste form at NTS. As part of the closure process, the sludges remaining in the ponds were removed with a vacuum truck and transferred to approximately 50 double-walled polyethylene tanks (10,000 gal. each) located on the 750 pad beginning in the spring of 1994. With the sludges containerized in permitted storage tanks, RFETS efforts were focused on management of the pond liners, ancillary apparatus, and underlying/adjacent soils and sediments concurrently with an evaluation of options for sludge treatment and ultimate disposal.

1.1 OBJECTIVES AND SCOPE

In response to a request by the DOE Rocky Flats Field Office (RFFO), the Los Alamos National Laboratory (LANL), through the Los Alamos Technology Office at Rocky Flats (LATO/RF), initiated an evaluation and screening of treatment and disposal options for the containerized SEP sludges consistent with the overall closure strategy for OU4. The objective of this effort was to identify, evaluate, and screen commercial and emerging technology options for treatment and disposal of the sludges removed from the ponds and containerized on the site. Specifically excluded from this analysis were existing inventories of pondcrete and other materials generated during earlier sludge treatment and site closure activities. It was recognized, however, that some technologies identified and applicable to the newly containerized raw sludges might be applicable to the existing pondcrete as well.

The principal work elements conducted during this project were (1) problem definition, including sludge characterization information and treatment and disposal constraints; (2) computerized and manual searches of databases and open-literature sources for identification of sludge treatment technologies potentially applicable to OU4; (3) survey of sites with experience in treatment and disposal of sludges similar to those of OU4; (4) survey of private industry technologies and their capability for treating OU4 sludges; (5) scoring and ranking of candidate treatment processes; (6) meetings with DOE, EG&G, and regulatory staff; and (7) ad hoc peer review (Fig. 1.1).

This report presents the results of this work, including a description of several applicable technologies and a relative ranking regarding those with greater or lesser promise for feasible and effective application to a successful sludge treatment and disposal system.

1.2 ORGANIZATION AND METHODOLOGY

RFFO sponsored the project and provided oversight, while LATO/RF organized and administered the project. Technical staff associated with LATO/RF (on temporary or permanent assignment) were responsible for project direction and conduct. Staff from Oak Ridge National Laboratory (ORNL) (from both Oak Ridge, TN, and Grand Junction, CO, installations) and RUST Geotech in Grand Junction, CO, made valuable contributions to the project. An ad hoc technical review committee consisting of national experts in sludge treatment and disposal was also assembled and provided valuable comments.

Throughout this effort, routine interactions occurred between the project team and OU4 technical and management personnel affiliated with EG&G, Inc., the managing and operating contractor for RFETS. This was done to ensure that the project team had a clear and complete understanding of the history and current status of the ponds, including any previous characterization and treatment studies. This communication also provided detailed and current information regarding ongoing and developing actions potentially impacting the handling, treatment, and disposal of the sludges. These interactions proved beneficial to project participants by providing key information as well as increasing understanding of the constraints likely to be placed on potential treatment and disposal options.

1.3 RELATIONSHIP TO OTHER ACTIVITIES

The work described herein is related to other ongoing environmental restoration and waste management actions at RFETS as described in this section. Closure actions for the OU4 SEPs are directed under the Rocky Flats Plant Interagency Agreement (IAG), which is under renegotiation with the Colorado Department of Public Health and Environment (CDPHE) as the lead regulatory agency (DOE 1991 and 1994a). Remedial investigations at OU4 have been split into two phases. Phase 1 addresses characterization of source materials and soils, whereas Phase 2 will investigate the nature and extent of surface water, groundwater, and air contamination and evaluate potential transport pathways. The Phase 1 Interim Measures/Interim Remedial Actions (IMs/IRAs) effort includes the Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation and closure action proposed at OU4. Closure of the SEP sources includes pond structures, liners, and contaminated surface and vadose zone soils. The contents of the SEPs (i.e., process wastewaters and sludges) were removed from the ponds via a separate remediation project before the closure/remediation activities were implemented.

One potential SEP sludge treatment technology, biodenitrification, is already being investigated at RFETS under a separate but related project. Biodenitrification in sequencing batch reactors (SBRs) is known to be a promising treatment technology for aqueous solutions and sludges associated with the SEPs (and other waste streams and media at RFETS) (Francis and Mankin 1977, Irvine and Busch 1979, Silverstein and Schroeder 1983, Cook et al. 1993). For aqueous solutions, the process can reduce nitrate concentrations and facilitate stabilization of sludges and unrestricted discharge of intercepted groundwaters (e.g., interceptor trench system water; >1 million gal./year). To evaluate the potential of this bioprocess for application at RFETS, an experimental investigation was undertaken wherein the rate and extent of treatment under variable waste concentrations are being examined and factors controlling the removal of nitrogen species are being identified.

Bioprocess effects on the characteristics and management of sludge residuals are also being studied. This work is being conducted by faculty and students at the University of Colorado at Boulder and the Colorado School of Mines in collaboration with national laboratory scientists and engineers at the LATO/RF. Field demonstration in FY 1995 is envisioned to include establishment and operation of a pilot-plant system at RFETS treating actual SEP waters and/or sludges.

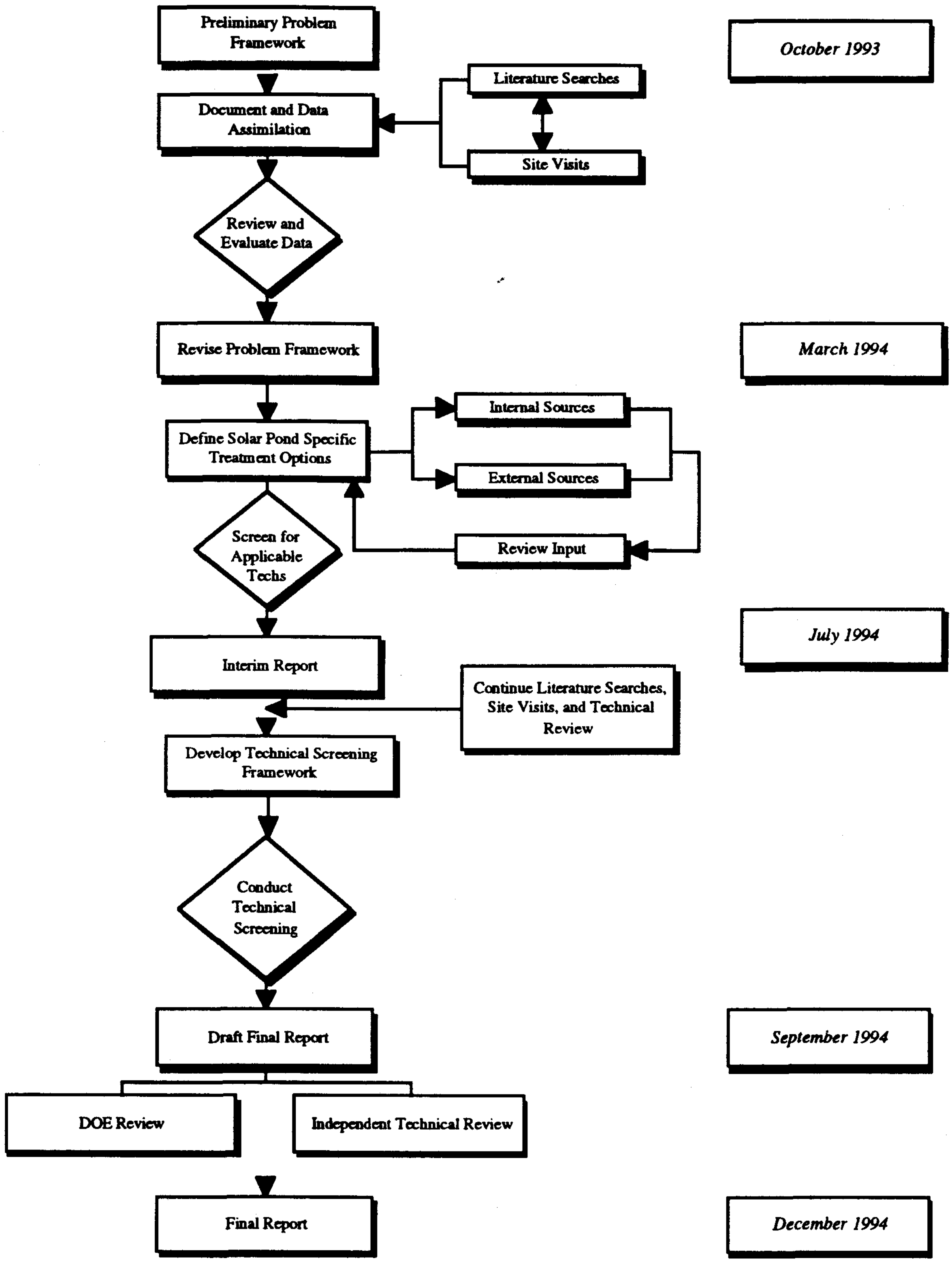

Fig. 1.1. Project elements and their inter-relationships and timing.

2.0 SITUATION DESCRIPTION

One of the first elements in this project involved familiarization with the site history and status, characterization of the pond contents, and feasible disposal options. The methods and results of this work are outlined below.

2.1 METHODS

This work was completed through various information-gathering activities. These included acquisition of numerous documents describing site history, sampling and analysis activities, and closure planning. Interviews were conducted with knowledgeable staff at RFETS in both DOE and EG&G. Project review meetings involving DOE, EG&G, CDPHE, and the U. S. Environmental Protection Agency (EPA) were also attended. The information gathered was reviewed and synthesized to create a concise understanding of the current situation and the history behind it, as well as what might be considered a feasible and effective solution for sludge treatment and disposal.

2.2 RESULTS AND DISCUSSION

2.2.1 Site History and Status

RFETS is located in Jefferson County approximately 16 miles northwest of Denver and 8 miles south of Boulder (Fig. 2.1). The SEPs are located in the northeast quadrant of the site (Fig. 2.2). RFETS is part of the nationwide Nuclear Weapons Complex and has been operated by DOE and its predecessors since 1951. Operations at RFETS have consisted of fabrication of nuclear weapons components from plutonium, uranium, and other non-radioactive metals. Other activities at RFETS include research and development in metallurgy, machining, non-destructive testing, coatings, remote engineering, chemistry, and physics. Both radioactive and non-radioactive wastes were generated in production processes (EG&G 1992). A synopsis of the SEP history and status is provided below; further details may be found in the "Phase 1 RFI/RI Work Plan Solar Evaporation Ponds Operable Unit No. 4, Volumes I and II" (EG&G 1992) and the "OU4 Solar Evaporation Pond Interim Measures/Interim Remedial Action Environmental Assessment Decision Document, Volumes I through VI" (DOE 1994a).

The first solar pond, constructed in 1953 and sealed with a bentonite clay liner, was designed to store and treat by evaporation low-level radioactive process wastes containing high nitrate concentrations and neutralized acidic wastes. The following year, a spring on the hillside north of the pond was found to be contaminated with nitrate. It was concluded that this resulted from leakage from the clay-lined pond. These findings prompted the construction of the asphalt-lined 207A pond in 1955 and the 207B ponds (north, center, and south) in 1960 (DOE 1994a) (Fig. 2.2). The original pond was regraded in 1970 during the construction of pond 207C, which is lined with asphaltic concrete and was constructed to provide additional storage capacity and to allow the transfer and storage of liquids from the other ponds in order to perform pond repair work.

The Water Control and Recycle Program was initiated in the early 1970s to study surface water features at RFETS, including the SEPs. A report of the findings stated that during the operation of the SEPs, cracks developed in the lining of the ponds and nitrate wastes entered the groundwater (EG&G 1992). Nitrate was found in the 207A pond, but at levels typically below drinking water standards most of the year, and no radionuclides were detected. In response to this contamination, a series of trenches and sumps were installed north of the SEPs from 1971 through 1974. The trenches and sumps collected seepage and groundwater and were in operation until the 1980s. At that time they were replaced by a french drain (a.k.a. interceptor trench system, ITS) which remains in use today.

Implementation of the Water Control and Recycle Program also included cleaning the 207B ponds. The 207B ponds received process waste until 1977. At that time, the existing residuals were moved into the 207A pond to allow for liner repairs in the 207B-north and -center ponds and installation of a flexible membrane liner in the 207B-south pond. During this work, low-level alpha contamination was detected around the perimeters of the SEPs. Contaminated soil from around the SEPs was subsequently removed over the next several years. Disposition of the removed soils is unknown to these authors.

In response to continued groundwater seepage (nitrate-contaminated) on the northern hillside below the SEPs, a program was initiated in the early 1980s to remove and manage the accumulated SEP sludge. Pond 207A received process wastes until 1986, at which time dewatering and sludge removal operations began. The 207B ponds have not contained process waste since 1977 (EG&G 1992) but have been used to store treated sanitary effluent, treated water from the reverse osmosis (RO) facility, backwash brine from the RO facility, and contaminated groundwater from the ITS. Pond 207C received process wastewater until 1986. Wastewaters in the pond at that time have remained there in storage pending ultimate disposal.

During the sludge removal operations in the 1980s, sludge treatment consisted of pumping the decant water on top of the pond sediments/sludge to the evaporators located in Building 374. The remaining sludge was then slurried and pumped into the clarifier for further dewatering and thickening. The thickened sludge was then blended with Portland Type I cement for stabilization. The resulting material, referred to as pondcrete, was cast into lined cardboard boxes (i.e., approximately 14-ft^3 tri-wall containers) and allowed to solidify. The resulting waste was then shipped to NTS for disposal (Halliburton NUS 1992a). The pondcrete was routinely disposed of at NTS until the fall of 1986, when it was first identified as low-level mixed waste (LLMW) (Rockwell International 1988a and Halliburton NUS 1992a). At that time, NTS was not permitted to accept LLMW, and waste shipments were terminated. However, production of pondcrete continued and the solidified waste was stored outside at RFETS on two storage pads until late 1988. At that time, it was discovered that several of the pondcrete tri-wall containers had deformed, partly because of weather exposure and partly because of incomplete hardening and solidification (Halliburton NUS 1992a).

After negotiations with the regulators, DOE initiated the present closure strategy for the ponds, wherein the sludges were removed from the ponds into 10,000-gal. double-wall polyethylene tanks while options were evaluated for final treatment and disposal. Sludge removal operations were initiated during Spring 1994. Sludges are being removed by vacuum truck from the existing ponds and placed into 53 10,000-gal. double-wall polyethylene tanks for temporary storage (Fig. 2.3). As of this writing, ponds 207A and 207B have been emptied, and pond 207C removal is ongoing. Because of space limitations in the tent-covered storage area, excess water in the sludge is being decanted after the tanks have been filled and the sludges allowed to settled. This is being done to make room for additional sludge in the tanks. The sludges will not be dewatered further prior to treatment.

2.2.2 Characteristics of the Pond Contents

An understanding of the volume, composition, and character of the pond contents (water and bottom sludges) is critical to evaluating options for treatment and disposal. Separate pond water and sludge samples were collected by Weston in May 1991 (Dames and Moore 1991) and by Halliburton NUS in August 1991 (Halliburton NUS 1992b). Selected chemical and physical characteristics of the pond water and sludges are summarized in Tables 2.1 and 2.2 and in Fig. 2.4; detailed summary tables are presented in Appendix A. Plans to empty the ponds were initiated in 1993 and resulted in commingling and mixing of residuals from pond 207A and the 207B series. It should be noted that the sample data in Tables 2.1 and 2.2 were collected prior to these pond operational activities, which included removal and transfer of pond waters and sludges both between and from the ponds. Residuals from the 207A/B ponds and the C pond have remained segregated during containerization. Although samples were collected before the pond contents were moved and mixed, these data represent the best available information. Variation of composition of the sludges as transferred and stored in the 10,000-gal. tanks is expected; however, the data in Table 2.2 provide reasonable insight into expected concentration ranges.

The characterization data summarized in Tables 2.1 and 2.2 clearly reveal that the ponds must be differentiated based on their contents. Ponds 207A and 207B may be characterized as a brackish solution in equilibrium with a mixed chemical and mineral sediment sludge. In contrast, pond 207C contents may be characterized as a brine solution in equilibrium with a chemical sludge. Given the marked differences, the characteristics of the pond contents are discussed separately, first for 207A/B and then for 207C.

Ponds 207A and 207B -- The water previously in ponds 207A/B was high in salts, as evidenced by total dissolved solids (TDS) of 7600 to 16,000 mg/L. The total suspended solids (TSS) were low at <40 mg/L. Primary cations included magnesium, calcium, potassium, and sodium; the primary anions were nitrate, sulfate, and chloride. Nitrate is particularly high at 300 to 2100 mg/L. The pond water was alkaline at pH ~9 (range of 8.3 to 9.9). The total organic carbon (TOC) was moderate at 30 to 300 mg/L. The principal hazardous substances in the water included heavy metals (e.g., arsenic, chromium), but they were present at only µg/L concentrations. Radioactive substances were present; gross alpha and beta activities were 50 to 3000 pCi/L.

Sludges from ponds 207A and 207B (north, center, and south) appear to be principally composed of fine-grained mineral matter, possibly derived from process wastewaters or wind-blown silts and clays. The leachable TDS are quite low at <800 mg/L. TOC ranges from 3000 to 34,000 mg/kg. The sludge pH is also alkaline (near 9). Volatile organic compounds (VOCs) and polyaromatic hydrocarbons (PAHs) were detected in some samples at low but appreciable levels. Polychlorinated biphenyls (PCBs) have not been detected. Only cadmium exceeds land disposal restriction (LDR) constituent concentrations in the waste extract (CCWE) limits. Radioactive substances are present but at low levels, with gross alpha and beta typically <100 pCi/g.

Pond 207C -- The contents of pond 207C could be characterized as a chemical brine and salt sludge. The pond water contained TDS at >300,000 mg/L and exhibited a specific gravity of ~1.3. Primary cations included potassium and sodium; the primary anions were nitrate, sulfate, and chloride. Nitrate and sulfate concentrations were very high at ~60,000 and 15,000 mg/L, respectively. The pond water was very alkaline at pH ~10. The TOC was moderate and similar to that of 207A/B. The principal hazardous substances in the water included heavy metals (e.g., arsenic, chromium, cadmium, nickel), and they were present at mg/L concentrations. Substantial radioactive substances were present, as evidenced by gross alpha and beta activities of 63,000 to 230,000 pCi/L.

The principal component of sludges from pond 207C appears to be chemical salts, probably derived from precipitation reactions potentially occurring during process wastewater storage in the pond. The TDS is high at ~21,000 mg/L, and the pH is quite alkaline at ~10.5. Nitrates were high at ~10,000 mg/L, as were sulfates at ~1100 mg/L. The organic carbon content was similar to that in ponds 207A/B, with TOC concentrations ranging from 6400 to 9000 mg/kg. VOCs and PAHs were detected in some samples, but at low ppb levels. PCBs have not been detected. Only cadmium and nickel were found in concentrations exceeding LDR CCWE limits. Radioactive substances are present at lower levels, with gross alpha and beta typically 2700 to 8700 pCi/g and 420 to 1200 pCi/g, respectively.

2.2.3 Waste Classification

Apart from the physical and chemical properties of the pond contents under consideration, the regulatory classification of the waste can affect what treatment and disposal options may be implementable. Based on process knowledge, DOE and EG&G/RF have determined that the sludges are listed hazardous wastes (i.e., F001, F002, F003, F005, F006, F007, F009, F039 [A/B ponds only], and D006). Given the time, cost, and uncertainty of delisting, it is assumed that delisting will not be feasible as part of any approved closure plan. Thus, LDRs apply to the pond sludges for most of the land disposal options being considered. (Note that corrective action management unit [CAMU] policy does not require the sludges to be treated to LDRs. See Section 2.2.4 for further discussion.)

Sludges from the 207A/B ponds exceed LDRs for cadmium, whereas sludges from pond 207C exceed LDRs for cadmium and nickel. In pond 207C, arsenic, chromium, cyanide (total), lead, and silver have also been detected in the pond water at concentrations above acceptable LDR constituent concentrations in waste (CCW) limits.

Alpha and beta radionuclides are also present but at low levels; typically, below 10 nCi/g. Radionuclides present are plutonium-239 from 0.18 to 23 pCi/g, americium-241 from 0.01 to 5.1 pCi/g, uranium-234 from 0.01 to 160 pCi/g, uranium-235 from 0.02 to 5.1 pCi/g, and uranium-238 from 0.04 to 190 pCi/g. (See Appendix A for more detailed information on radionuclide distribution.) Within the DOE Complex, there is no established *de minimis* level of radioactive content below which a material is considered a non-radioactive waste. Similarly, DOE has not established an environmental cleanup standard for radionuclides. However, CDPHE has set a state standard for plutonium in surface soil in response to past problems at RFETS. The regulation states that soils in uncontrolled areas that exceed 2.0 dpm/g of dry soil because of plutonium require special construction techniques to minimize the resuspension of plutonium from the soil (EG&G 1993a).

2.2.4 Disposition Options

Also critical to an evaluation of treatment technologies is identification of feasible disposal options. The disposal options must be defined to permit establishment of the treatment performance objectives that will be compared with treatment technology potential. Unfortunately, final disposition of the sludges has not been determined. Possible scenarios include both on-site disposal (OU4 burial or a new RCRA cell) or off-site disposal at either

NTS or Envirocare of Utah (ICF Kaiser Engineers 1993b; Sams, Jones, and Sams 1994; and LATO/RF 1994). Table 2.3 summarizes disposition and final waste form requirements. Based on these disposal options (excluding CAMU), it is assumed that the sludge must be treated to meet LDRs at a minimum (Table 2.4). Detailed information pertaining to waste disposal acceptance criteria is included in Appendix B.

On-Site Disposal Options and Requirements -- In-place closure of the SEPs would require, at a minimum, consideration of regulations promulgated under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), RCRA, the National Environmental Policy Act (NEPA), DOE orders, and various Colorado environmental laws (EG&G 1993a). Regulations relating to Corrective Action Management Units (CAMUs) and hybrid closures are being considered and have the potential to enable different treatment and disposal options and possibly reduce closure costs. Because CERCLA closure requirements are generally less specific than RCRA requirements and also have an equivalent RCRA counterpart, CERCLA closure is not discussed in this report.

RCRA closure on-site must meet either clean closure or disposal unit closure requirements. Clean closure requires more stringent waste treatment but may be favorable because it indicates the willingness of DOE to minimize the environmental and health impacts of the site. Clean closure requires that the materials removed or decontaminated be properly handled and disposed of, including potentially disposing of the materials as a hazardous waste (40 CFR 265.228(a)(1)). Clean closure can usually be obtained if soils remaining in place contain "background" levels of contamination (e.g., mean background concentration plus two standard deviations) or are demonstrated to meet some other soil standard protective of human health and the environment. It must be noted that any listed hazardous waste must be delisted before clean closure can be obtained, even if background contaminant levels are achieved.

Closure as a disposal unit does not require treatment to the same levels but does, however, acknowledge that contamination remains at the site. This may be less desirable and even unacceptable to stakeholders and decision makers. Closure as a disposal unit requires that any free liquids be removed or solidified (40 CFR 265.228(a)(2)(i)) and that any remaining wastes be stabilized to a bearing capacity sufficient to support final cover for the unit (40 CFR 265.228(a)(2)(ii)). If liners and contaminated soils are removed for treatment and are then to be replaced into the location from which they were excavated, LDR requirements become effective (40 CFR 268.2(c)).

Provisions for CAMUs and temporary units under subpart S of 40 CFR part 264 were promulgated by EPA on February 16, 1993. Provisions for CAMUs were also made by the State of Colorado based on modifications to the analog in 6 CCR 1007-3, which was promulgated on May 31, 1994. These regulations allow for implementation of the CAMU concept in the State of Colorado at RCRA sites.

These units "function solely to manage wastes that are generated at a RCRA facility for the purpose of implementing remedial actions required at that facility" and "will not and cannot be used to manage 'as-generated' hazardous wastes" where as-generated wastes are defined as those wastes generated from ongoing production processes or other industrial activities (EPA 1993g). Among other provisions, the rulemaking allows remediation wastes to be consolidated or processed on-site without triggering LDRs or minimum technology requirements and then replaced within the same CAMU boundaries. EPA has noted that the CAMU option is likely to result in a substantial decrease in closure and remedial costs.

The rulemaking does not specify CAMUs as being contiguous areas of contamination, and they may be used for wastes generated as part of the corrective action at that facility. Additionally, the rulemaking does not address where compliance with cleanup standards must be achieved. Contaminated media can also be managed with the CAMU even if they were originally located at the facility but outside of the CAMU. Contaminated media include groundwater, surface water, soils and sediments that contain listed hazardous wastes or characteristic hazardous waste. Limitations to the CAMU rulemaking include the following: (1) a CAMU can be designated only by EPA or the authorized state and such designations are subject to public review and comment; (2) the CAMU can contain only contaminated areas; (3) the CAMU is a land area and non-land based units, such as incinerators or tanks, cannot be considered part of a CAMU; and (4) remediation waste from outside the CAMU that would be placed within the CAMU would be subject to LDRs (EPA 1993g).

Seven decision criteria are considered for CAMU designation: (1) facilitation of reliable, effective, protective, and cost-effective remedies; (2) minimization of risks during remediation (i.e., short term-effectiveness); (3) exclusion of uncontaminated areas; (4) minimization of future releases; (5) expedited timing of remedy implementation; (6) enhancement of long-term effectiveness; and (7) minimization of land areas where wastes will remain in place. These criteria are intended to capture the intent of the CAMU rulemaking because remedy selection standards have not been finalized.

The CAMU concept is relatively new and has not been widely implemented nor tested in court. To date, no CAMU permits have been issued in Colorado. Thus, uncertainties remain regarding implementation at OU4.

Off-Site Disposal Options and Requirements -- Off-site disposal of treated sludges is also a viable option that is being considered. Options for disposal include shipment and land burial at Envirocare of Utah, Inc., and NTS. Negotiations between DOE and Envirocare have led to a DOE-wide permit for disposal at Envirocare signed May 1994. Although treated solar pond sludges were sent to NTS in the past, disposal is deemed unlikely based on the inability of NTS to accept LLMW. Off-site disposal would require, at a minimum, consideration and compliance with all applicable U. S. Department of Transportation (DOT) regulations and waste acceptance criteria of the disposal facility. Furthermore, off-site disposal requires, at a minimum, that the waste be treated to meet LDRs.

2.2.5 Treatment Constraints and Performance Objectives

In identifying and screening feasible treatment technologies, consideration must be given to the performance requirements mandated by the feasible disposal options and the effects on performance of various waste characteristics. Although the ultimate disposition of the sludge was unknown at the time of this writing, it is assumed that treatment will, at a minimum, be required to meet LDRs (unless CAMU is implemented). Thus, the primary sludge treatment technology constraint is removal or immobilization of constituents to meet LDR requirements. Key waste characteristics that could affect treatment performance include the high salt content, particularly in pond 207C, where nitrate and sulfate concentrations approach 0.1 to 5.0 wt % or more (Tables 2.1 and 2.2). Because of the high nitrate concentrations in the sludges, candidate technologies must be robust to fluctuations in nitrate concentrations, which potentially affect some processes like S/S. Because the sludges are considered to be listed waste, any secondary waste generated is also considered to be listed and must be disposed of in the same manner, which could significantly impact cost. Thus, minimization of secondary waste streams is also a treatment technology constraint.

Process performance criteria were developed in this work, with metals as the target parameter for evaluation. For the purposes of this work, "metals" refers to the eight characteristic metals identified in 40 CFR 261, with the addition of nickel. Other potential contaminants are present within the sludge, including some VOCs, nitrates, and radionuclides (Section 2.2.2); however, metals were selected as targets because they are present in the sludge at levels above LDRs.

For the purposes of this technology evaluation and screening, any technology recommended for further consideration and potential implementation will have to be capable of achieving the following minimum performance criteria:

1. Reduction or immobilization of heavy metals so that
    a. the CCWE meets LDRs, or
    b. where LDRs are not applicable, contaminant concentrations are below U.S.-stipulated hazardous waste classification levels; and
2. Physical form that meets the waste acceptance criteria as listed in Table 2.3.

These basic performance criteria were judged to be consistent with regulatory commitments made previously by DOE and EG&G and with cleanup criteria used in similar situations (IM/IRA). Moreover, project team members believed that one or more of the candidate technologies could meet or exceed these criteria shown.

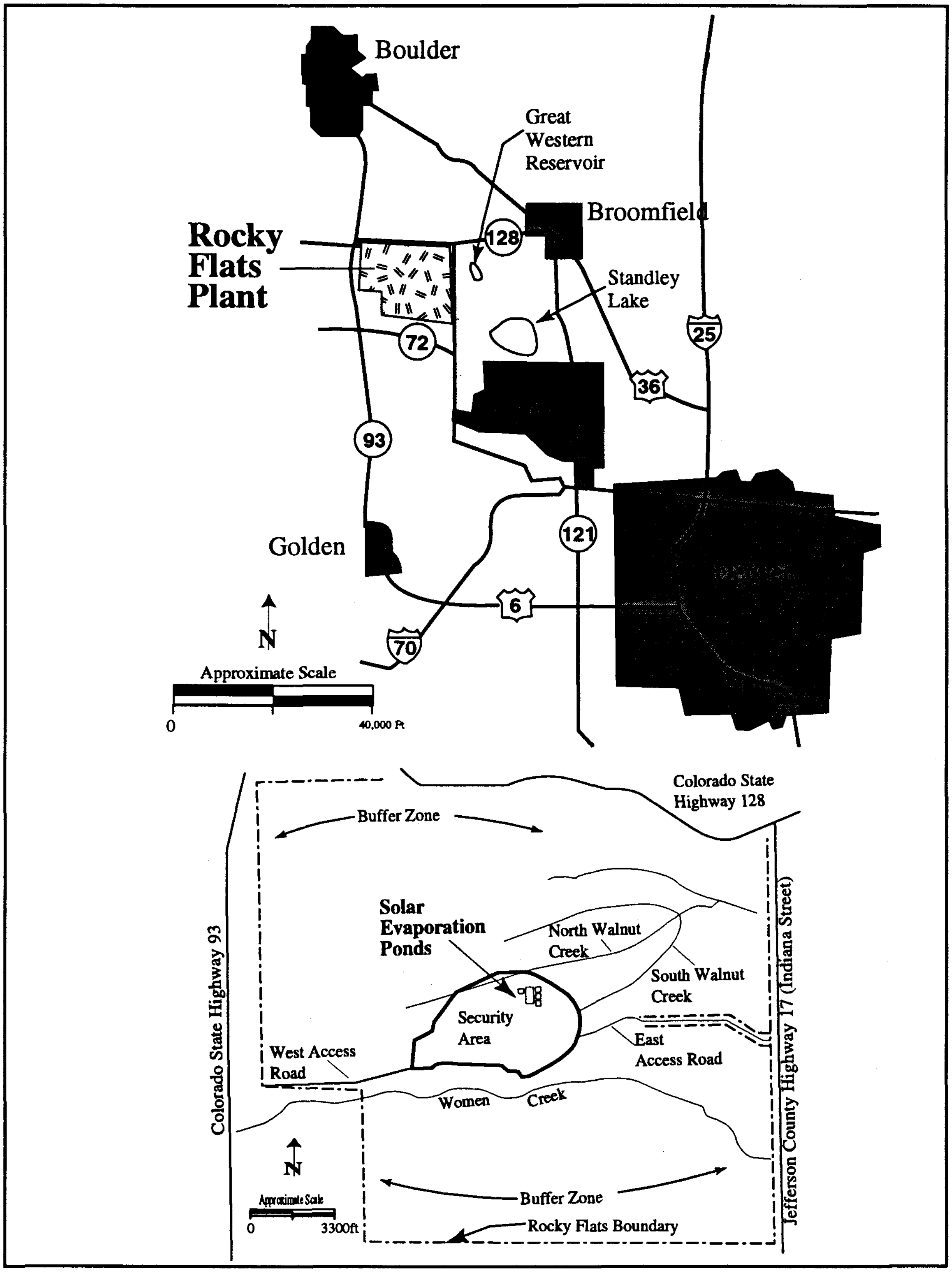

Figure 2.1. Location of the DOE Rocky Flats Environmental Technology Site.

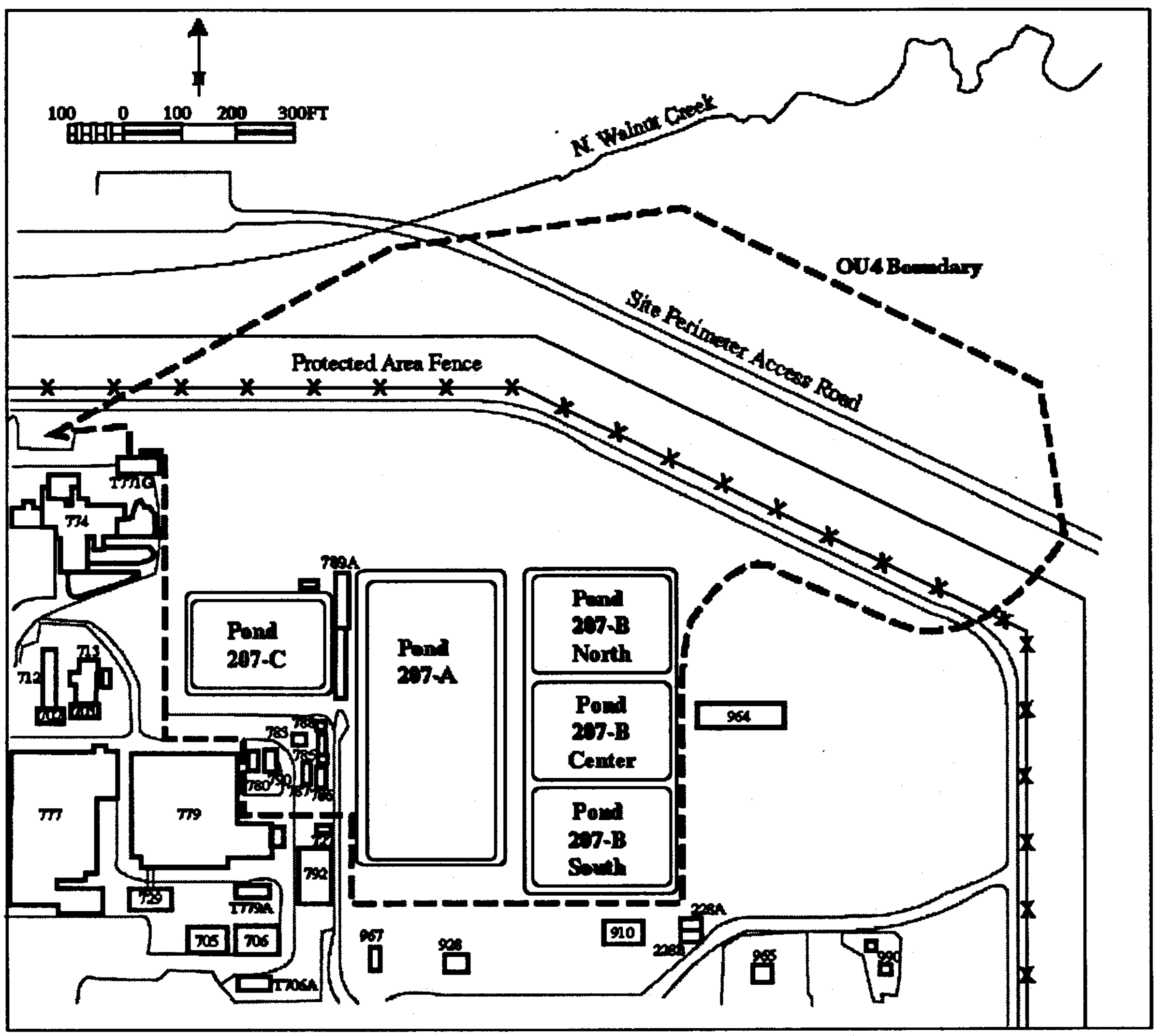

Figure 2.2. Location map of the solar evaporation ponds at the DOE RFETS.

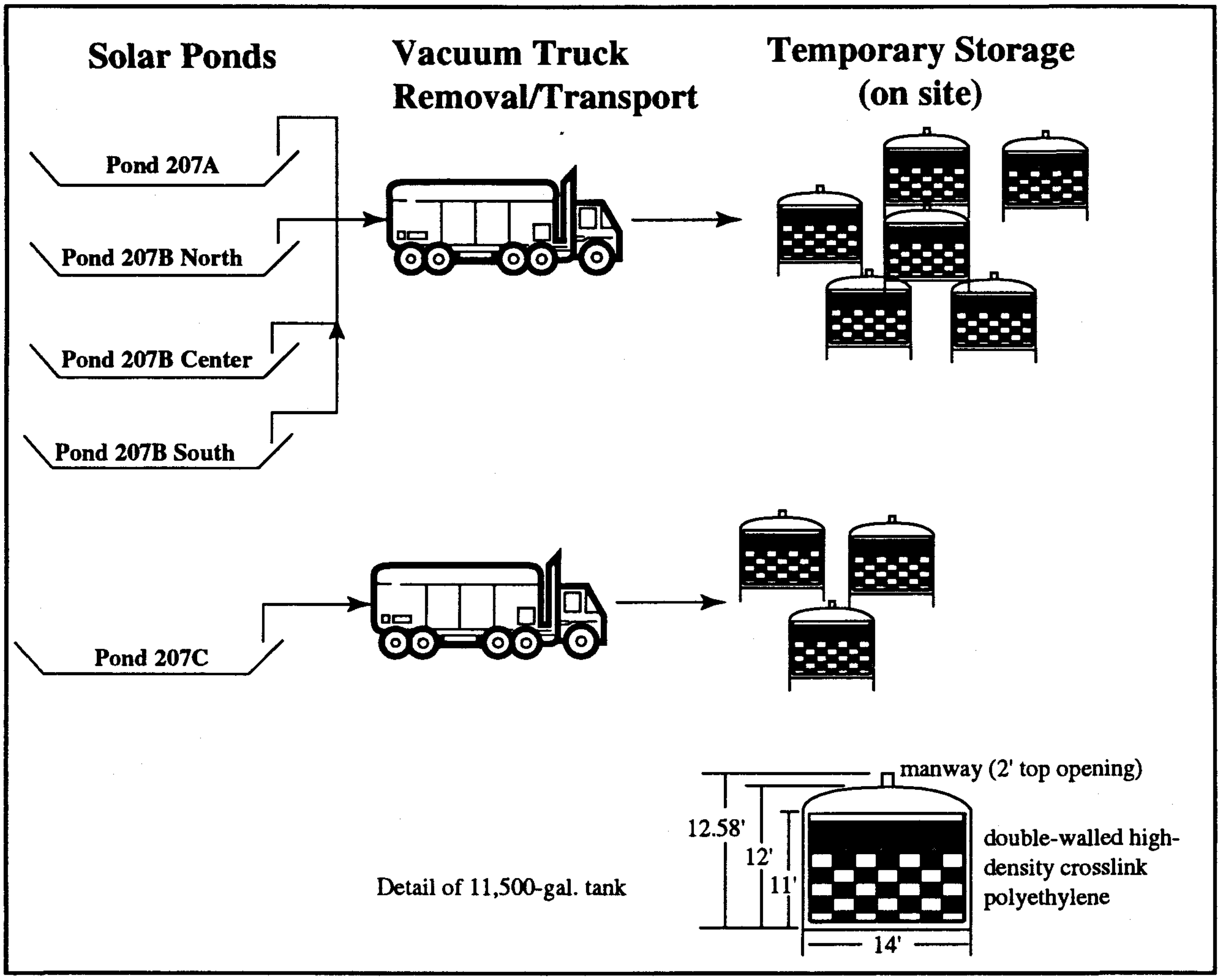

Figure 2.3. Sludge removal action that occurred during 1994.

(Note: Dewatering of supernatant in tanks occurred following initial placement and settling.)

Table 2.1. Representative Characteristics of Solar Pond Water[a]

Characteristic	units	207A	207B North	207B Center	207B South	207C
2-Butanone	µg/L	- [b]	-	-	-	77-110
Methylene Chloride	µg/L	-	-	-	-	8
Atrazine	µg/L	3.5	1.1	5	6	-
Arsenic	µg/L	188-224	60-63	13.8-330	16.4-276	3350-4110
Barium	µg/L	135-141	117-120	68-70	110-118	110-150
Boron	µg/L	1260-1460	149-173	2770-3530	2730-2800	360,000-494,000
Cadmium	µg/L	5	-	-	-	312-560
Calcium	mg/L	60.4	137-189	22.6-27.7	18.9-52.7	-
Chloride	mg/L	380-430	96-147	763	745	18,300-25,000
Chromium	µg/L	38-49	10-16	22-93.8	14-22.8	2360-3940
Copper	µg/L	-	-	34.8	37.4	6790
Cyanide - Total	mg/L	0.39-0.48	0.016-0.043	0.34-0.57	0.28-0.51	3.3-20
Lead	µg/L	3.9	-	-	-	300
Lithium	µg/L	1420	332	2600	2670	-
Magnesium	mg/L	120-124	64.8-79.3	181-220	180-190	1.3-3.87
Nickel	µg/L	-	-	28-31	20-40	2540-5090
Nitrate	mg/L	970-1000	310-330	1900-2100	1600-1800	57,000-66,000
Nitrate as N	mg/L	1000	39	1600	1800	2600
Potassium	mg/L	376-397	55.7-58.8	729-807	684-791	102,000-142,000
Selenium	µg/L	14.9	8.2-76	81	-	600-3000
Sodium	mg/L	1610-1870	254,000-403,000	2060-4060	2010-2940	102,000-142,000
Sulfate	mg/L	409-510	120-160	736-1000	540-784	12,200-18,000
Strontium	µg/L	2350	2220	2130	2370	-
Zinc	µg/L	27.5	47.9	-	37.1	-
pH	units	9.6-9.9	8.3-8.5	9.1-9.2	9.1-9.2	10-10.2
Gross Alpha	pCi/L	300-790	40-59	1800-2400	1500-2100	63,000-130,000
Gross Beta	pCi/L	930-1000	75-510	2700-3900	2300-2900	170,000-230,000
Alkalinity (methyl orange)	mg/L	110-250	75-110	1000-1400	860-910	45,000-63,000
Alkalinity (phenolphthalein)	mg/L	84-89	2-3	230-240	140-160	25,000-32,000
Conductivity at 25 °C	µmhos	8800	3380	1350	23,000	610,000
Specific gravity	none	1.01-1.012	1.008	1.016-1.018	1.016-1.02	1.316-1.348
Total Organic Carbon	mg/L	68-70	7.6-37	93-320	58-297	54.9-1600
Total Dissolved Solids	mg/L	7600-7900	2700-3200	13,000-16,000	14,000-16,000	300,000-510,000
Total Suspended Solids	mg/L	14-23	15-18	11-16	6-39	76-1400

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (October 1991) reports. Samples were collected from water within the ponds and above the existing sludge blanket. Concentration range applies to detected values only. Refer to Appendix A for further details.

[b] '-' = non detect.

Table 2.2. Representative Characteristics of the Solar Pond Sludges[a]

Characteristic	units	207A	207B North	207B Center	207B South	207C
Volume (apprx)[b]	gal.	18,100-127,000	172,000-307,400	73,500-194,000	80,200-199,000	47,400-281,000
1,1,1-Trichloroethane	µg/kg	24	-[d]	-	-	-
Tetrachloroethene	µg/kg	290	-	37-180	32-460	8-73
Trichloroethene	µg/kg	29	-	-	47-57	5-7
Benzene	µg/kg	-	-	-	-	7-31
Phenol	µg/L	-	7400	-	-	-
Pyrene	µg/L	-	4600	-	-	190-320
Arsenic	mg/kg	40.2	-	39.6-60.0	59.7	18-37
Barium	mg/kg	210	89.1-144	46.5-120	62.2-134	13.2-61.4
Boron	mg/kg	84.3	12.8	151	336-349	455-781
Cadmium	mg/kg	1300	6.7-18.8	46.5-110	7.4-30.4	27.3-665
Cadmium (TCLP leachate conc.)	mg/L	0.485	0.054-0.104	0.114-0.153	0.019-0.032	0.342-5.230
Chromium	mg/kg	658	7.9-70.6	48.5-390	25.2-51.9	252-960
Copper	mg/kg	-	15.3-18.9	64.6-103	-	-
Cyanide - Total	mg/kg	1.6	-	0.34-1.3	0.46-4.1	13-170
Lead	mg/kg	89	9.6-21.3	10.2-14.4	61	7.9-38.5
Magnesium	mg/kg	11,400	3270-5070	7190-19,800	5140-15,200	1340-6250
Nickel	mg/kg	102	7.1-9.5	-	-	17.4-146
Nickel (TCLP leachate conc.)	mg/L	-	0.02-0.056	0.028	-	0.563-2.140
Nitrate[c]	mg/L	35	-	50-74	77-89	8900-11,000
Nitrate as N	mg/kg	-	380-860	8,400-13,000	-	-
Sulfate[c]	mg/L	20	150-160	150-160	23-40	810-1300
Zinc	mg/kg	-	77.6-105	110-277	-	-
pH	units	8.9	7.6-7.7	9.1-9.2	9.1	10.2-10.5
Gross Alpha	pCi/g	570	5.2-38	13-19	31-61	2700-8700
Gross Beta	pCi/g	95	5.1-46	12-16	21-47	420-1200
Alkalinity (total)	mg/kg	-	180-440	2700-3500	1700-5500	17,000-24,000
Atterberg - Liquid Limit	none	83	71-75	77-85	70-101	-
Atterberg - Plastic Index	none	49	34-40	20-40	28-41	-
Atterberg - Plastic Limit	none	34	33-37	45-65	41-60	-
Bulk Density (dried solids)	g/cc	-	0.84-0.90	0.81-0.88	-	-
Moisture - Gravimetric	%	87.3	71.8-76.8	89.9-93.4	88.3-92.3	34.8-48.8
Moisture - Karl Fisher	%	34	23.5-27.9	42-53	39-50	-
Particle Size, 4.75 mm (sand)	%finer	97.5	98.2-100	96.9-100	99.9-100	39.4-100
Particle Size, 0.075 mm(silt/clay)	%finer	65.3	75.9-90.4	59.1-88.3	60.1-84.2	0.1-100
Specific gravity	none	1.1	1.2	1.0	1.0-1.1	-
Swell Test	%	40	0-10	60-70	30-60	0-10
% Recovery of solids	%	11.6	16.6-25.8	9.3-13.7	6.4-12.4	9.2-18.8
Total Organic Carbon	mg/kg	14,000	3000-34000	5500-8800	6800-11,000	6400-9000
Total Dissolved Solids[c]	mg/L	480	160-220	670-770	740-790	18,000-24,000

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (October 1991) reports. Concentration range applies to detected values only. Refer to Appendix A for further details.

[b] Low volume values were estimated from sludge thicknesses measured in the field during sampling (Halliburton NUS 1992b). High values were estimated from water levels and as built drawings (Dames and Moore 1991).

[c] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS).

[d] '-' = Non detect.

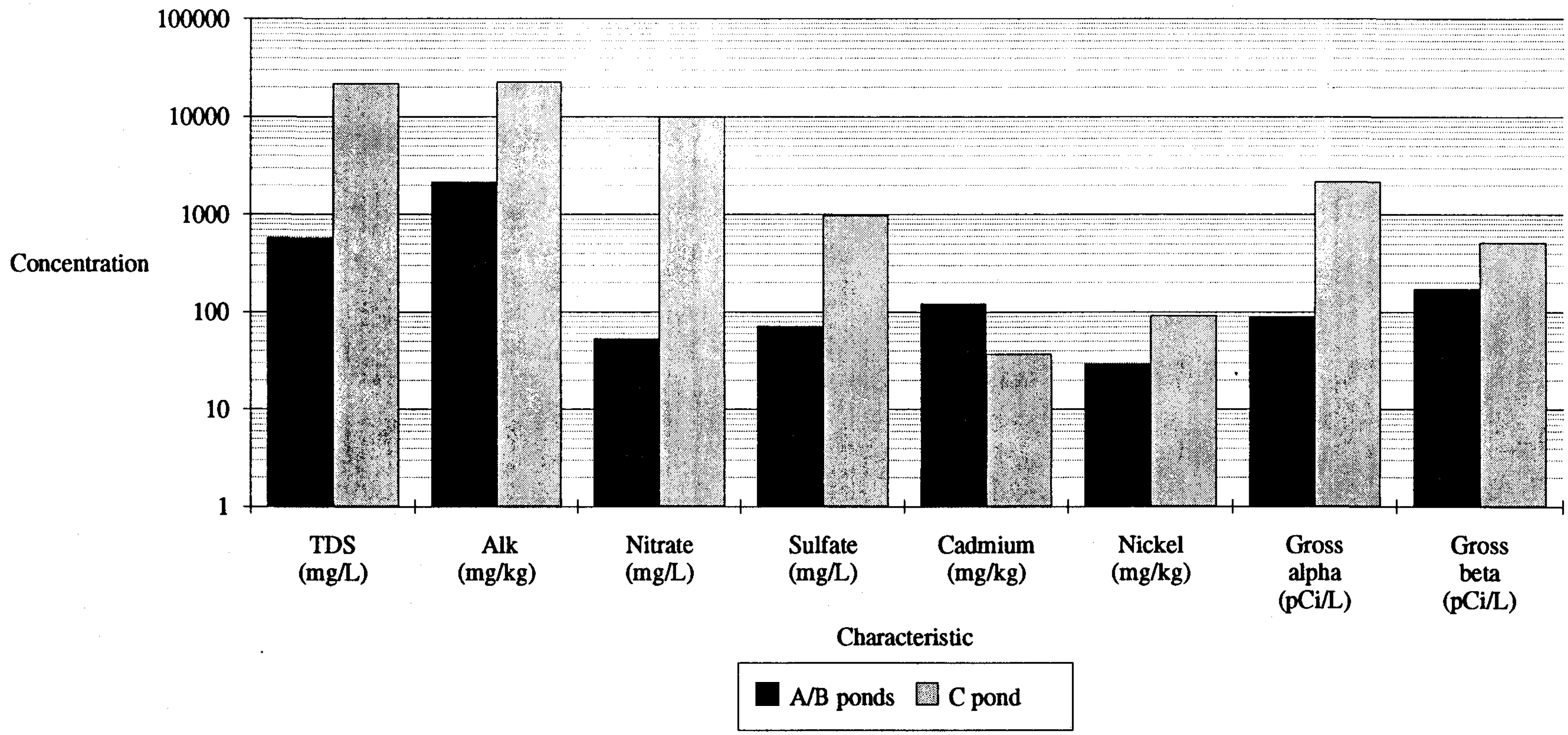

Fig. 2.4. Selected estimated average sludge concentrations from samples collected in 1991.

(Note: See Table 2.2 and Appendix A for sample collection and unit explanations.)

Table 2.3. Sludge Disposition Options and Selected Features[a]

Disposition option	Waste form	Waste acceptance criteria	Handling/ shipping
Off-site			
Nevada Test Site Las Vegas, Nevada	No free liquids. Immobilized waste (no more than 1 wt % of <10 μm particulates or 15 wt % <200 μm particulates). Mixed waste is not accepted for bulk disposal. Waste (and/or package) must be capable of supporting a uniformly distributed load of 4000 lbs/ft^2 (28 psi).	Treatment standards expressed as CCWE as required by 40 CFR 268 LDRs (specifically for): cadmium: 0.066 mg/L, and nickel: 0.32 mg/L 49 CFR 173 Activity Limits and External radiation levels for packages < 200 mrem/h on contact.	If immobilization is impractical, acceptable waste packaging must be used (e.g., overpacking, steel box with no liner, or wooden box with plastic liner). Applicable DOT requirements.
ENVIROCARE of Utah, Inc. Tooele County, Utah	No free liquids. Volumetric bulky materials or debris (concentration of radionuclides must be homogeneous within physical form). Optimally, physical form should not be >10 inches in any dimension. Larger waste forms are accepted but are subsequently crushed to under this size limitation.	Treatment standards expressed as CCWE as required by 40 CFR 268 LDRs (specifically for): cadmium: 0.066 mg/L, and nickel: 0.32 mg/L If a single radionuclide is present the maximum average concentration shall not be exceeded (specifically): ^{234}Uranium : 3.7E+4 pCi/g ^{235}Uranium: 7.7E+2 pCi/g ^{238}Uranium: 2.8E+4 pCi/g ^{239}Plutonium: 9.9E+3 pCi/g If a mixture of radionuclides is present then the following relationship must be met: Σ(radionuclide concentration/maximum average waste concentration for disposal)≤ 1.	Acceptable waste packaging (ranging from barrels, boxes, bags to bulk rail cars). Applicable DOT requirements -- Transport by truck or rail available.

[a] Information in this table was generated from Accelerated Sludge Processing Conceptual Design (Halliburton NUS Corp. 1994), NTS (DOE and REECo 1992) and Envirocare (Envirocare 1989 and 1994) waste acceptance criteria.

Table 2.3. Sludge Disposition Options and Selected Features[a] (*continued*)

Disposition option	Waste form	Waste acceptance criteria	Handling/ shipping
On -site			
OU4 burial	No free liquids. All particles must pass through a 3-in. mesh screen. Must be compacted to 90% Proctor density.	To be negotiated with regulators at the time of permitting for CAMU option.	To be negotiated with regulators. On-site RFETS Transportation Committee following DOT transport requirements.
RCRA disposal cell	No free liquids. Volumetric bulky materials or debris.	At a minimum 40 CFR 268 LDRs (see above) if sludges are removed for treatment and then replaced into a new location from which they were excavated.	To be negotiated with regulators. On-site RFETS Transportation Committee following DOT transport requirements.

[a] Information in this table was generated from Accelerated Sludge Processing Conceptual Design (Halliburton NUS Corp. 1994), NTS (DOE and REECo 1992) and Envirocare (Envirocare 1989 and 1994) waste acceptance criteria.

Table 2.4. Land Disposal Restrictions for Target Metal Constituents

Target analyte	Units	LDR (CCWE) [a]
Antimony	mg/L	0.23
Arsenic	mg/L	5.0
Barium	mg/L	52
Cadmium[b]	*mg/L*	*0.066 (1.0)*
Chromium (total)	mg/L	5.2
Lead	mg/L	0.51
Mercury	mg/L	0.025
Nickel	*mg/L*	*0.32*
Selenium	mg/L	5.7
Silver	mg/L	0.072

[a] Sludges are considered to be listed as F001, F002, F003, F005, F006, F007, F009, F039 (207 A/B ponds only), and D006. The value in parentheses applies to D006 listed waste. LDR CCWEs are found in 40 CFR 268.41.

[b] Italics indicate target constituents present in the sludges at levels above LDRs.

3.0 TECHNOLOGY IDENTIFICATION

The first element of the evaluation and screening work consisted of literature review and assimilation to identify conceivable options and current sludge treatment processes at other facilities. Several literature searches and reviews were conducted as well as a DOE site survey and a survey of private industry technology vendors. Literature search and reviews provided information regarding the available options for sludge remediation and the factors considered during the alternative selection process. Information regarding both potentially applicable technologies and their private industry providers, including operation and performance data based on manufacturers' literature and reports or independent research and demonstration projects, was also obtained. A survey of projects at other DOE, U.S. Department of Defense (DOD), and EPA Region 8 sites that involve the remediation of sludges similar to the RFETS solar pond sludges provided information on remediation options selected and/or implemented at other sites. Additionally, a formal survey of private industry technology vendors designed to obtain detailed information regarding sludge treatment technology operation and performance characteristics was conducted.

3.1 METHODS

Literature reviews were designed to answer the following questions: (1) What cleanup options have been used for remediation of sludges similar to the RFETS solar ponds sludges at other federal facilities as well as in industry? (2) What were the bases for decisions made during investigation of the remediation processes? (3) What types of remediation processes were implemented? and (4) What are the lessons learned from treatment implementation? The following sources were among those used to obtain information on case studies and technologies used to treat sludges included: (1) EPA's Records of Decision (RODs) database (EPA 1992b), (2) Proceedings from the National Technology Information Exchange (TIE) Workshops (DOE 1993b), (3) DOE Office of Technology Development (EM-50) reports (DOE 1993a and c, 1994b, c, d, and e), (4) EPA's Vendor Information System for Innovative Treatment Technologies (VISITT) database (EPA 1993d), (5) "Cleaning Up the Nation's Waste Sites: Markets and Technology Trends" (EPA 1993a), and (6) EPA's "Innovative Treatment Technologies, Semi-Annual Status Report" (EPA 1992a and 1993b).

A questionnaire was developed to facilitate comparison of site information to RFETS solar pond sludges, and phone inquiries were made directly to site personnel. Emphasis was placed on collecting data primarily from DOE sites, but DOD sites, sites managed by other federal agencies, and sites under the jurisdiction of EPA Region 8 were also reviewed. Attempts were made in all cases to talk with site personnel from both waste management and environmental restoration groups. Much of the information presented is the result of current efforts by waste management groups under the Federal Facilities Compliance Act (FFCA). Specific information on environmental restoration sludges was difficult to obtain as many sites are still conducting site characterization or did not have environmental restoration sludges. However, many sites are currently managing process sludges within waste management. Characteristic and treatment information on these sludges was deemed valuable for providing insight into DOE Complex-wide sludge treatment. Key sources of information included DOE site reports, including available treatability study results and preliminary design reports, and the DOE-EM30/50 Mixed Waste Inventory Report.

To provide information on the stage of development and commercial availability of sludge treatment technologies, information was solicited from a large number of technology vendors with potential for providing one or more sludge treatment technologies. The vendor list was developed and compiled from several sources, including those vendors responding to the Commerce Business Daily expression of interest for the Oak Ridge Reservation K-25 pond waste management project, bidders from previous soil treatment projects (Siegrist et al. 1993), vendors responding to the DOE Oak Ridge Operations privatization expression of interest for treatment of soils and sludges, and additional vendors known to the project team members and DOE/RFFO staff.

3.2 RESULTS AND DISCUSSION

Information obtained during the literature reviews and surveys is summarized below.

3.2.1 Database Literature Searches and Reviews

Table 3.1 was compiled from EPA publications of federal demonstrations of innovative technologies (EPA 1993c and e). It lists technologies applicable to sludges that have been or are planned for demonstration and summarizes relevant data from each demonstration. In most cases, specific site details were not available; however, vendor or technology developer contacts are provided if further information is required.

RUST Geotech completed a literature review that concentrated on DOE and DOD sites in EPA Region 8 with sludges similar to the solar pond sludges. The EPA Records of Decision (RODs) database (EPA 1992b) search indicated there were no federal Superfund sites in EPA Region 8 with sludges similar to those at the solar ponds. The only federal site included in the database from EPA Region 8 was the Ogden Army Depot; the remediation at this site addressed debris and soil but did not address sludge. The database search of information for all other EPA regions produced few federal sites with signed RODs that dealt with sludges.

To compare remedial options selected for sludges with those most often used for Superfund sites in general, a breakdown of all technologies selected in Superfund RODs from FY1982 through FY1991 was reviewed (EPA 1993b). Both incineration and S/S are considered by EPA as established technologies and were the options of choice for most National Priority List sites. S/S was by far the most commonly selected remedy for application to sludges. To provide further information on S/S technologies, an EPA Engineering Bulletin on S/S is provided in Appendix C.

EPA's Innovative Treatment Technologies Semi-Annual Status Reports (EPA 1992a, EPA 1993b) include performance data for Superfund sites at which remedial action with innovative technologies (essentially everything except incineration and S/S) has been completed. These reports cite changes in the status of sites that were included in previous editions of the status report, most of which involve the selection of a remedial technology other than that originally specified. This information provided insight into the factors that must be considered during selection of a technology for a given site.

Because performance data in the status reports for sludge remediation projects are limited, sites involving soil remediation efforts were also included in the survey of results. Some of the observations made regarding technology implementation are summarized below.

- Initial estimates of contaminant mass were too low, leading to design of undersized treatment equipment. Better quantification of contaminant volume is required to design the optimum system.

- Waste components originally intended to be recycled could not be recycled because of impurities contributed by the presence of other contaminants.

- Treatment process required uniform material as process feed, which caused materials-handling problems at the beginning of the project.

- Fluctuations in ambient conditions that were caused by seasonal/temporal changes were not anticipated to have such a drastic effect and decreased system efficiency.

- A later step in a multistep process would have been more effective if an earlier step had been more complete. This lack of planning points out the need to look at a treatment process from start to finish and to optimize the output of one component to be suitable as the input for another component.

- Temperature, pressure, and moisture content were all monitored during the treatment process.

The following factors were among those that led to changes in technology selection after an innovative technology was initially chosen.

- Demonstration of technology infeasibility during post-ROD treatability studies.

- Discovery of new contaminants.

- Discovery of contaminants in higher concentrations than anticipated.

- Inability of selected technology to handle variability of wastes.

- Community concern over selected remedy.

- Technology not becoming commercially available as anticipated.

Finally, review of the data compiled for this report led to the development of a number of observations. These observations are briefly outlined below.

- No case study was found that had similar waste characteristics and a similar regulatory situation (EPA Region 8) to the sludges at the RFETS solar ponds.

- S/S is the most often selected option for remediation of sludges, particularly those contaminated with inorganics. Vitrification takes a distant second place.

- Soil washing and chemical extraction show promise for some wastes, but their application to wastes containing diverse constituents with differing behaviors has been less than satisfactory.

- Site-specific conditions and the reasons for selection of the preferred alternative varied considerably. In most cases, solidification was chosen as the preferred technology for sludges and many soils. Solidification was sometimes selected as the preferred alternative even when other technologies, such as incineration, were deemed to provide better reduction in toxicity, mobility, and volume. On the basis of cost, solidification was considered the best alternative for reduction in toxicity and mobility.

- Superfund policy states that S/S generally is appropriate only for material containing inorganics, semivolatile organics, and nonvolatile organics. Superfund policy does not consider S/S to be an effective treatment option for VOCs. Use of S/S for organics usually requires treatability testing to demonstrate effectiveness.

- The presence of high concentrations of nitrates can adversely affect the performance of cement-based S/S.

- Many case studies considered only S/S technology for treatment of sludges; no other options were evaluated. In some instances, regulatory agencies dictated the type of treatment to be used; other options were not available.

- When S/S was not chosen as the preferred alternative, it was usually because of the increase in volume created when S/S technology is used. The uncertainty about the long-term effectiveness of S/S also was considered a disadvantage to S/S.

- Process monitoring and control are the keys to successful application of a technology, particularly if waste streams tend to be somewhat heterogeneous.

3.2.2 Experiences at Federal Facilities

Detailed information obtained from informal site queries is presented in Appendix D and is summarized as follows. Thirty-two sites were evaluated for pertinent information on their selection of treatment and disposal options for sludges. Four sites questioned had no waste applicable to the survey. The remaining 28 sites provided information on 40 different sludges. Information relating to sludge characteristics and the selected remedial alternatives are summarized in Table 3.2. General observations indicate that only a few technologies were used to treat most sludges and that, like Superfund sites in general, established technologies were chosen most frequently, specifically stabilization.

Of the sites queried, most are currently evaluating treatment options or preparing treatment plans or similar documents. Only a small percentage have completed these plans, and a few sites are still characterizing the sludges. Four cases have undergone treatment and disposal with the remaining cases in evaluation or treatment phases. In cases in which treatment has been selected, approximately half of the sludges have either used, or are planned to use, S/S by cementation or grout. Other options that are either under consideration or in the treatment process include in situ vitrification, flyash immobilization, dewatering, thermoplastic encapsulation, chemical stabilization, aqua-set, petri-set, and denitrification.

Disposal options considered for sludges were also surveyed (Fig 3.1). Approximately 75% of the sites have or plan to dispose of the treated sludges off the site. Off-site disposal of sludges can be broken down to final disposition at Envirocare of Utah (~30%), at Hanford (~20%), at NTS (~10%), and at other various landfills (~10%); the remaining 30% were undetermined. Of the sites that have considered on-site disposal, about half of the remediations were completed in the 1980s prior to the new stringent land disposal regulations. The remaining sites considering or currently operating an on-site option include larger sites such as NTS, Hanford, Idaho National Engineering Laboratory (INEL), LANL, Portsmouth, and Savannah River.

Finally, sites were queried regarding implementation and consideration of the CAMU concept. Of those questioned, all were familiar with the CAMU concept but remained focused on off-site disposal options. Reasons given included political constraints, space limitations, environmental setting, and/or regulatory considerations. Perhaps more important, many of the sludge waste streams are from current operations and thus CAMUs are not applicable.

Hanford was the only site that had actual experience with CAMUs as a disposal option for sludge. Its application was denied by EPA Region 10. After reviewing the option at Hanford, EPA denied the application because it felt the proposed option could not be defended to the public and other stakeholders. It should be noted that other on-site options that were considered by other sites are very similar to the CAMU concept. For example, at INEL, investigation-derived waste (CERCLA waste) is subject to a DOE policy that declares the entire INEL site to be one area of concern. The State of Idaho and EPA have not agreed to the CAMU concept but, instead, approve sampling and analysis plans that identify that residuals will be stored at INEL until a ROD is signed. The State of Idaho agreed that CERCLA waste generated during investigations can be taken to a RCRA facility with one-year LDR requirements. This strategy has the same benefits of CAMU. Fernald reported implementation of CAMU for solid waste landfills, but not for other waste streams.

Brief case studies of the alternatives analysis and the rationale (technical and non-technical) for final remedy selection for federal sites with available information were completed. Additionally, certain factors or waste characteristics that led to the elimination of particular technologies from further consideration were evaluated. These case studies, presented in detail in Appendix D, can be summarized as follows. In cases in which innovative technologies were selected as the preferred alternative, the following factors were observed: (1) there is a scarcity of sites that are judged to be "completed"; (2) most completed projects involved soil treatment, although a few removal actions have been performed; and (3) materials-handling problems and complications resulting from the diversity of contaminants were cited as issues for sludge treatment. Factors that led to changes in technology selection after an innovative technology was initially chosen (often resulting in the use of more established technologies) included (1) demonstration of technology infeasibility during post-ROD treatability studies, (2) discovery of new contaminants, (3) discovery of contaminants in higher concentrations than anticipated, (4) inability of selected technology to handle variability of wastes, (5) community concern over selected remedy, and (6) technology not becoming commercially available as anticipated.

3.2.3 Commercially Available Technologies

Information packages were sent to a total of 86 vendors (Table 3.3). Each vendor received a letter of inquiry and a short narrative describing the site characteristics of interest. RFETS was intentionally not mentioned in any correspondence or communications. A form was provided to guide the vendor responses and to facilitate interpretation and comparison. A follow-up letter was mailed two weeks later. A copy of this information is presented in Appendix E.

Seventeen vendors responded to the inquiry, proposing a total of 24 processes (Table 3.4). These processes can be subdivided into six types of treatment technologies (of varying development stage):

- stabilization/solidification,
- chemical extraction/precipitation,
- polyethylene immobilization,
- vitrification,
- molten metal, and
- pyrolytic concentration.

All vendor responses, independent of the stage of development of the process, included the requirement for treatability testing ranging from simple bench-scale to field demonstration. Detailed information was provided on process description, number of successful installations/remediations, treatment efficiencies, limiting conditions, processing rates, cost, and unusual environmental and worker health and safety concerns. To represent the large volume of information received from vendors, two sample responses are presented in Appendix E. However, the information from all vendors is summarized in Table 3.5. A complete set of vendor responses is contained in a supplementary volume to this report.

Table 3.1 Federal Site Remediation Technology Demonstrations for Sludges

Technology Type	Contaminants	Demonstration Status	Estimated Cost	Performance	Technology Developer
Chemical Treatment / Immobilization (cement/flyash)	Organics, heavy metals, oils, and grease	Several including full-scale	\$40 to \$60/ ton for metals and \$75 to \$100/ ton for organics	Metals meet TCLP; 220 to 1,570 psi UCS	Ray Funderburk; Funderburk and Assoc. (800) 227-6543
Physical Separation / Chemical Extraction (acid wash)	Radionuclides and metals	Pilot-scale at INEL Warm Waste Pond	\$1,000/ yd^3	Excellent removal of cobalt and chromium; unsatisfactory for cesium	Robert Montgomery: EG&G Idaho (208) 525-3937
SAREX Chemical Fixation Process	Low-level organics and metals	Laboratory and field-scale tests	NA	Organics driven off as vapors; metals meet TCLP	Joseph De Franco; Separation & Recovery Systems, Inc. (714) 261-8860
In situ Vitrification	Organics and inorganics	22 pilot-scale tests and 10 large-scale tests	NA	1 to 2 in./ hour; 4 to 6 tons/ hour; 20 to 40% volume reduction	James Hansen; Geosafe Corp. (206) 822-4000
In situ Vitrification	Organics, inorganics, and radionuclides	Two field-scale tests	\$300 to \$450/ ton (excluding mobilization and demobilization)	>97% cesium retention; >99.99% retention of strontium, plutonium, and TRU surrogates	James Hansen; Geosafe Corp. (206) 822-4000
Plasma Arc Vitrification	Organics and metals	Pilot-scale test (4,000 lbs)	\$757 to \$1819/ ton depending on operating conditions	Organic destruction removal efficiency from 99.9968 to 99.9999%; residuals meet TCLP; off-gas particulates may exceed standards	R. C. Eschenbach and L. B. Leland; Retech, Inc. (707) 462-6522
Soil Washing / Catalytic Ozone Oxidation	Semivolatile organic compounds, PCBs, pesticides, dioxin and cyanide	Scheduled for SITE demonstration	\$70 to 130/ yd^3	1 to 27 yd^3/ hour for solids; treats contaminant up to 20,000 parts per million	Lucas Boeve; Excalibar Enterprises, Inc. (809) 571-3418 (809) 571-3419

Reference: EPA 1993c and e.

Table 3.1. Federal Site Remediation Technology Demonstrations for Sludges (*continued*)

Technology Type	Contaminants	Demonstration Status	Estimated Cost	Performance	Technology Developer
Membrane Microfiltration	Organics, inorganics, and oily wastes	Demonstrated for liquid waste	O&M at $213K to $549K/ year	1 to 2 gal./min of slurry; <5,000 ppm concentration solids	Ernest Mayer; E. I. Du Pont de Nemours & Co. (302)366-3652
In situ Stabilization / Solidification Process	Organics and inorganics	SITE demonstration	$111 to $194/ ton	14- to 18-in. depths; 10^{-6} to 10^{-7} permeability; up to 1,500 psi UCS	Chris Ryan; Geo-Con Inc. (412)856-7700
Stabilization / Solidification	Organics and inorganics	Bench- and field-scale demonstration	NA	Treats waste with up to 40% contaminants by volume	E. Benjamin Peacock; WASTECH, Inc. (615)483-6515
Stabilization / Solidification	Organics and inorganics	SITE demonstration; full-scale use	$200/ yd^3 for >15,000 yd^3 total volume	Pass TCLP (54 to 99% leachate concentration reduction); 260 to 350 psi UCS; 10^{-7} permeability; 68% average volume increase	Stephen Pelger and Scott Larsen; Silicate Technology Corp. (602) 948-7100
Soliditech Stabilization / Solidification Process	Organics, inorganics, metals, oil and grease	Field / full-scale	NA	Immobilized metals and organics undetected	Bill Stallworth; Soliditech, Inc. (713) 497-8558

Reference: EPA 1993c and e.

Table 3.2. Site Survey Summary of Remediation Options for Sludges[a]

Site Project	Sludge Characteristics			Treatment Type	Comments
	Radioactive	Organics	Inorganics		
Argonne National Laboratory (#1)	cobalt and cesium	-	metals	In situ vitrification / off-site disposal.	Currently in bench-scale testing.
Argonne National Laboratory (#2)	tritium	PCBs	-	On-site solidification / off-site disposal.	Treatments under consideration are solvent washing, thermal adsorption, or supercritical CO_2 extraction.
Bettis (Westinghouse Bettis)	not specified	-	-	Ex situ solidification / off-site disposal.	Small volume of waste (<20 m^3).
Brookhaven National Laboratory	-	-	-	Ex situ solidification / off-site disposal.	Currently in characterization process and technology development (thermoplastic encapsulation).
Colonie Interim Storage	-	-	-	Ex situ solidification / off-site disposal.	Small quantity of two sludges (60 gal.). Approximately 3 cement drums.
Fernald	uranium	-	barium and other metals	Ex situ chemical stabilization / off-site disposal.	720,000 yd^3 of sludge in six waste pits. Precipitation of BaCl to $BaSo_4$.
General Atomics	not specified	not specified	metals	Ex situ stabilization / off-site disposal.	Currently evaluating options, including aqua-and petri-sets.
Grand Junction Projects Office	-	-	-	NA	Not applicable - the only sludge is a 5-gal. container. However, GJPO is currently constructing an on-site mixed-waste treatment facility.
Hanford	not specified	-	lead, mercury, and other metals	Ex situ stabilization / on-site disposal.	28,000 m^3 of sludge for grout and polyethylene immobilization and on-site storage in RCRA trench.
Idaho National Engineering Laboratory	-	-	mercury	Ex situ stabilization / on-site disposal.	Several various sludges scheduled for stabilization and on-site disposal per FFC Act. Currently evaluating mercury retort option.

[a] Information presented was based on responses to a telephone query from each respective DOE site.

Table 3.2. Site Survey Summary of Remediation Options for Sludges[a] (continued)

Site Project	Sludge Characteristics			Treatment Type	Comments
	Radioactive	Organics	Inorganics		
INEL Power Burst Facility, Idaho	-	-	-	Ex situ solidification / on-site landfill at RWMC.	100 yd^3 of sediment stabilized, sludge treated by grouting.
Institute for Toxicology	not specified	not specified	-	Ex situ stabilization / off-site disposal.	Stabilization with magnesium flyash to a monolith. Remaining waste in characterization.
Kansas City Plant	-	PCBs	metals	Ex situ stabilization / off-site landfill.	Dewatered and disposed of cake material in permanent landfill (1985).
Knolls Atomic Power	-	-	-	Ex situ solidification / off-site disposal.	Total waste stream projected at 10 to 14 m^3 for five years.
Lawrence Berkeley Laboratory	none	-	-	NA	Not applicable. No mixed waste sludges.
Los Alamos National Laboratory	not specified	-	metals	Ex situ solidification / on-site landfill.	Currently evaluating options to dispose of several different sludges. Technology development of "skid" or mobile treatment units; ER constructing an on-site mixed waste facility.
Maxey Flats Nuclear Disposal, Kentucky[b]	tritium and others	VOCs, TCE, benzene, and toluene	arsenic and lead	Ex situ solidification / on-site landfill.	Remedial action is for 3,000,000 gal. of trench leachate.
Mound	-	-	-	NA	Permit for low-level radioactive waste from water treatment facility.
Nevada Test Site	uranium	-	metals	Not yet determined.	Currently in characterization process.
Oak Ridge K-25 Plant	uranium	-	nickel, cadmium, and chromium	Ex situ solidification / off-site disposal.	46,000 drums of LLMW underwent neutralization. Majority has been fixed in flyash and concrete.

[a] Information presented was based on responses to a telephone query from each respective DOE site.
[b] Source: EPA ROD Data Base.

Table 3.2. Site Survey Summary of Remediation Options for Sludges[a] *(continued)*

Site Project	Sludge Characteristics			Treatment Type	Comments
	Radioactive	Organics	Inorganics		
Oak Ridge K-25, TN, OU4 (former uranium isotope processing subsite[b]	not specified	not specified	-	Incineration (thermal dry after dewater) / filter press.	Interim remedial action, dried sludge repacked and stored on site.
Oak Ridge National Laboratory (S-3 Ponds)	uranium and technetium	not specified	nitrates	In situ vitrification / on-site.	RCRA closure in early 1980s. Ponds stabilized in-place and capped.
Oak Ridge National Laboratory (incinerator sludge)	uranium, technetium, neptunium, and low-level TRU	PCBs	mercury and metals	Not yet determined.	Currently dewatering. Evaluation of treatment options under way. Considering off-site disposal.
Oak Ridge National Laboratory (West End Treatment Facility)	uranium and technetium	not specified	metals	Not yet determined.	Plating operation waste sludge is currently stored in 4 to 5 500,000-gal tanks. Currently treatment is out for private contract bid.
Oak Ridge National Laboratory (old hydrofracture facility)	-	-	-	Cement stabilization or asphaltic stabilization or in situ stabilization with quick lime and other pozzolanic materials.	Treatment processes identified for facility were not implemented because of lack of funding in 1987.
Oak Ridge Reservation, TN, OU2 (inactive uranium recovery landfill)[b]	strontium	-	NO_x	On-site landfill.	Multi-layered cover placed on soil, sludge, and debris.
Ogden Defense Depot, Utah, OU3[b]	-	pesticide	arsenic and others	On-site incineration / ex situ solidification / off-site landfill.	Stabilization for soils/sludges not meeting TCLP.
Paducah E.R.	technetium	TCE	metals	Ex situ solidification / off-site disposal.	About 2,000 drums of sludge originating from intensive groundwater investigation. Draft treatment plan in preparation.
Paducah Gaseous Diffusion Plant	uranium, technetium and TRU	-	metals	Ex situ stabilization / off-site disposal.	Process waste and legacy waste. Currently, draft site treatment plan is in preparation.

[a] Information presented was based on responses to a telephone query from each respective DOE site.
[b] Source: EPA ROD Data Base.

Table 3.2. Site Survey Summary of Remediation Options for Sludges[a] (*continued*)

Site Project	Sludge Characteristics			Treatment Type	Comments
	Radioactive	Organics	Inorganics		
Pantex	-	-	-	Ex situ stabilization / off-site disposal.	Small volume (<5 m^3). Part of DOE/AL mixed-waste treatment plan.
Pinellas Plant	tritium	-	-	Ex situ solidification / off-site disposal.	116,000 lbs of raw sludge shipped to landfill in South Carolina. No hazardous components and negligible radioactive component.
Portsmouth Gaseous Diffusion Plant	uranium and technetium	TCE	-	Ex situ stabilization / off-site disposal.	Approximately 1400 yd^3 stored in B-25 boxes. Will potentially be stabilized and disposed of off the site. Currently undergoing evaluation.
Portsmouth Gaseous Diffusion Plant	uranium and technetium	-	metals	Ex situ stabilization / off-site disposal.	Currently undergoing treatment option evaluation. Potentially will be stabilized with grout and disposed of off the site.
Robins Air Force Base, Georgia[b]	-	-	not specified	Ex situ solidification.	Solidification for lagoon sludge only.
Rocky Mountain Arsenal	none	-	copper, brine salt	Off-site recycling and disposal.	Process wastes (Basin F Brine Salts). Copper recovery and off-site disposal.
Sacramento Army Depot, California[b]	-	-	not specified	Dewatering / ex situ solidification / off-site landfill.	Contaminants of concern from plating operations.
Sandia	-	-	-	NA	Not applicable. No mixed waste sludges.
US 001 Sangamo Crab Orch, NWR, OU1, 1L, Region 5[b]	none	none	lead, cadmium, and chromium	Ex situ solidification / on-site landfill.	Remedial action treated 9,000 yd^3 using stabilization and fixation.
US 001 Sangamo Crab Orch, NWR, OU2, 1L, Region 5[b]	none	PCBs	lead	On-site incineration / in situ vitrification. Ex situ solidification of residuals after incineration or in situ vitrification. On-site landfill.	Remedial action includes excavation, incineration or in situ vitrification, then stabilization.
Savannah River Site	uranium	-	nickel	On-site vitrification / off-site disposal.	250 to 500,000 gal of electroplating waste stored in tanks - six waste streams (006 mixed waste).

[a] Information presented was based on responses to a telephone query from each respective DOE site.
[b] Source: EPA ROD Data Base.

Table 3.2. Site Survey Summary of Remediation Options for Sludges[a] (*continued*)

Site Project	Sludge Characteristics			Treatment Type	Comments
	Radioactive	Organics	Inorganics		
Teledyne Wah Chang, Oregon[b]	not specified trace levels	not specified	not specified	Ex situ solidification / off-site landfill.	Partial solidification of 35,000 yd^3.
Weldon Springs Site	not specified	PCBs	not specified	On-site stabilization (cementation) and disposal.	Treatment plan in preparation. 250 yd^3 of sludge from raffinates will potentially undergo cement stabilization. Plan to potentially use on-site disposal cell.
West Valley Project	cesium	-	metals	On-site cementation disposal site not determined.	Site treatment plan in preparation. Plans to use cementation on-site for 19,000 drums of decontaminated supernate from waste tanks.

[a] Information presented was based on responses to a telephone query from each respective DOE site.
[b] Source: EPA ROD Data Base.

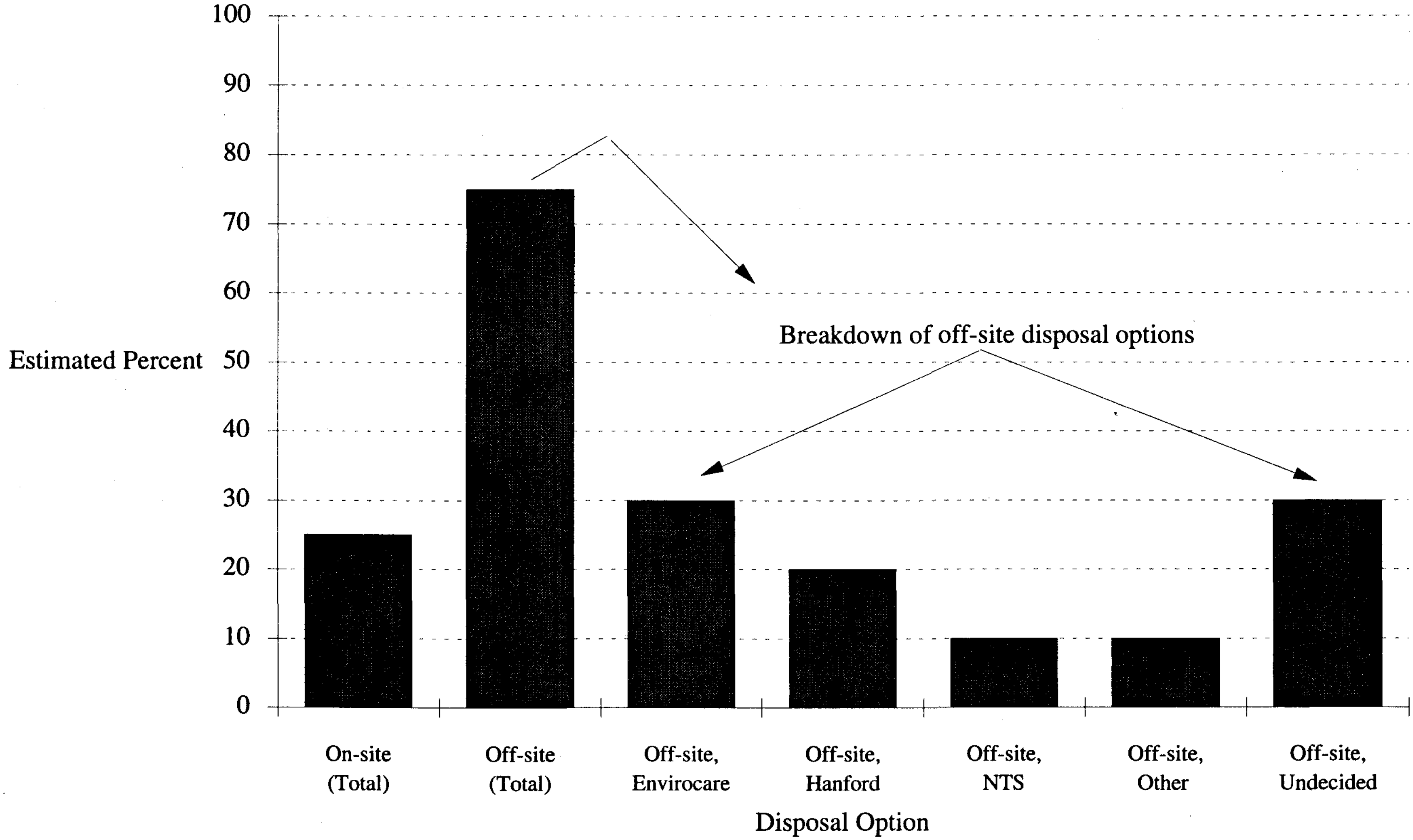

Fig. 3.1. Illustration of DOE-complex disposal options.

Table 3.3. List of Private Industry Vendors to Whom Queries Were Distributed

Vendor	Street	City	State
Acurex Environmental	555 Clyde Avenue	Mountain View	CA
Applied Environmental Services	27432 Calle Arroyo	San Juan Capistrano	CA
Argonne National Laboratory	9700 S. Cass Avenue EID/900	Argonne	IL
Ariel Industries	2204 Industrial South Road	Dalton	GA
B & W Nuclear Enviornmental Services, Inc.	P. O. Box 10548	Lynchburg	VA
Babcock & Wilcox	1562 Beeson Street	Alliance	OH
Battelle	1093 Commerce Park Drive	Oak Ridge	TN
BNFL, Inc.	Suite 950, 9302 Lee Highway	Fairfax	VA
Brand Companies, Inc.	Suite 800, Five Westbrook Corporation	Westchester	IL
Brown & Root Environmental	P. O. Box 4574	Houston	TX
Brown & Root Environmental	Suite A-600, 800 Oak Ridge Turnpike	Oak Ridge	TN
Canonie Environmental Services Corporation	800 Canonie Drive	Porter	IN
Clean Technologies International Corp.	1411 West Vve., Suite 200	Austin	TX
Cognis, Inc.	2330 Circadian Way	Santa Rosa	CA
Creative Waste Management, Inc.	700 Ashland Avenue	Folcroft	PA
Denver Mineral Engineers, Inc.(and IC Technologies)	Suite 110, 8122 South Park Lane	Littleton	CO
Disposal Technologies, Inc.	9 Royal Court	Nesconset	NY
Diversified Environmental Services, Inc.	P. O. Box 254	Seymour	TN
Diversified Technologies	2680 Westcott Boulevard	Knoxville	TN
DRE Environmental Remedial Services Inc.	Suite 420, 111 Westwood Place	Brentwood	TN
Ecotek	219 Banner Hill Road	Erwin	TN
ECOVA, Corporation (Amico)	800 Jefferson County Parkway	Golden	CO
EDC Engineering, Inc.	2107 Avenida De Las Alturas	Santa Fe	NM
EM & C Engineering Associates	Suite 104, 1665 Scenic Avenue	Costa Mesa	CA
Emtech	625 Howard	Deer Park	TX
Ensco	Suite 260, 100 TriState International Street	Lincolnshire	IL
Envirocare of Utah, Inc.	Suite 240, 46 West Broadway	Salt Lake City	UT
Environmental Consulting & Technology, Inc.	3701 NW 98th Street	Gainsville	FL
Envirotech	1819 Albert Street	Jacksonville	FL
ETAS Corporation	Suite 413, 8828 North Stemmons Freeway	Dallas	TX
FERtech Enviro Systems, Inc.	Suite 107, 630 North Morley	Moberly	MO
Filter Flow	Suite 110, 3027 Marina Bay Drive	League City	TX
Fluid Tech, Inc.	Suite 3, 4335 West Tropicana	Las Vegas	NV
GDC Engineering	822 Neosho Avenue	Baton Rouge	LA
GTS Duratek	Suite 200, 8955 Guilford Road	Columbia	MD
Hazen Research	4601 Indiana Street	Golden	CO
International Technology Corporation	312 Directors Drive	Knoxville	TN
Kalkaska Construction Services, Inc.	500 South Maple	Kalkaska	MI
Kimmins	P. O. Box 120	Niagara Falls	NY
Lockheed Environmental Systems & Technology Co.	980 Kelly Johnson Drive	Las Vegas	NV
MacTec	Suite 230, 5460 Ward Road	Arvada	CO
METCO Environmental, Inc.	P. O. Box 368	Cumberland	MD
Metropolitan Environmental, Inc.	P. O. Box 378	Celina	OH
Morrison Knudsen Environmental Services	1500 West 3rd Street	Cleveland	OH
Nobile Oil Services	5617 Clyde Rhyne Drive	Sanford	NC
NOVATERRA	Suite 890, 2029 Century Park East	Los Angeles	CA
NRT Corporation	P. O. Box 85608	San Diego	CA
Nuclear Fuel Services, Inc.	1205 Banner Hill Road	Erwin	TN
ODGEN	Suite 100, 1009 Commerce Park Drive	Oak Ridge	TN
Odgen Cisco, Inc.	4377 Heckscher Drive	Jacksonville	FL
OHM Corporation	P. O. Box 551	Findlay	OH
Parsons Environmental Services, Inc.	4701 Hedgemore Drive	Charlotte	NC

Table 3.3. List of Private Industry Vendors to Whom Queries Were Distributed (*continued*)

Vendor	Street	City	State
Perma Fix, Inc.	Suite 210A, 9050 Executive Park Drive	Knoxville	TN
PET-CON Soil Remediation, Inc.	P. O. Box 205	Spring Green	WI
Pittsburgh Mineral & Environmental Technology, Inc.	700 Fifth Avenue	New Brighton	PA
Purgo, Inc.	Suite 203, 4906 Cutshaw Avenue	Richmond	VA
Quadrex Corporation	1940 NW 67th Place	Gainesville	FL
R. E. Wright Associates, Inc.	3240 School House Road	Middletown	PA
R & R International, Inc.	4920 East Fifth Ave.	Columbus	OH
Radian Corporation	120 Jefferson Circle	Oak Ridge	TN
Recovery Specialists, Inc.	201 North Park Street	Ypsilanti	MI
Resource Technologies Group	Suite 250, 3190 South Wadsworth	Denver	CO
RETEC	9 Pond Lane	Concord	MA
Roy F. Weston, Inc.	1 Weston Way	West Chester	PA
Rust Federal Services, Inc.	100 Corporate Parkway	Birmingham	AL
Rust Environment & Infrastructure	Suite 200, #2 Garden Center	Broomfield	CO
Science Applications International Corp (SAIC)	545 Shoup Ave.	Idaho Falls	ID
Science & Technology, Inc.	700 South Illinois Avenue	Oak Ridge	TN
Scientific Ecology Group, Inc.	1560 Bear Creek Road	Oak Ridge	TN
Sen-Tech Environmental	13333 South Cicero	Crestwood	IL
Separtation & Recovery Systems Inc.	1762 McGaw Ave.	Irvine	CA
Sigma Science Eng. & Tech. Applications Corp.	Suite 2, 901 Oak Ridge Turnpike	Oak Ridge	TN
Soil Purification, Inc.	P. O. Box 72515	Chattanooga	TN
Soiltech	800 Canonie Drive	Porter	IN
SRS, Inc.	1762 McGraw Avenue	Irvine	CA
SSCI Environmental & Consulting Services	Suite 214, 16811 El Camino Real	Houston	TX
Surface Combustion, Inc.	1700 Indian Wood Circle	Maumee	OH
Technics Development Corporation	255 South Tulane Avenue	Oak Ridge	TN
Texarome, Inc.	P. O. Box 157	Leakey	TX
Tide	8325 Washington, NE	Albquerque	NM
Vertac Site	P. O. Box 547	Jacksonville	AR
Vesta	1670 West McNab Road	Fort Lauderdale	FL
VFL Technologies Corporation	42 Lloyd Avenue	Malvern	PA
Wastemaster, Inc.	Suite 604, 4801 E. Independence Blvd.	Charlotte	NC
Wastren, Inc.	255 South Tulane Avenue	Oak Ridge	TN
The Western Company	Suite 1660, 1660 Lincoln Street	Denver	CO
Westinghouse Remediation Ser., Inc. (Aptus)	Bldg. F, Suite 100, 675 Park North Blvd.	Clarkston	GA
Williams Environmental Services	2075 West Park Place	Stone Mountain	GA
Woodworth & Co., Inc.	1200 East D Street	Tacoma	WA

Table 3.4. Commercially Available Technologies Based on Vendor Responses[a]

Vendor	Vendor-Proposed Sludge Treatment Process
Babcock & Wilcox	Cyclone Vitrification
Battelle PNL	Vitrification (slurry-fed melter)
Clean Technologies International Corp.	Molten Metal (alkaline alloy bath at 850 °C)
Diversified Technologies	1) Polyethylene Encapsulation 2) Ceramic Vitrification
ETAS Corp.	Stabilization/Solidification (enhanced cement)
Filter Flow Technology	Biodenitrification/dewatering/solidification
GTS Duratek	Vitrification
IT Corp.	1) Dewatering/stabilization/cement immobilization 2) Dewatering/drying/polyethylene immobilization 3) Dewatering/calcination/cement immobilization 4) Dewatering/calcination/polyethylene immobilization
Nuclear Fuel Services	Precipitation and dewatering
Ohm Corp.	Stabilization/solidification (cement)
RFS Clemson Technical Center	1) Chemical extraction 2) Filter press dewatering/stabilization 3) Vitrification 4) Stabilization
SAIC	Plasma-based vitrification (fixed plasma hearth)
Separation Recovery Systems Inc.	SARAX chemical fixation process (CaO based exothermic reaction, then cement added for strength)
Surface Combustion	Rotary hearth furnace (pyrolytic concentration)
TIDE Co.	Dewatering/Phoenix ash technology compression with flyash
WasteMaster Inc.	Stabilization with fluid tech clay based agents (batch process)
Weston	Dewatering/thermal treatment/solidification

[a] Refer to Table 3.5 for further details.

Table 3.5. Summary of Vendor Responses[a]

Vendor	Technology	Stage of Development	No. of successful installation / remediations	Limiting conditions	Processing rates	Estimated Cost
Babcock & Wilcox	Vitrification	Developmental	None	Water content of sludge	3.3 tons/hr of raw sludge	$465/ton
Battelle PNL	Vitrification	Ready for deployment	Technology has been transferred to several sites - West Valley, Japan, Germany, Hanford, Savannah River and others	None	0.1 to 100 ton/day	$1000 to $3000/ton
Clean Technologies International Corp.	Molten Metal	Pilot-scale demonstration	One pilot-scale demonstration	None	3 yd^3/hr	$200 /$yd^3$
Diversified Technologies	Polyethylene Encapsulation	Developmental	Pilot- and full-scale demonstrations at Brookhaven NL	None	1 to 5 tons/hr	$9.50 to $12/gal.
	Ceramic Vitrification	Bench-scale testing	None	Water content of sludge	1 to 20 tons/hr	$15 to $20/gal.
ETAS Corp.	Stabilization/ Solidification	Commercially available	Two	None	Processing rates are not available	$7/$yd^3$ for labor and cement agents
Filter Flow Technology	Biodenitrification / dewatering / solidification	Each unit is commercially available	Several	High nitrates and sulfates may impact cement solidification	0.5 to 8 tons/hr	Processing unit costs not available
GTS Duratek	Vitrification	Commercially available	Two systems are operational at Catholic University, 1 system at Fernald, and 1 system at Vitreous State Laboratory	None; system should handle NO_x levels	30 to 3000 kg/day of raw sludge	$2183 to $4367/ton

[a] Information presented was based on the respective vendors' responses to a written query.

Table 3.5. Summary of Vendor Responses[a] (*continued*)

Vendor	Technology	Stage of Development	No. of successful installation / remediations	Limiting conditions	Processing rates	Estimated Cost
IT Corp.	Dewatering / cement S/S	Commercially available	Numerous	High nitrates will impact formulation development	30 to 60 yd^3/hr of dewatered sludge	$70 to $100/$yd^3$
	Dewatering / drying / polyethylene S/S	Developmental; pilot-scale testing	None	High nitrates will impact formulation development	1 to 50 ton/hr	$500 to $900/ton
	Dewatering / calcination / cement S/S	Commercially available	Full-scale demonstration at INEL	High nitrates will impact formulation development	30 to 60 yd^3/hr of dewatered sludge	$1000 to $1600/ton
	Dewatering / calcination / polyethylene S/S	Developmental; pilot-scale testing	Full-scale demonstration at INEL	High nitrates will impact formulation development	1 to 20 ton/hr	$1100 to $1700/$yd^3$
Nuclear Fuel Services	Precipitation and dewatering	Full-scale operation	One; processing facility has processed over 6000 55-gal. drums of metal precipitates	None	270 gal./hr of raw sludge	Processing unit costs not available
OHM Corp.	Cement S/S	Commercially available	Several	pH, solids content, salt content, and contaminant levels will impact formulation	30 to 200 tons/hr	$60/ton
RFS Clemson Technical Center	Chemical extraction	Pilot-scale demonstration	Three	None	100 lbs/hr of raw sludge	&75 to $125/ton
	Filter press dewatering / stabilization	Commercially available	Several	Variations in pH will be addressed in formulation	200 to 400 gal./hr of raw sludge	$179 to $270/ton
	Vitrification	Potential for full-scale operation	None	Water content of sludge	1 to 20 kg/hr	$100 to $200/$ft^3$
	Cement S/S	Commercially available	Eight	Variations in pH will be addressed in formulation	35 to 130 tons/day	$179 to $270/ton

[a] Information presented was based on the respective vendors' responses to a written query.

Table 3.5. Summary of Vendor Responses[a] (*continued*)

Vendor	Technology	Stage of Development	No. of successful installation / remediations	Limiting conditions	Processing rates	Estimated Cost
SAIC	Plasma hearth S/S	Developmental	Information not provided	None	1000 kg/hr	Processing unit costs not available
Separation Recovery Systems Inc.	SARAX chemical fixation	Information not provided	Information not provided	Information not provided	Processing rates not available	Processing unit costs not available
Surface Combustion	Rotary hearth furnace	Commercially available	New application of proven technology	None	1000 to 10,000 lbs/hr	Processing unit costs not available
TIDE Co.	Dewatering / Phoenix ash technology compression with flyash	Advanced developmental	Several bench-scale demonstrations	Salts may impact formulation including proprietary additives	10 tons/hr	Processing unit costs not available
WasteMaster Inc.	Stabilization with fluid tech clay	Information not provided	Information not provided	Information not provided	Processing rates not available	Processing unit costs not available
Weston	Dewatering / thermal treatment / solidification	Full-scale production unit	Three	None	15,000 lbs/hr	$185 to $320/ton

[a] Information presented was based on the respective vendors' responses to a written query.

4.0 DEVELOPMENT OF THE CANDIDATE TECHNOLOGY LIST

One element of the project required assimilation and integration of information obtained through literature reviews, the DOE site survey, and the commercial technology vendor survey to develop a candidate technology list for scoring and ranking. The process used to develop the candidate technology list and a description of the candidate technologies are described in this section.

4.1 METHODS

Based on initial vendor responses and literature reviews, a preliminary list of commercially available technologies with purported application to the SEP sludges was developed (Appendix F, Table F.1). Information on commercially available and emerging technologies was simply obtained and no attempt was made at this point to screen candidate technologies. This list was subsequently reviewed and refined based on (1) increasing knowledge about site characteristics and contamination levels, (2) evolving knowledge about potentially viable sludge treatment technologies, and (3) the information gained from literature reviews, DOE site experiences, and commercial vendors (Section 3).

A candidate list of systems for evaluation and screening was generated that included complete treatment and disposal systems (beginning with sludges in the tanks through final disposition) (Table 4.1, and Figs. 4.1 and 4.2). This system approach was required for evaluation because, at the time of evaluation, the final disposition of the sludges was uncertain and screening of only treatment technologies may not have provided an accurate evaluation of the complete treatment system. The initial candidate list was screened further based on the likelihood of system implementation. For example all NTS disposal options were removed from further consideration due to the improbability that NTS would be able to accept LLMW. This revised list includes the treatment and disposal systems ultimately reviewed and assessed by members of the technology evaluation team (Sect. 5). To facilitate this effort and to enable rapid review and understanding, a Technology Description Fact Sheet and associated flowsheets were developed for recording key information about each system. These descriptions and flowsheets were prepared based on literature review, personal inquires, and vendor information. Technology Description Fact sheets and associated flowsheets are presented in Appendix F.

4.2 RESULTS AND DISCUSSION

Candidate technologies retained for evaluation and screening as part of this project are summarized in Table 4.2. Brief descriptions of the technologies are presented in this section. Information was obtained through existing literature to identify treatment options and constraints potentially applicable to sludge treatment. Literature searches were conducted on several databases, including VISITT (EPA 1993d), Alternative Treatment Technology Information Center (ATTIC), Uncover, and DIALOG. Searches were structured to look for references specific to sludge containing high metal, radionuclide, or nitrate concentrations; to stabilization/solidification processes; and to other applicable treatment processes. Key DOE sources of information included the ORNL Logic Diagram (ORNL 1993), Feasibility Studies for Treatment System Determination for the X-701B Boxed Sludge (Davenport, Hylton and Perona 1993), and previous DOE funded efforts. An ad hoc technical review committee consisting of national experts in sludge treatment and disposal was also assembled and provided valuable comments (Appendix F, Table F.2).

4.2.1 Simple Stabilization

Simple stabilization involves minimal treatment by mixing the contaminated sludge with chemicals such as flyash and lime to produce a physically and chemically encapsulated stabilized waste form (Barth 1990). The specific flyash/lime formulation, determined by treatability studies, is generally intended to ensure that the hazardous constituents are maintained in their least mobile or toxic form (Halliburton NUS 1992c and d, and 1994).

Stabilization treatment systems typically consist of screens, filter presses or centrifuges if necessary, conveyors, reagent silos, and pug mills. The treatment may or may not require processing steps, including mixing and equalization, dewatering, and size screening. A typical stabilization process mixes flyash with the waste, creating a moist mass that can easily be handled. The waste/flyash mixture is then loaded onto a conveyor, where a metered amount of lime is added. Next, the mixture is run through a pug mill and transported for disposal. Another stabilization process requires pumping the sludge directly into a pug mill (or ribbon blender) where reagents are blended. The treated mixture is then pumped to the disposal area. The stabilized waste form typically has a soil-like consistency. Processing rates average approximately 25 yd^3/d.

This technology has been successfully used in managing hazardous and industrial waste. However, the contaminant performance generally is such that a hazardous waste would still be classed as hazardous after treatment.

4.2.2 Cement Stabilization/Solidification

Cement S/S involves the intimate mixing of contaminated sludge with chemicals and reagents such as cement, flyash, blast furnace slag, polysilicates, and adsorbents. Specific formulation, determined by treatability studies, will chemically bind and physically encapsulate the hazardous and radioactive components within the matrix (Barth 1990, Conner 1990, Roy et al. 1993, and Chang et al. 1993). Cement S/S can be used for low-level waste, organics, metals, and mixed waste and is accepted for RCRA metals, CERCLA remediation, and low-level radioactive waste. S/S is one of the most widely used techniques for the treatment and ultimate disposal of hazardous wastes and low-level radioactive wastes (ORNL 1993).

Cementitious materials are the predominant materials of choice because of their low costs, compatibility with a wide variety of disposal scenarios, and normal ability to meet stringent processing and performance requirements. Cementitious materials include cement, ground granulated blast furnace slag, flyash, lime, and silica fume. Various clays and additives are used to help immobilize contaminants or otherwise enhance the waste form properties. Soluble constituents in the waste chemically interact with the cementitious materials to form low-solubility products at the high pH and the Eh prevailing in the waste form. These interactions usually affect the cementitious hardening and properties to some degree. Testing with a specific waste or waste stream is normally required to tailor the formulation to the desired properties. Sufficient attention must be given to characterizing the waste, to developing the formulation to treat the waste, and to implementing this formulation in the field to ensure correct mixing of the formulation. Adding these dry ingredients inevitably increases the volume of the waste treated, which can add significantly to lifetime disposal costs. The volume decrease claimed for techniques such as thermoplastic encapsulation comes from evaporation of the water and encapsulation of the solids. The same evaporation pretreatment could be used with cement S/S to obtain a net volume decrease, but some of the simplicity of the cement S/S would be lost. Cementitious waste forms are porous, making them more leachable than polymeric or glass waste forms. The key has been controlling this leachability (by pH, Eh, and/or absorbents) within satisfactory limits for a simpler and cheaper treatment.

Cement S/S treatment equipment systems typically consist of screens, filter presses or centrifuges, conveyors, reagent silos, pug mills, and water treatment equipment. The treatment may require several processing steps, including mixing and equalization, dewatering and/or drying if necessary (Davis 1989), and size-screening. Depending on the final waste form requirements, the stabilized/solidified output will have a soil-like consistency or will be a pumpable slurry that sets up into a solid monolith after curing.

The costs for cementitious waste forms from Dole and Trauger (1983) and Kessler et al. (1984) are \$0.05–\$0.15/waste gal. for materials cost and \$0.10–\$0.50/waste gal. total disposal cost (including material, capital, and operating costs). At the other end of the spectrum, Myrick et al. (1992) had a total estimated project cost of \$115/gal. concentrated liquid low-level waste for solidifying 47,000 gal. of waste. This cost is unusually high for S/S, even for such a small quantity of waste. The cost of an aluminosilicate stabilization was estimated by Bates et al. (1992) to be \$190–\$360/yd^3 (\$0.90–\$1.78/gal.) to treat 15,000 yd^3 of a SITE demonstration waste.

Jacobs et al. (1984) estimated the costs for treatment (including transportation and burial) of 12,700 ft^3/year for 30 yd^3 of concentrated boiling water reactor waste for the following options:

- Crystallization followed by S/S: \$37.00/ft^3; \$4.95/gal.
- Drying followed by S/S: \$28.93/ft^3; \$3.87/gal.
- Evaporation followed by encapsulation in asphalt: \$35.20/ft^3; \$4.71/gal.
- Drying followed by encapsulation in DOW binder (VES): \$24.60/ft^3; \$3.29/gal.
- Evaporation followed by S/S: \$89.21/ft^3; \$11.93/gal.

Better understanding of the immobilization mechanisms and the chemistry of these waste forms can lead to improved performance and better predictions about their durability. Formulations need to be developed, or at least tested, for the specific wastes intended for treatment. Proper implementation is necessary to ensure that the waste form tested in the laboratory represents what will be produced in the field. This means having the equipment and expertise necessary to properly blend and mix these solid constituents and managing the operation properly so that the right formulation is mixed. Limitations to the process relate to the effects of the waste on the setting and stability of the final waste form. For example, high concentrations of sulfates and halides may retard setting because of their leachability. This technique is currently in wide-scale use, is available from numerous vendors, and has been routinely applied for treatment of hazardous and/or radioactive wastes.

4.2.3 Biochemical Stabilization

Biochemical stabilization is similar to simple stabilization with the addition of biodenitrification for nitrate removal, which may reduce the leachability of other constituents in the sludge. Precipitation may also be employed to reduce levels of metals in the sludges prior to stabilization. Residuals from precipitation are expected to require solidification before disposal. Following biodenitrification, sludges are mixed with chemicals such as flyash and lime to produce a chemically bound stabilized waste form. Treatability studies would be required to determine the applicability and optimum operating conditions for biodenitrification and/or precipitation and to develop stabilization formulas specific to the different waste compositions.

Bioremediation, in its most general sense, refers to a wide range of biological processing options that rely on microbial transformation of organic contaminants to effect cleanup of sludges (Walton and Dobbs 1980). The microorganisms, principally bacteria, metabolize the constituents into benign forms to obtain energy and/or carbon (Atlas and Bartha 1981). Bioremediation can occur in situ (at the contaminant location) or ex situ (away from the contamination site). Nitrates are more readily degraded anaerobically (i.e., biodenitrification) (Thibault and Elliot 1979).

The difficulty of biodegradation depends upon the contaminants of interest. Biodenitrification in SBRs is known to be a promising treatment technology for aqueous solutions and sludges associated with the SEPs (and other waste streams and media at RFETS) (Francis and Mankin 1977, Irvine and Busch 1979, Silverstein and Schroeder 1983, Cook et al. 1993). For aqueous solutions, the process can reduce nitrate concentrations and facilitate stabilization of sludges and unrestricted discharge of intercepted groundwaters (e.g., interceptor trench system water; >1 million gal./year). An experimental investigation to study the rate and extent of treatment under variable waste concentrations and factors controlling the removal of nitrogen species has begun. Bioprocess effects on the characteristics and management of sludge residuals are also being studied. Field demonstration in FY 1995 is envisioned to include establishment and operation of a pilot-plant system at RFETS treating actual SEP waters and/or sludges.

Precipitation is a chemical treatment process by which soluble contaminants are removed from water by converting them into insoluble compounds (Taylor and Robinson 1991). Soluble contaminants may include metals, alkaline earth ions (hardness), or other inorganic anions. An example of chemical precipitation is metals precipitation using hydroxide, sulfide, phosphate, or carbonate ions as the precipitating agent. Metal hydroxide precipitation is a pH adjustment process used to treat aqueous wastes containing metals. Base (usually lime or caustic) is added to adjust the pH to the point where the constituents to be removed have the lowest solubility. This treatment results in a metal sludge and a treated effluent that has an elevated pH. Flocculants may enhance the precipitate removal (Carter and Scheiner 1991).

Sometimes, metal sulfide precipitation is used to remove metals to reach lower concentrations than can be achieved using hydroxide precipitation. Sodium or ferrous sulfide is added as a precipitating agent. After precipitation, excess sulfide ions must be removed by oxidation. Effluent metal concentrations of less than 1 mg/L (and sometimes lower) are achievable. Chromium can be precipitated to less than 0.1 mg/L if reduction is used as a pretreatment step to convert hexavalent chromium to trivalent chromium.

Biodentrification treatment systems typically consist of bioreactors and water treatment equipment. Innovative bioreactors that can handle solids, retain organisms, and optimize reactor conditions should be considered. The use of ex situ bioreactors offers better control over temperature, chemical, and biological conditions than in situ operations. The technology of biodegradation and bioreactor design are developing rapidly, and improvements in cost and performance appear to be resulting from current activities. Ex situ techniques should be thoroughly evaluated for process flexibility and cost effectiveness when other, possibly less expensive, in situ applications are available.

Precipitation treatment systems primarily consist of mixing and settling tanks for addition of acids or bases and other coagulants. Stabilization treatment systems typically consist of screens, filter presses or centrifuges if necessary, conveyors, reagent silos, and pug mills. The treatment may or may not require processing steps including mixing and equalization, dewatering, screening for removal of large items, and mixing of reagents and waste in a pug mill. The stabilized waste form typically has a soil-like consistency. Processing rates are approximately 25 yd^3/d.

Costs for the in situ bioremediation methods are generally lower than ex situ methods but vary considerably. Costs for ex situ bioremediation are likely to be moderate; e.g., costs in the range of $100–$200/ton may be achieved. One estimate suggested a cost of $165/ton (Stinson, Skovronek, and Ellis 1992). Although these estimated costs are for bioremediation of organic compounds, biodenitrification costs are assumed to be similar.

Biodegradation, including biodenitrification, requires careful treatability studies, and the acceptable treatment level needs to be established. Precipitation requires careful characterization of the waste stream and sludge recovered from precipitation requires disposal. Treated effluent from metal hydroxide precipitation may require pH adjustment before discharge while treated effluent from metal sulfide precipitation may require sulfide removal before discharge. Both technologies are commercially available from numerous vendors and have been applied for treatment of hazardous and/or industrial wastes and wastewaters.

4.2.4 Pressure Stabilization/Solidification

Pressure S/S is a proprietary process developed by the TIDE Company of Albuquerque, NM. The process involves the compression of a mixture of flyash, and waste that chemically binds and encapsulates the waste into a small brick like waste form. The process is capable of producing various size brick waste forms (NETAC 1993 and Spence et al. 1993). Treatability studies would be required to determine the proper moisture content, flyash to waste ratio, and operating pressure of the press.

The Phoenix Ash Technology (PAT) is a patented process to create formed products for construction or to encapsulate toxic waste products using ASTM Class C flyash. PAT consists of mechanically pressing a particularly reactive Class C flyash with the waste into a solid product (i.e. such as a brick). Class C flyash hydrates and reacts in the presence of water to form a calcium silicate hydrate by itself. It has been used in combination with cement, but many vendors avoid its use based on the reactive nature and tendency to harden almost immediately ("flash set") upon mixing inside equipment. Class C flyash is a powdery material with a high calcium content that ensures "flash setting" upon compression with a minimal amount of water (about 15 wt % of the waste mass is required for the PAT process)

(Spence et al. 1993). A polymer coating may be applied to the compressed brick to water proof the surface.

Pressure S/S treatment equipment systems typically consist of screens, filter presses or centrifuges, conveyors, flyash silo, brick press, and waster treatment equipment. The treatment may require several processing steps including removing sludges from the tanks, dewatering and or drying, screening for removal of large items, mixing of the flyash and waste and pressing of the mixture into bricks.

The TIDE stabilization process depends on high pH for chemical stabilization and a solid cementitious matrix for physical encapsulation. This technology is in the developmental stage. However, several treatability studies have been performed on surrogate, hazardous, and mixed waste using a range of equipment from bench- to full-scale.

4.2.5 Biodenitrification with Cement Stabilization/Solidification

This treatment is the same as cement S/S with biodenitrification employed prior to cement S/S (see Section 4.2.2 for discussion of cement S/S, and Section 4.2.3 for discussion of biodenitrification). High nitrate levels are known to adversely affect the cement S/S process (Mattus and Gilliam 1994, Barth et al. 1990). Biodenitrification reduces the nitrate levels in the waste potentially enhancing cement S/S.

Cement S/S techniques are currently in wide-scale use (Section 4.2.2). Both technologies are commercially available from numerous vendors and have been applied for treatment of hazardous and/or industrial wastes and wastewaters. The need for biodenitrification and method of implementation requires treatability studies.

4.2.6 Polymer Stabilization/Solidification

Polymer S/S involves the intimate mixing of dried contaminated sludge with molten polyethylene to encapsulate the waste and produce a stabilized waste form. The ratio of waste to polyethylene is determined through treatability studies.

Polymer S/S may also be referred to as thermoplastic encapsulation and is applicable to low-level waste, organics, metals, mixed waste (Cote and Gilliam 1989, Gilliam and Wiles 1992). Two thermoplastics—bitumen and polyethylene—have been developed as encapsulation waste forms. Ostensibly, thermoplastics do not interact with the waste, so extensive testing to tailor the waste form is not required and net volume reductions can result for liquid wastes. The waste must be dried and the dried solids encapsulated in the thermoplastic. The waste is exposed to higher temperatures during drying and mixing with the molten thermoplastic, so volatile species such as mercury may not be amenable to such treatment. The processing is more complex than cement S/S. The waste is not chemically immobilized or stabilized, but the thermoplastic is nonporous and, hence, less leachable. It is questionable whether such physical encapsulation waste forms will pass the TCLP. Also, current EPA guidance is that chemical fixation, rather than just physical encapsulation, is required.

Bitumen has been used extensively in Europe, and a couple of commercial vendors offered bitumen encapsulation in the U.S (Chalifoux, Coley, and Low 1988). However, bitumen creeps and requires a container (e.g., a 55-gal. drum or concrete vault) for structural integrity. Bitumen also absorbs water, swelling as it does so. Encapsulated soluble salts will set up large osmotic pressures within thermoplastic waste forms upon contact with water, causing further expansion for bitumen waste forms. Concern also exists about encapsulating nitrate salts (known oxidizers) in thermoplastics and the biodegradability of these waste forms. Once ignited, such a mixture may burn without access to air. The combination of these problems has made bitumen less popular, despite its superior leach resistance as compared to cementitious waste forms.

Polyethylene may overcome most, if not all, of the problems with bitumen, but it is in early development stages. Polyethylene offers the structural integrity lacking in bitumen. Also, the Brookhaven National Laboratory (BNL) has studied polyethylene as a waste form for DOE and claims that nitrate salts encapsulated in polyethylene will pass fire and self-ignition tests. BNL has not developed the technology for drying the waste before encapsulation in polyethylene or encapsulated actual wastes. It has mainly studied the properties of dry salts encapsulated in polyethylene (Kalb, Keiser, and Colombo 1991a, 1991b, and 1992; Kalb and Colombo 1991; and Arnold et al. 1983).

Sulfur polymer cement (SPC) encapsulation is like thermoplastic encapsulation in that the dried waste solids are encapsulated in the molten sulfur. The advantages are similar in that little interaction is anticipated, a nonporous waste form results in less leaching, and drying liquids result in a net volume decrease (Darnell 1992). Sulfur is resistant to acid attack, so SPC has been used as a construction material in aggressive acid environments. On the other hand, sulfur cannot be used in other environments, such as high alkalinity. These deleterious environments have been identified and must be avoided, illustrating the importance of waste characterization. SPC has been studied as a waste form at BNL and in Europe (Kalb, Keiser, and Colombo 1991c). These studies have been on a laboratory scale, so pilot-scale studies and demonstrations are still needed. As with thermoplastics, it is questionable whether SPC will pass the TCLP test as a purely physical encapsulation technique. The Europeans succeeded in pretreating ion exchange resins, so that resin encapsulated in SPC could be immersed in water without resin swelling and breakdown of the SPC matrix.

Finally, polymer-impregnated concrete / polymer-modified concrete is a technique that achieves waterproofing after cement S/S. Polymer impregnation has been studied over many years and is usually restricted to treatment within a few millimeters of the surface; polymer modification has been developed and introduces polymer throughout concrete during the mixing step (Mattus and Spence 1989). Both have been used as a means of waterproofing and environmental protection for structural concrete (Ohama 1984). Impregnation usually is attempted as remedial protection years after the concrete structure was made. A technique was invented at ORNL to achieve essentially complete monomer permeation throughout a waste form by adding polystyrene foam during mixing of the cementitious waste form. The same technique is used in polymer modification in which latex, for example, is mixed into the concrete. The foam bits introduce porosity into the waste form, potentially making a weaker product, not of great concern for waste forms. The styrene monomer collapses the polystyrene foam, helping to pull monomer throughout the cementitious matrix. The monomer then is polymerized, giving a waterproofing component throughout the waste form. This treatment protected cementitious waste form samples from attack by concentrated hydrochloric acid. Laboratory development still is needed to optimize the treatment and to test the properties of the resulting waste form. The product has the advantages of a cement waste form with the added protection of a waterproofing layer throughout the waste form. Leaching will still occur across the polymeric barrier from the porous cementitious waste form. BNL acquired a patent using polymer impregnation of cement as a means of disposing of treated water (Colombo, Neilson, and Becker 1979).

Silvey and Kaczmarsky (1988) estimate that asphalt encapsulation of spent beads and powdered resin from a boiling-water reactor (BWR) will result in volume reduction factors of 4.4 over cement-based S/S, of 2.22 over dewatering bead resin, and of 1.67 over Ecodex in high-integrity containers. Significant cost savings over the replaced technology are expected using volume reduction and asphalt encapsulation. Chalifoux, Coley and Low (1988) report ratios of initial waste volume to disposal volume (V/R) of 1.9 to 4.0 for different radioactive wastes from a BWR encapsulated in asphalt compared to a typical V/R range of 0.5 to 0.75 for BWRs that use volume-increase technology such as S/S. The spent resin V/R was 1.9, resulting in a volume reduction factor over S/S of 2.5 to 3.8, compared to the 4.4 reported by Silvey and Kaczmarsky (1988).

Polymer S/S treatment equipment systems typically consist of screens, filter presses or centrifuges, conveyors, heated polyethylene tanks, heated pug mills, and off-gas and water treatment equipment. The treatment may require several processing steps including removing sludges from the tanks, dewatering and or drying, screening for removal of large items, mixing of the polyethylene and waste in a heated pug mill or extruder , and off-gas treatment equipment.

Estimated costs for treatment were similar with those costs presented for cement stabilization (see Section 3.2.2).

Passing the TCLP test needs demonstration along with development of technology to dry the waste before encapsulation (for polyethylene). Additionally, resistance to biological degradation needs to be demonstrated. A means for handling volatile species can be explored, such as conversion of mercury into nonvolatile species or incineration of organics. Materials susceptibility to corrosion at the elevated temperatures for the processing equipment needs to be explored, especially if chloride or fluoride species are present in the waste. Most of these thermoplastic technologies require further development and testing. However, BNL has a 2000 lb/hr full-scale demonstration system for testing hazardous, radioactive, and/or mixed waste.

4.2.7 Vitrification

Vitrification is a high temperature thermal process in which waste and glass forming fluxes are fed into a melter or furnace to produce a pool of molten glass at the bottom of a reactor in which solid wastes react (Armstrong and Klinger 1986; Barth 1990; Conner 1990; Hartman, Oden, and White 1993; Unknown 1993; and Oden et al. 1994). Any volatile components present in the waste (e.g. organics) are vaporized and treated in the off-gas system. The nonvolatile components in the waste are oxidized and melted into a vitrified waste form. The process is very sensitive to the proper composition of waste and fluxes in order to produce an acceptable waste form. Therefore, waste characterization is very important and these formulations must be developed from treatability studies specific for each different waste composition in order to insure production of an acceptable waste form. The technology is in the developmental stage.

Vitrification is a physical encapsulation technique that has been accepted for high-level waste (Gillins, Steverson, and Balo 1991; Gimpel 1992a, b, and c; Brickford et al. 1992; Diggs 1992; Greenhalgh 1992; and Unknown 1992). Vitrification results in a net volume reduction, even starting with a bed of solids and no liquids. This results in significant economic savings for ultimate disposal which can compensate in part for the higher capital and production costs required to generate this waste form (compared to cement waste forms) (Diggs and Gimpel 1992). Ostensibly, no interaction with the waste occurs, but it is questionable whether vitrified waste will pass the TCLP test. The waste form is nonporous and less leachable than cemented waste forms, but the RCRA metals may be just as extractable after treatment as before, if truly allowed to come to equilibrium, as intended in the TCLP test. Laboratory testing is required, as with cement waste forms, to identify the compatible melt compositions. This technique occurs at higher temperatures than for thermoplastic encapsulations. Thus, water is driven off, but it is inappropriate for volatiles and may not be appropriate for semivolatiles. Organics are likely destroyed, but other volatiles and semivolatiles that cannot be destroyed (e.g., mercury, tritium, cesium, and technetium) may not be amenable to vitrification. Such contaminants are commonly found in low-level radioactive wastes.

Vitrification treatment equipment systems typically consist of screens, filter presses or centrifuges, conveyors, flux storage tanks, melter or furnace, off-gas and water treatment equipment. The treatment may include several processing steps including removal of sludges from the tanks, dewatering and or drying if necessary, screening for removal of large items. processing of the material in the melter or furnace, off-gas treatment, and handling of the glass discharged from the system. Depending on the final waste form requirements, the system is capable of producing either a monolith or marble sized glass pieces.

The white paper prepared for EG&G Idaho, Inc., (Haz Answers, Inc. 1991) evaluates the advantages, disadvantages, and costs of thermal treatment technologies, including vitrification by glass furnace and vitrification by microwave melting. Included among the disadvantages were relatively high energy and capital costs and unproven technology for hazardous wastes. The capital cost and operating costs for glass furnace vitrification were estimated to be $3.9M and $0.78/kg feed. (Assuming a feed density of 1 kg/L, operating costs convert to $780/m^3$ or $2.95/gal.)

Koegler et al. (1988) provided the following insights regarding waste vitrification:

- Estimated capital cost of $24.1M and total operating costs of $73M for granular glass, or $97M for casting into canisters, for a facility to vitrify 264K tons of waste over 6.5 year. This works out to $91/ton capital costs and $277–$367/ton operating costs.
- "A favorable property of glass is its ability to accommodate a wide variety of compositional variations and still maintain its basic durability."
- "The amount of glass to be produced is expected to be determined by the fluoride solubility limit in the glass. Fluoride, a major constituent in the raffinate sludges, has a maximum glass solubility of about 5 wt%."
- "Of the priority pollutant metals, mercury is known to escape from the glass during vitrification due to its high vapor pressure."
- "On a cost-per-volume basis, the disposal costs are estimated at $256/m^3$ or $322/m^3$, depending on whether the glass product is fritted or placed in canisters."

Buelt (1985) reported the following about vitrification:

- "The process is not amenable to waste solutions with significant concentrations of sulfates (i.e., <2% on a dry solids basis). Sulfate solubility in glass is limited to 0.5 wt%."
- "In addition to producing a geologically stable waste form, MEVS significantly reduces the volume of the waste to be destroyed." (MEVS stands for the Mobile

Encapsulation and Volume Reduction System touted by the author. MEVS employs a joule-heated glass melter to vitrify low-level wastes.)

- "The cementation process actually increases the evaporated waste volume by a factor of 1.3, which increases the transportation and disposal cost."
- The estimated disposal cost for cementation, MEVS of resins, and MEVS of concentrated liquid are $295, $218, and $191/ft^3 wet wastes ($39.44, $29.14, and $25.53/gal. wet wastes), respectively, including amortized capital, processing, transportation, and disposal costs. (Processing costs for cementation in this reference are orders of magnitude higher than those from other sources.)
- "Burial costs are 1/3 and 1/2 of the cementation disposal costs for resins and concentrated liquids respectively."

Laboratory testing of a specific waste or waste stream is necessary to establish the glass composition. The need exists to demonstrate the technology's effectiveness for those semivolatile species commonly found in low-level waste (Ritter et al. 1992). For hazardous waste, incinerator efficiencies must be demonstrated for organics as well as the ability to handle volatile and semivolatile metals. Typically, mercury must be removed before vitrification, and Cs-137 has been found in the off-gas (Horton and Ougouag 1986). Catholic University is studying this technique for DOE (Unknown 1992). Claims are made that vitrified wastes pass the TCLP test, but this must be verified, and the RCRA metal limits in the vitrified waste must be quantified. This technology is in a relatively early developmental stage.

4.2.8 Microwave Melter

Microwave S/S is a high-temperature thermal process developed by EG&G. Waste and glass forming fluxes are fed into a melter and microwave energy is transmitted with internal temperatures reaching up to 1000 °C (EG&G 1994). Any volatile components present in the waste (e.g., organics) are vaporized and treated in an off-gas system. The nonvolatile components are melted into a vitrified waste form.

Microwave S/S treatment equipment consists of screens, a 180 °C dryer, conveyors, flux storage tanks, melter or furnace, and off-gas and water treatment equipment. The treatment may include several processing steps, including removal of sludges from the tanks, dewatering if necessary, drying, screening for removal of large items, processing of the material in the melter, off-gas treatment, and handling of the final waste-containing drums. The system produces a vitrified waste contained in 30-gal. stainless-steel drums. The technology is in the developmental stage; therefore, treatability studies would be needed to determine the applicability of the process to treat the sludges.

4.2.9 Plasma Hearth

Plasma hearth is a thermal treatment process using an electric arc plasma to melt noncombustible wastes and vaporize/oxidize combustibles. Vaporized organics are partially oxidized in the primary chamber and completely oxidized in the subsequent secondary combustion chamber. The noncombustible materials melted into the hearth are separately removed as slag and metal melts. Any volatile components present in the waste (e.g., organics) are vaporized and treated in the off-gas system. The process encapsulates the nonvolatile components in the waste and produces a vitrified waste form. Unlike vitrification, the process is not as sensitive to changing waste composition to produce an acceptable waste form. Therefore, waste feed characterization can be minimized.

The plasma arc furnace (PAF) is a new and promising technology that may be an alternative to cementation and incineration. The term "plasma" refers to a highly ionized gas. Plasmas can be generated by a variety of techniques and occur over a wide range of pressures and energy levels. Typically, a torch uses a flowing gas to stabilize an electrical discharge (arc) between two electrodes. One or both of these electrodes is contained within the torch. For treatment of solid materials, the second electrode is usually the material being processed (using arc welding terminology, this is called the "workpiece"). Energy is dissipated as heat and light as the electrical current flows through the gas. Through resistance heating (Joule heating), this process creates a high-temperature gas as well as directly heating the workpiece (Morris 1992). Plasma torches have high energy densities with local temperatures up to 15,000 K (Hoffelner et al. 1992). Qualitative benefits of this technology are high-integrity final waste form, portability, low off-gas, and contamination control. Potential disadvantages are that plasma processes are very energy intensive, and power costs could limit applications to small-scale (Borduin et al. 1989).

Several pilot-scale systems have been established, including Centrifugal Retech Furnace, Switzerland; Centrifugal Retech Furnace (Retech Inc. 1992); DOE/EPA Site Program, Butte, Montana; Fixed Hearth Retech Furnace, Ukiah, California; Plasma Facility, Charleston, South Carolina (McCulla 1992); and Westinghouse Pilot Facility, Pittsburgh, Pennsylvania (McCulla 1992). Some operating and emissions data exist for these facilities, but additional data are needed for process design and scale-up.

Plasma treatment equipment systems typically consist of feed-handling equipment, the plasma arc and processing chamber, and off-gas treatment. A continuous plasma torch is typically operated in transfer mode (one end of the torch arc impinges on the material being heated) or non-transferred mode. The system includes an enclosed feeder, an afterburner, a slag removal system, a waste-gas chiller, a waste-gas scrubber, a continuous emissions monitoring system, stack samplers, and various controls and diagnostic equipment. The PAF can be operated under reducing or oxidizing conditions. The treatment may involve several processing steps that include removing the sludge from the tanks, processing the material in the processing chamber, treating off-gases, and handling the glass discharged from the system. Dewatering would not be required but may be advantageous to the overall process operation.

Research and development are required to assess metals carry-over from the primary chamber (not zone) and to optimize slag chemistry regarding metals stabilization, variations in waste input streams, reintroduction of condensed volatile metals into the slag phase, and radionuclide partitioning in the effluent streams, including metal specification studies in the entrained particulates in the off-gas as a function of particle size (Berry et al. 1992 and Whiteworth et al., year unknown). Additional development is required to determine and improve electrode life, materials of construction in general, destruction and removal efficiency of hazardous/toxic organics, power efficiency, mass/energy balances to effect minimum secondary waste generation, and optimal safe operating methods as a function of heterogeneous waste processing. This technology is in developmental stages, especially for mixed and radioactive waste, and therefore treatability studies would be needed to determine the applicability of the process to treat the sludges.

Table 4.1. Summarized Listing of Conceivable Sludge Treatment and Disposal Options

Option	System Description[a]	Disposal	Comments	Kept[b]
1A	Simple Stabilization	OU4 burial	Treated sludge is not required to meet LDRs based on CAMU WACs.	Y
1B		New cell burial	Unlikely to be implemented as sludges would not meet LDR WACs.	N
1C		Envirocare	Unlikely to be implemented as sludges would not meet LDR WACs.	N
1D		NTS	Unlikely to be implemented as sludges would not meet LDR WACs.	N
2A	Cement Stabilization/Solidification (S/S) no pretreatment	OU4 burial	Provides added waste stability over option 1A, but at increased treatment cost and volume.	Y
2B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
2C		Envirocare	Volume reduction will minimize transportation and disposal costs.	Y
2D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N
3A	Biochemical Stabilization	OU4 burial	Reduction of nitrates by biodenitrification may make sludge more stable (less leachable). Precipitation may help stabilize metals in the final waste form.	Y
3B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
3C		Envirocare	Reduction of nitrates by biodenitrification may make sludge more stable (less leachable). Precipitation may help stabilize metals in the final waste form.	Y
3D		NTS	Unlikely to be implemented as sludges would not meet WACs.	N
4A	Pressure S/S	OU4 burial	Provides added waste stability over option 1A, but at increased cost. Process is in commercial developmental stage.	Y
4B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
4C		Envirocare	Lower volume increase reducing transportation and disposal costs over option 2C. Process is in commercial developmental stage.	Y
4D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N

a Conceptualization of treatment and disposal options was made with knowledge of current and future constraints on operation, performance, cost, and implementation time.

b Retained for scoring and ranking based on technical evaluation team discussion and consensus on 8/30/94.

Table 4.1. Summarized Listing of Conceivable Sludge Treatment and Disposal Options (*continued*)

Option	System Description[a]		Comments	Kept[b]
5A	Biodenitrification, cement S/S	OU4 burial	Reduction of nitrates may make S/S sludge more stable (less leachable).	Y
5B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
5C		Envirocare	Reduction of nitrates may make S/S sludge more stable (less leachable).	Y
5D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N
6A	Polymer S/S	OU4 burial	Provides added waste stability over option 1A, but at increased treatment cost. Provides greater treatment than required by CAMU WACs.	Y
6B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
6C		Envirocare	Possible lower volume increase reducing transportation and disposal costs over option 2C.	Y
6D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N
7A	Vitrification S/S	OU4 burial	Provides greater treatment than required by CAMU WACs.	N
7B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
7C		Envirocare	Volume reduction may minimize transportation and disposal costs but at higher treatment costs.	Y
7D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N
8A	Microwave Melter	OU4 burial	Provides greater treatment than required by CAMU WACs. Process is in bench-scale developmental stage.	N
8B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
8C		Envirocare	Volume reduction may reduce transportation and disposal costs, but at higher treatment costs. Process is in developmental stage.	Y
8D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N

a Conceptualization of treatment and disposal options was made with knowledge of current and future constraints on operation, performance, cost, and implementation time.

b Retained for scoring and ranking based on technical evaluation team discussion and consensus on 8/30/94.

Table 4.1. Summarized Listing of Conceivable Sludge Treatment and Disposal Options (*continued*)

Option	System Description[a]	Disposal	Comments	Kept[b]
9A	Plasma Hearth S/S	OU4 burial	Provides greater treatment than required by CAMU WACs. Process is in developmental stage.	N
9B		New cell burial	May be difficult to permit and implement within near future based on siting, design, and construction.	Y
9C		Envirocare	Volume reduction may reduce transportation and disposal costs, but at higher treatment costs. Process is in developmental stage.	Y
9D		NTS	Unlikely based on uncertainty of NTS' ability to accept waste.	N

a Conceptualization of treatment and disposal options was made with knowledge of current and future constraints on operation, performance, cost, and implementation time.

b Retained for scoring and ranking based on technical evaluation team discussion and consensus on 8/30/94.

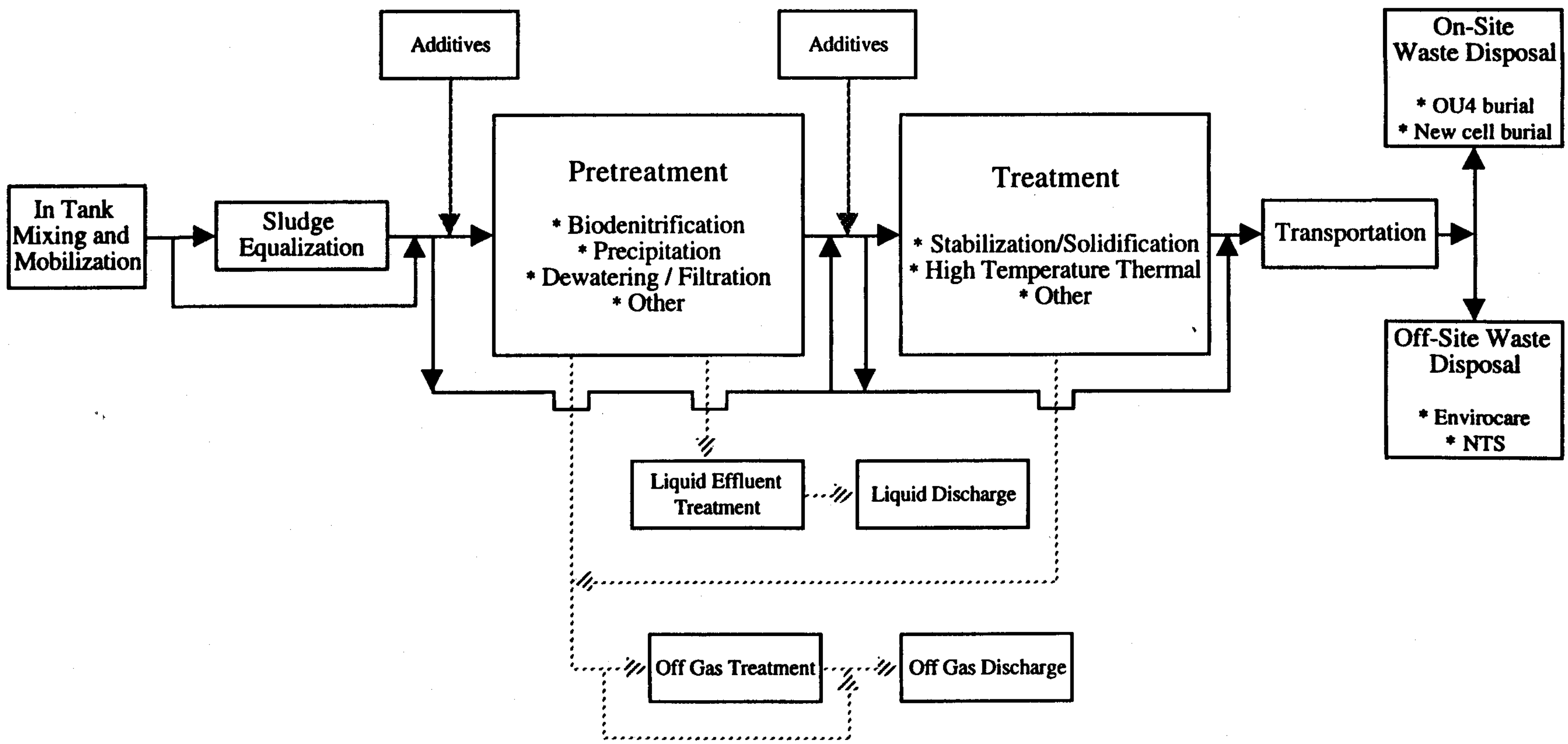

Fig. 4.1. Conceptual sludge management system.

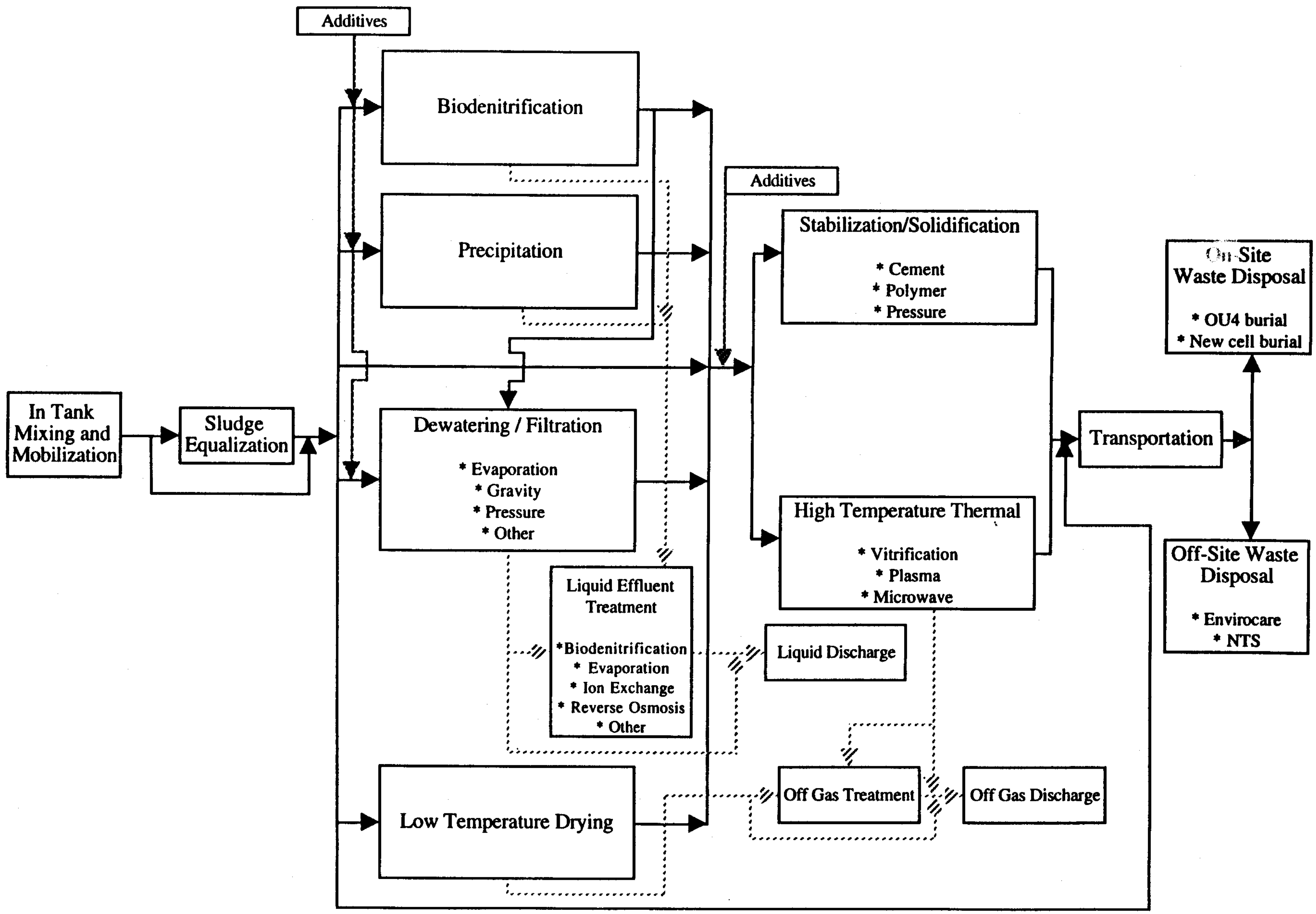

Fig. 4.2. Conceptual sludge treatment system.

Table 4.2. Summary of Candidate Treatment Technologies

Sludge Treatment Technology	Technology Description
Simple stabilization	Minimal treatment by mixing sludges with stabilizers such as flyash or lime to produce a chemically bound waste form.
Cement stabilization/solidification	Mixing of sludge with chemicals and reagents such as cement, flyash, blast furnace slag, polysilicates, and adsorbents to produce a chemically bound solidified waste form.
Biochemical stabilization	Biotreatment of sludges to reduce nitrates followed by minimal treatment by mixing sludges with stabilizers such as flyash or lime to produce a chemically bound waste form. Precipitation may also be used to reduce metals but may require solidification of the precipitate.
Pressure stabilization/solidification	Proprietary process involving the compression of a mixture of flyash and waste to chemically bind and encapsulate the waste into a brick-like waste form.
Biochemical stabilization/solidification	Biotreatment of sludges to reduce the nitrate concentrations prior to mixing of sludge with chemicals and reagents such as cement, flyash, blast furnace slag, polysilicates, and adsorbents to produce a chemically bound solidified waste form.
Polymer stabilization/solidification	Mixing of sludge with molten polyethylene to encapsulate the waste and produce a stabilized waste form.
Vitrification	High-temperature thermal process in which waste and glass forming fluxes are fed into a melter. Nonvolatile components are oxidized and melted into a vitrified waste form.
Microwave melter	High-temperature thermal process in which waste and glass forming fluxes are fed into a melter. Microwave energy is transmitted to produce a vitrified waste form.
Plasma Hearth	High-temperature thermal process in which waste and glass forming fluxes are fed into a melter with thermal plasma used to generate high temperatures. Nonvolatile components are encapsulated in a vitrified waste form.

5.0 SCREENING OF CANDIDATE TECHNOLOGIES

Evaluation and screening of technologies for application to a specific environmental problem must necessarily be based on some form of comparison and selection process. A variety of selection criteria and ranking methods have been developed for this purpose (e.g., Kepner-Tregoe System [Kepner and Tregoe 1973], Technology Evaluation Framework [EG&G 1993b]). The screening method established for this work was intended to identify applicable and feasible treatment and disposal systems and then group them according to their relative advantages across several key attributes, not necessarily to select a specific technology based on a high numerical score. This screening process should thus indicate which treatment and disposal systems appear to provide greater benefits than other competing systems. Based on the outcome of this screening process, a more rigorous selection process, possibly supported by treatability studies, may be necessary and appropriate.

Different technology screening and evaluation methods were considered in developing one specific to this project. The technology screening method used here is a rational process with criteria based on the nine evaluation criteria presented in the National Oil and Hazardous Substances Pollution Contingency Plan and the statutory requirements in CERCLA Section 121. This method and the associated criteria were chosen because they were being used for other environmental restoration IM/IRA projects at OU4 and they encompass broad evaluation areas of concern for sludge treatment and disposal. The comprehensive ranking system developed for use at RFETS, the Technology Evaluation Framework (EG&G 1993b), was considered but not chosen for use in this project. The principal reason for this was that it was not currently being used for OU4 work and the Technology Evaluation Framework was judged to be unduly rigorous for the state of knowledge and input anticipated to be available for evaluation and screening. It is recognized that the technologies identified as feasible and promising for treatment of the containerized sludges may be evaluated further (e.g., by the Technology Evaluation Framework) prior to final selection and implementation of a treatment and disposal system.

An ad hoc technology evaluation team composed of 11 scientists and engineers, representing ORNL, LANL, and EG&G, was established to review and screen applicable treatment and disposal systems (Table 5.1). The individuals involved possess a wide range of professional expertise and project perspectives. The results and conclusions presented in this section of the report are based on this team evaluation and concurrence. It should be noted that complete treatment and disposal systems were evaluated, beginning with sludges in the tanks through final disposition. This approach was agreed to by the team because, at the time of evaluation, the final disposition of the sludges was uncertain and screening of only treatment technologies would not have provided an accurate evaluation of the complete treatment and disposal system (see Section 4.2 for discussion of treatment systems).

5.1 METHODS

5.1.1 Screening Criteria

The waste under study comprises about 750,000 gal. of LLMW removed from the SEPs. The waste was removed from the ponds during the first half of 1994 by a vacuum truck and then immediately placed into 10,000-gal. double-wall polyethylene storage tanks. The composition of the waste in the ponds (and now in the tanks) was quite variable but typically included appreciable concentrations of heavy metals with low levels of organics and radioactive substances in an aqueous matrix with high concentrations of dissolved solids.

For the purposes of this work, process performance criteria were proposed with heavy metals constituting the target parameters. Heavy metals refers to the eight metals regulated by virtue of toxicity characteristic as identified in 40 CFR 261.24, with the addition of nickel based on its waste listing and presence in the sludge. While other potential contaminants are present within the sludge (i.e., nitrates, radionuclides, and organics), heavy metals were selected as targets based on their prevalence in the sludge at concentrations above LDRs (Table 2.4). See Section 2 for a complete listing of contaminants present in sludge, waste listings, and other applicable waste acceptance criteria (Table 2.3).

A treatment technology that yields effective treatment of the sludges should at a minimum result in the following:

1. Reduction or immobilization of heavy metals so that
   a. the CCWE meets LDRs, or
   b. where LDRs are not applicable, contaminant concentrations are below U.S.-stipulated hazardous waste classification levels; and
2. Physical form that meets the waste acceptance criteria as listed in Table 2.3.

It is important to note that at the time of this writing, final disposition of the sludges was not determined by DOE nor approved by state and federal regulators. Possible scenarios include both on-site disposal (e.g., in-place OU4 burial and closure or new RCRA cell) or offsite disposal (e.g., NTS or Envirocare of Utah). Table 2.3 summarizes disposition and final waste form requirements. Regardless of the ultimate disposal scenario, it is envisioned that the sludge will, at a minimum, have to be treated to meet LDRs. The possible exception is on-site disposal under a CAMU permit. Evaluation of waste acceptance criteria as performance criteria is required, but the final waste form is not required to satisfy those for all disposal options (e.g., 28 psi compressive strength for NTS and <10 in. in any dimension for Envirocare of Utah). In other words, each disposal option that can be facilitated through treatment to meet the relevant waste acceptance criteria should be identified, but all waste acceptance criteria do not have to be satisfied. For these reasons, the technology evaluation team agreed to add flexibility of the final waste form to the criteria for evaluation.

If the above basic performance criteria were met, the technologies were then evaluated and screened based on nine criteria presented in the National Oil and Hazardous Substances Pollution Contingency Plan and the statutory requirements in CERCLA Section 121, with the addition of flexibility of the waste form. These criteria are as follows (order of presentation does not reflect priority of the criteria):

1. Overall protection of human health and the environment;
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs);
3. Flexibility of the final waste form;
4. Long-term effectiveness and permanence;
5. Reduction of toxicity, mobility, and volume through treatment;
6. Short-term effectiveness;
7. Implementability;
8. Cost;
9. Regulatory agency acceptance; and
10. Community acceptance.

These screening criteria, as defined below, were used as the basis for evaluation and scoring of treatment and disposal systems by the technology evaluation team. The criteria are defined in a fashion consistent with that in the OU4 IM/IRA (DOE 1994a).

Overall protection of human health and the environment: This criterion concerns the ability of the process to adequately eliminate, reduce, or control the chemical and radiological risks associated with each exposure pathway. The process should be assessed to determine both long- and short-term risks to human health and the environment. Scoring of this criterion is based on the process' ability to isolate the contaminated media in excess of the performance goals so that human health and environmental exposures are minimized or eliminated.

Compliance with ARARs: This criterion relates to the ability of the process to satisfy the requirements specified in the list of ARARs. The process should satisfy or provide grounds for a waiver of all identified ARARs.

Flexibility of the final waste form: Not one of the nine CERCLA criteria, this criterion was added to the list by the technology evaluation team. The ability of the process to produce a final waste form that meets the waste acceptance criteria for multiple disposal options under consideration should be considered.

Long-term effectiveness and permanence: This criterion is based on the anticipated ability of the process to maintain reliable protection of human health and the environment over time, once the IM/IRA objectives are met. The process should provide long-term effectiveness and permanence, and it should have a relatively high certainty of success. Factors to be considered are the magnitude of risk from untreated waste or from treatment residuals of the remedial activities and the adequacy and reliability of controls, such as containment systems and institutional controls, necessary to manage treatment residuals and untreated waste.

Reduction of toxicity, mobility, and volume through treatment: This criterion concerns the anticipated performance of the treatment process. The degree that the process reduces toxicity, mobility, or volume of waste or residuals should be considered.

Short-term effectiveness: This is the time required to achieve the IM/IRA objectives and assess the adverse impacts to human health and the environment that result from implementation of the process. Short-term effectiveness factors to be considered include (1) short-term risks that might be posed to the community during implementation of the process; (2) potential impacts on workers during implementation of the process; (3) potential environmental impacts of the process; (4) the effectiveness and reliability of mitigative measures during implementation; and (5) the time required to achieve protection. In addition, the factors required to be assessed under NEPA should be integrated into this screening criterion. The NEPA assessment criteria include consideration of direct and indirect impacts, unavoidable adverse impacts, irreversible or irretrievable commitment of resources, and cumulative impacts.

Implementability: This criterion is based on the technical and administrative feasibility of the process and the availability of materials and services required to implement the process. The following factors affect the ease of implementing the process: (1) technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology; (2) reliability of the technology; (3) ease of undertaking additional remedial actions (if required); and (4) ability to monitor the effectiveness of the remedy.

Cost: This is the amount of funds required to implement the process. Factors that should be considered are capital costs, both direct and indirect costs, and annual operating and maintenance costs. Cost should not be used to justify selection of a process without regard to higher-priority criteria (e.g., protection of human health and the environment).

Regulatory agency acceptance: This criterion concerns the ability of the process to address concerns raised by the regulatory agencies, including the agency's position and key concerns related to the process and agency comments on implementation of the ARARs or the proposed use of waivers. Although the regulatory agency concerns will not be entirely known during the screening process, these concerns should be considered with past experience and any new information.

Community acceptance: This refers to the public's general response to the process, including community support or opposition to the process. Although the public's concerns will not be entirely known until the public comment period is over, these concerns should be considered with past experience and any new information.

5.1.2 Screening Methodology

A rational method was used to evaluate and rank the candidate treatment and disposal systems to facilitate selection of a technology or a set of technologies. For this purpose, a method that provides a format for developing objectives, listing alternatives, and weighing the alternatives against the objectives and against each other was used (Siegrist et al. 1993). The method is commonly referred to as the Kepner-Tregoe method (Kepner and Tregoe 1973), a general description of which is given below.

The ranking process begins with the assembly of a team of professionals to participate in the evaluation process. The team develops a consensus on the problem and generates a list of objectives. The objectives are divided into those that absolutely have to be met (the performance criteria, or the "musts") and those that are desirable but not necessarily essential or do not provide a clear rejection criterion (the screening criteria, or the "wants"). Next, weighting factors are assigned by the team to the "wants." Finally, the alternatives are scored and ranked individually by team members and the weighting factors are applied to determine the overall relative ranking of each alternative evaluated.

As previously discussed, the evaluation team for this project comprised 11 scientists and engineers, representing ORNL, LANL, and EG&G (Table 5.1). The individuals involved possess a wide range of professional expertise and project perspectives. Several working meetings were held by the team to conduct the screening process.

The first team meeting was held in June 1994 to (1) define the decision statement, (2) define the objectives, and (3) divide the objectives into musts and wants. This was accomplished by issuing to the evaluation team a preliminary version of the decision statement and the objectives. This list of objectives was then divided into those that absolutely had to be met (the performance criteria, or the "musts") and those that are desirable but not necessarily essential or do not provide a clear rejection criterion (the screening criteria, or the "wants"). Comments were requested on the objectives list, and a team meeting was later held to review the comments. Consensus by the team resulted in objectives being divided into "musts" and "wants" as summarized in Table 5.2. The decision statement agreed to for this project is provided below:

Select a treatment process(es) for containerized solar pond sludges for reduction or immobilization of metals such that the constituent concentration in the waste extract meets LDRs; or the constituent concentrations are below U. S. stipulated hazardous waste criteria levels; and such that the final waste form meets waste acceptance criteria. In addition, the selected process(es) should have a high probability of success and be amenable to implementation.

Next, the team members individually ranked each of the wants in accordance with its perceived importance, on a scale of 1 to 10 (1 = lowest, 10 = highest). The central tendency (i.e., average) of the individual team member weights was then used as the weighting factor for each of the wants when the alternatives were later scored.

A list of proposed treatment and disposal systems was then developed as described in Section 4.1. A working team meeting was held to review, discuss, and comment on the alternatives. These alternatives were screened by the team based on professional knowledge and experience and alternatives were retained or rejected for scoring and ranking (Table 4.1).

A working meeting was held and technology description fact sheets and flowsheets were distributed for comment and review. Next the retained alternatives (Table 5.3) were scored and ranked by individual team members. The musts were evaluated first. Only yes/no evaluations were required because the musts are the truly essential objectives and any alternative that failed to meet a must was rejected outright. Alternatives that met all of the musts were carried on and evaluated against the wants.

Because the wants are items that do not provide clear rejection criteria, alternatives meeting all of the musts were rated for each want using a scale of 1 to 10. The individual team member scores were compiled into an average team score, and these values were then multiplied by the weighting factor of each want to create a matrix of ratings. The sum of all ratings for each alternative was then obtained, forming the basis for a numerical comparison of the candidate systems. Nonparametric statistical tests were performed to determine if there were significant differences within the overall scoring of the systems.

The alternative(s) with the highest score(s) was identified as the one(s) that met all required objectives (i.e., musts) and met the other desired objectives (i.e., wants) to the greatest extent. The ratings matrix documents the strengths and weaknesses of each of the alternatives (see Appendix G for individual treatment and disposal system rating matrices). The documented matrix forms a structure for others to comment on the decision-making process.

5.2 RESULTS AND DISCUSSION

The results of the screening and evaluation of the treatment and disposal systems are presented in this section. Treatment and disposal systems retained for team scoring and ranking are listed in Table 5.3. (See Appendix F for associated technology description sheets and flowsheets used during scoring and ranking.) Discussion on the selection of treatment systems evaluated is presented in Section 4.1.

The final weights assigned to each of the ten technology wants were analyzed to determine the central tendency and deviation (Table 5.4, Fig. 5.1). As summarized in Table 5.4 and illustrated in Fig. 5.1, there was a wide variation in the weights assigned to the different wants, although values tended to cluster around an average value for each want. The greatest average weight (9.6) and the least variation were for want No. 1, overall protection of health and the environment. This is not surprising as this want encompasses the fundamental goal of environmental restoration. In contrast, the lowest weight and the most variation were for want No. 6, short-term effectiveness, and this was attributed to the most varied perception by individual team members.

It was recognized by the team that the wants as defined for this project were broad and qualitative, which resulted in crossover between wants when weighting factors were assigned. Additionally, it was noted that want No. 2, compliance with ARARs, and want No. 9, regulatory agency acceptance, appear to be similar but were weighted very differently. Differentiation between the two wants was attributed to required regulations versus regulator biases. Although a weighting factor was assigned to want No. 8, cost, the information available was limited (e.g., capital costs were provided in some cases and lacking in others). It was agreed by the team that the scoring for this want would be on a high, medium, or low basis relative to the other treatment processes. High cost effectiveness (i.e., low overall process cost) would be assigned a high score of 8, medium cost effectiveness a medium score of 5, and low cost effectiveness a low score of 2.

Each of the 11 evaluation team members scored each of the treatment and disposal systems listed in Table 5.3 in each of the criteria areas or wants. The results of this process are summarized in Table 5.5 and Figs. 5.2 and 5.3. Detailed scoring sheets as well as comments provided by team members are included in Appendix G.

As indicated in Table 5.5, the treatment and disposal systems were ranked such that there were three different groupings.

The top-ranked system was

- cement stabilization/solidification.

The middle-ranked systems were

- simple stabilization,
- biochemical stabilization,
- biodenitrification followed by cement stabilization/solidification,
- pressure stabilization/solidification, and
- polymer stabilization/solidification.

The lower-ranked systems were

- vitrification,
- microwave stabilization/solidification, and
- plasma hearth stabilization/solidification.

Because treatment and disposal *systems* were evaluated, each treatment technology was evaluated with different likely disposition options. In contrast to the treatment technologies, there were no clear trends indicating a strong preference for one disposal option over another.

Nonparametric statistical tests were performed to determine if there were significant differences within the overall scoring of the 22 treatment and disposal systems. Both the Quade and the Friedman tests were performed (Conover 1981). Both tests are appropriate for cases of several related samples (i.e., experiments that are designed in blocks to detect differences in different treatments). The tests are typically called randomized complete block designs, where the "block" is an individual scorer and the "treatment" is the different treatment processes. The Quade test is a nonparametric method that depends only on the ranks of the observations within each block and the ranks of the block to block sample ranges and may therefore be considered a two-way analysis of variance on ranks. The Friedman test is an extension of the sign test and has been found to be more powerful than the Quade test if the number of treatments is greater than five (Conover 1981). Both tests have the following assumptions: (1) the weighting factors are constants and independent of the scoring, (2) the random variables are mutually independent (the results within one block do not influence the results within the other blocks), (3) within each block the observations may be ranked according to some criterion of interest, and (4) the sample range may be determined with each block so that the blocks may be ranked. Although some of the above assumptions may be questionable for these data sets, the test results are helpful as a preliminary step in ranking the different treatment and disposal systems. Both tests are valid even if there are many ties in the rankings.

The results of the statistical analysis revealed that the different systems could be differentiated into the three groupings as given above (Tables 5.6 and 5.7, Appendix H). Cement S/S was scored the highest of the various systems considered, and this top ranking was statistically significant. The systems included in the middle-ranked grouping were significantly different than those in the top- and lower-ranked groupings, but they were not statistically different among themselves (i.e., simple stabilization does not differ significantly from biochemical stabilization, which does not differ significantly from biodenitrification followed by cement S/S, which does not differ significantly from pressure S/S, which does not differ significantly from polymer S/S). The lower-ranked systems (i.e., vitrification, microwave S/S, and plasma hearth S/S) were statistically different from the top- and middle-ranked systems.

Table 5.1 Team Members for Evaluation and Ranking of Candidate Technologies for Treatment and Disposal of the Containerized Solar Pond Sludges

Team Member	Affiliation
K. Dickerson (team leader)	Health Sciences Research Division, ORNL
R. Siegrist	Environmental Sciences Division, ORNL
M. Morris	Chemical Technology Division, ORNL
C. Brown	Chemical Technology Division, ORNL
D. Moody	Chemical Science & Technology Division, LANL
L. Collins	Solar Ponds Remediation Program, EG&G
M. Prochazka	Solar Ponds Remediation Program, EG&G
K. London	Solar Pond Projects Regulatory Systems, EG&G
E. Garcia	Technology Development, EG&G
N. Candido	Industrial Hygiene, EG&G
D. Norton	Radiological Engineering, EG&G

Table 5.2 Summary of Decision Framework Used in Evaluating Candidate Technologies for Containerized Solar Pond Sludge Treatment

Decision Framework for Technology Evaluation and Screening

Objectives:

1. Reduce or immobilize metals to meet LDRs
2. Produce a final waste form that meets waste acceptance criteria for disposal
3. Protect worker health and the environment
4. Meet all applicable site, EG&G, DOE, and regulatory requirements
5. Provide reliable protection to human health and the environment over time
6. Maximize treatment performance and minimize secondary waste streams
7. Minimize human health and environmental impacts during treatment implementation
8. Minimize time and efforts for implementation of treatment
9. Minimize costs: equipment installation, processing, and decommissioning
10. Address regulatory concerns
11. Address public concerns

Musts:

1. Reduction or immobilization of metals such that the CCWE meets LDRs or, where LDRs are not applicable, the constituent concentrations are below U. S. stipulated hazardous waste criteria levels
2. Physical form that meets waste acceptance criteria
3. Treatment process must control and contain radioactive substances in accordance with ALARA

Wants:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Flexibility of final waste form to meet waste acceptance criteria
4. Long-term effectiveness and permanence
5. Reduction of toxicity, mobility, and volume through treatment
6. Short-term effectiveness
7. Implementability
8. Cost effective
9. Regulatory agency acceptance
10. Community acceptance

Table 5.3 Revised List of Candidate Treatment Technologies for Scoring and Ranking for Containerized Solar Pond Sludge[a]

Treatment System Number	Treatment and Disposal Components
1A	Simple physical/chemical stabilization and on-site disposal, OU4 burial
2A	Cement stabilization/solidification and on-site disposal, OU4 burial
2B	Cement stabilization/solidification and on-site disposal, New cell burial
2C	Cement stabilization/solidification and off-site disposal, Envirocare
3A	Biochemical stabilization and on-site disposal, OU4 burial
3B	Biochemical stabilization and on-site disposal, New cell burial
3C	Biochemical stabilization and off-site disposal, Envirocare
4A	Pressure stabilization/solidification and on-site disposal, OU4 burial
4B	Pressure stabilization/solidification and on-site disposal, New cell burial
4C	Pressure stabilization/solidification and off-site disposal, Envirocare
5A	Biochemical stabilization/solidification and on-site disposal, OU4 burial
5B	Biochemical stabilization/solidification and on-site disposal, New cell burial
5C	Biochemical stabilization/solidification and off-site disposal, Envirocare
6A	Polymer stabilization/solidification and on-site disposal, OU4 burial
6B	Polymer stabilization/solidification and on-site disposal, New cell burial
6C	Polymer stabilization/solidification and off-site disposal, Envirocare
7A	Vitrification stabilization/solidification and on-site disposal, New cell burial
7B	Vitrification stabilization/solidification and off-site disposal, Envirocare
8A	Microwave stabilization/solidification and on-site disposal, New cell burial
8B	Microwave stabilization/solidification and off-site disposal, Envirocare
9A	Plasma Hearth stabilization/solidification and on-site disposal, New cell burial
9B	Plasma Hearth stabilization/solidification and off-site disposal, Envirocare

[a] See Appendix F for associated technology description fact sheets and flowsheets.

Table 5.4 Summary of Weighting Factors Used for Each Technology "Want"

Technology "Want"	"Want" Weighting Factor Statistics[a]				
	No.	Average	Std. Dev.	Coef.Var.	Range
1. Overall protection of human health and the environment	11	9.64	0.81	0.08	8 to 10
2. Compliance with ARARs	11	7.55	1.75	0.23	5 to 10
3. Flexibility of final waste form	11	6.27	2.41	0.38	3 to 10
4. Long-term effectiveness and permanence	11	7.27	1.85	0.25	4 to 10
5. Reduction of toxicity, mobility, and volume through treatment	11	8.00	1.67	0.21	5 to 10
6. Short-term effectiveness	11	5.27	3.20	0.61	1 to 10
7. Implementability	11	9.09	1.30	0.14	6 to 10
8. Cost effectiveness	11	6.55	1.44	0.22	4 to 9
9. Regulatory agency acceptance	11	6.18	2.09	0.34	3 to 10
10. Community acceptance	11	6.18	2.18	0.35	3 to 10

[a] See Fig. 5.1 for graphical illustration of data. See Appendix G for further details.

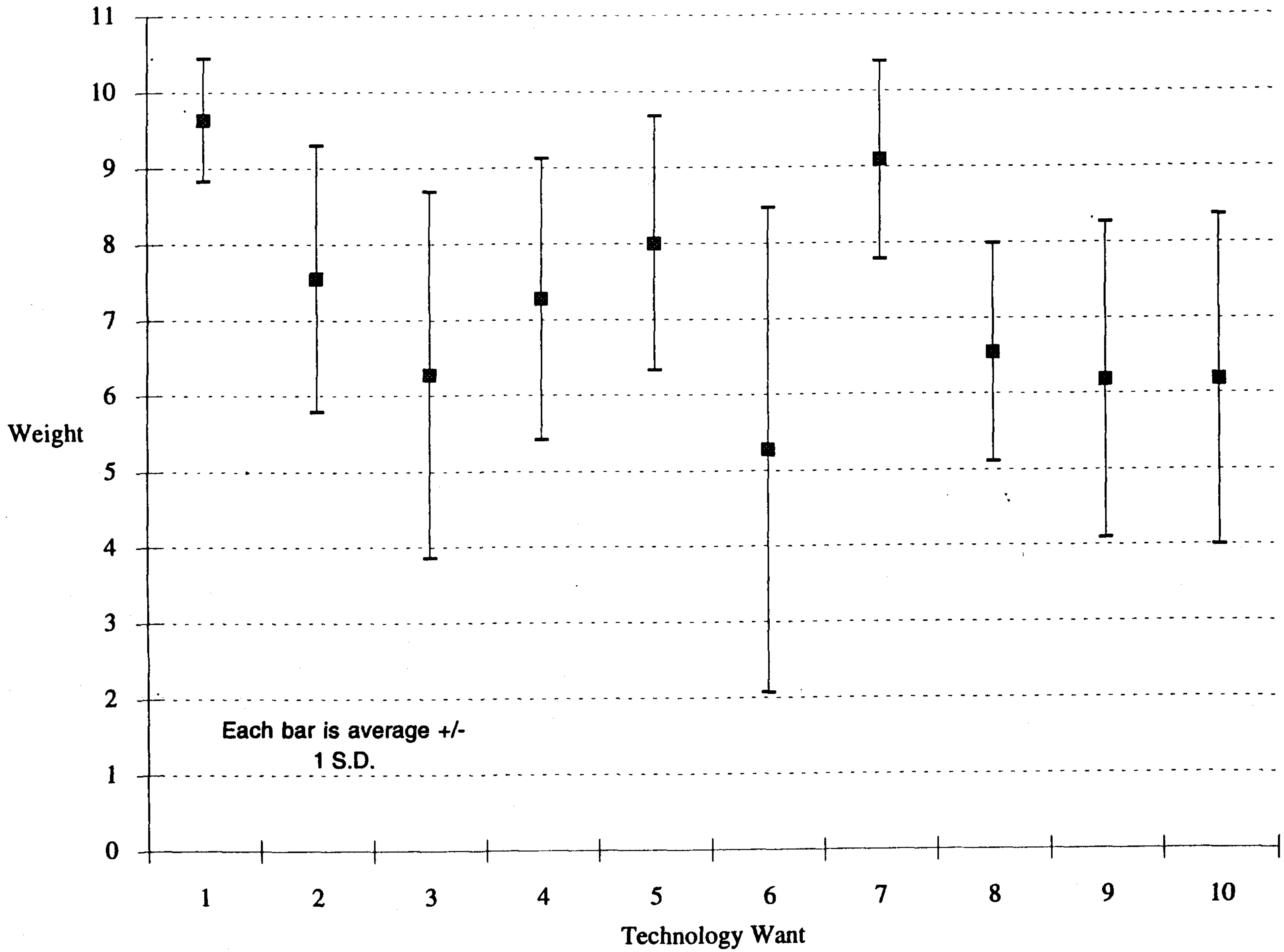

Fig. 5.1. Graphical illustration of weighting factors.

Table 5.5 Summary of Solar Ponds Kepner-Tregoe Analysis[a]

System	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total Score	Rank
System 1 - Simple Stabilization												
Weighted score	65.4	66.1	44.1	45.1	43.6	47.7	87.7	49.6	40.6	29.9	519.9	5
System 2A - Cement S/S, OU4 burial												
Weighted score	81.2	69.5	50.4	61.0	58.9	44.8	76.9	42.5	50.7	42.8	578.9	2
System 2B - Cement S/S, New cell												
Weighted score	86.4	66.1	53.3	62.4	58.9	42.9	75.3	41.4	50.2	44.5	581.3	1
System 2C - Cement S/S, Envirocare												
Weighted score	79.4	64.8	50.4	59.1	58.2	43.8	76.1	34.3	52.4	50.2	568.6	3
System 3A - Biochemical Stabilization, OU4 burial												
Weighted score	67.2	62.7	47.5	53.8	56.7	42.9	63.7	38.4	40.6	32.7	506.2	8
System 3B - Biochemical Stabilization, New cell												
Weighted score	72.4	52.5	44.1	54.4	58.2	40.0	64.5	37.8	37.2	34.4	495.6	12
System 3C - Biochemical Stabilization, Envirocare												
Weighted score	67.2	52.5	43.0	53.8	56.0	41.0	63.7	30.7	38.3	40.0	486.1	14
System 4A - Pressure S/S, OU4 burial												
Weighted score	68.1	60.7	41.2	51.8	54.5	39.0	53.8	34.3	39.4	37.8	480.6	15
System 4B - Pressure S/S, New cell												
Weighted score	74.2	62.0	47.0	53.8	56.0	38.5	54.6	36.0	36.6	39.4	498.2	11
System 4C - Pressure S/S, Envirocare												
Weighted score	69.8	60.7	41.8	47.8	52.4	36.1	52.9	32.5	39.4	43.4	476.9	16
System 5A - Biochemical S/S, OU4 burial												
Weighted score	75.0	64.1	45.2	55.7	58.2	41.0	57.9	37.2	44.0	34.9	513.3	7
System 5B - Biochemical S/S, New cell												
Weighted score	79.4	62.0	48.1	57.7	58.2	39.0	59.6	35.4	44.5	39.4	523.5	4
System 5C - Biochemical S/S, Envirocare												
Weighted score	75.1	62.0	46.4	56.4	58.2	40.0	61.2	30.1	46.2	44.0	519.6	6
System 6A - Polymer S/S, OU4 burial												
Weighted score	70.7	63.4	52.7	60.4	58.2	35.2	49.6	25.4	40.0	38.3	493.9	13
System 6B - Polymer S/S, New cell												
Weighted score	75.1	63.4	53.3	60.4	58.2	33.2	50.5	26.0	40.0	41.7	501.7	10
System 6C - Polymer S/S, Envirocare												
Weighted score	73.3	63.4	55.0	59.7	58.2	34.7	50.5	22.4	40.6	45.1	502.9	9

[a] See Fig. 5.2 for graphical illustration of data.

Table 5.5 Summary of Solar Ponds Kepner-Tregoe Analysis (*continued*)[a]

	Wants Criteria											
System	1	2	3	4	5	6	7	8	9	10	Total Score	Rank
System 7A - Vitrification, New cell												
Weighted score	73.3	57.3	39.5	57.7	66.9	24.6	22.3	13.0	27.6	27.6	409.9	19
System 7B - Vitrification, Envirocare												
Weighted score	70.7	57.3	38.4	56.4	65.4	25.1	23.2	11.8	28.7	28.7	405.2	20
System 8A - Microwave, New cell												
Weighted score	77.6	61.4	43.5	61.1	68.4	24.6	33.1	13.0	35.5	37.8	455.9	17
System 8B - Microwave, Envirocare												
Weighted score	75.1	61.4	40.1	59.7	66.9	25.1	33.9	11.8	36.1	39.4	449.5	18
System 9A - Plasma Hearth, New cell												
Weighted score	62.8	56.6	33.8	55.7	64.0	16.9	15.7	13.0	23.1	20.8	362.5	21
System 9B - Plasma Hearth, Envirocare												
Weighted score	60.2	56.6	33.8	55.1	63.3	16.4	16.5	11.8	23.7	22.0	359.3	22

[a] See Fig. 5.2 for graphical illustration of data.

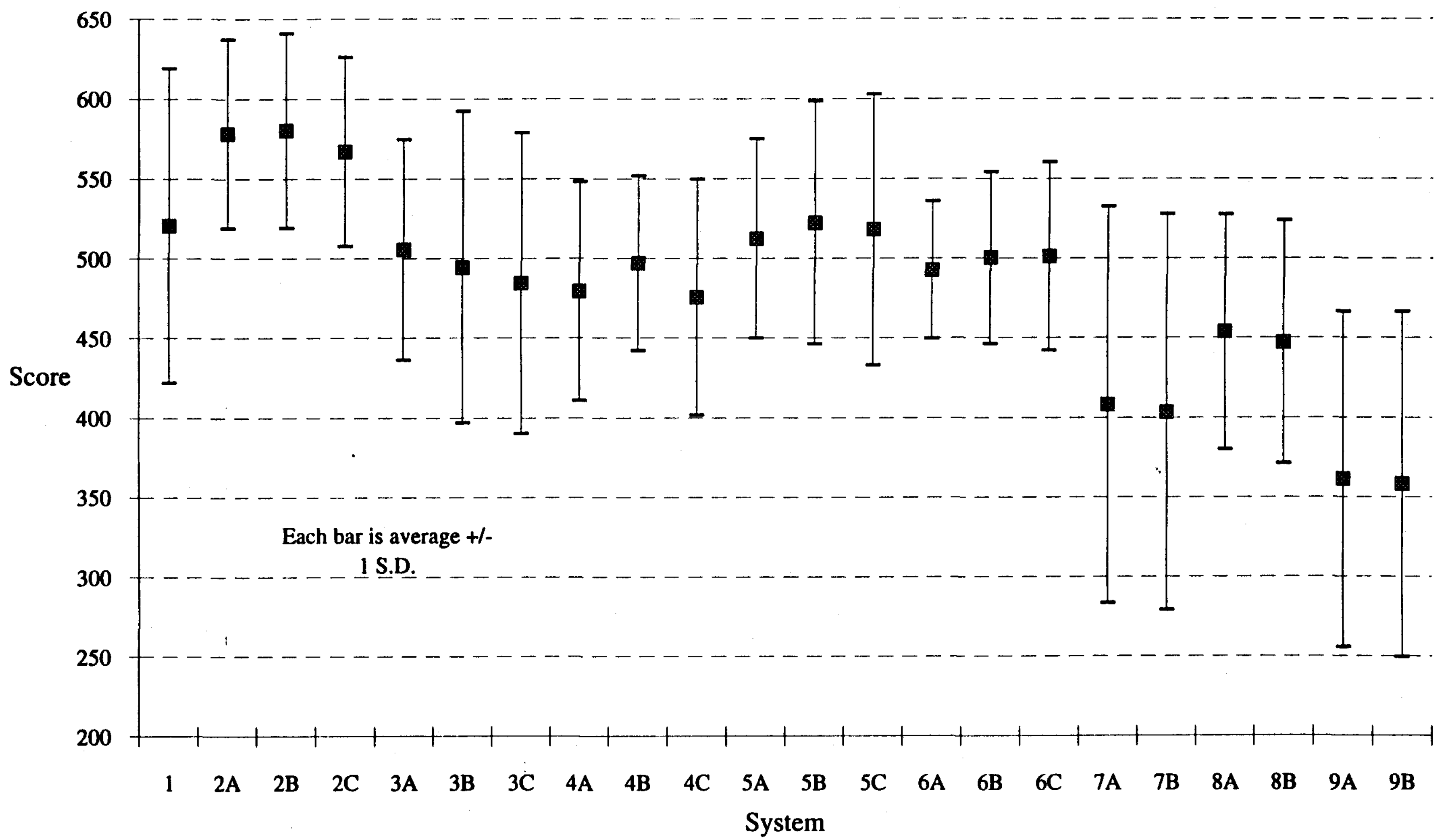

Fig. 5.2. Illustration of relative scores.

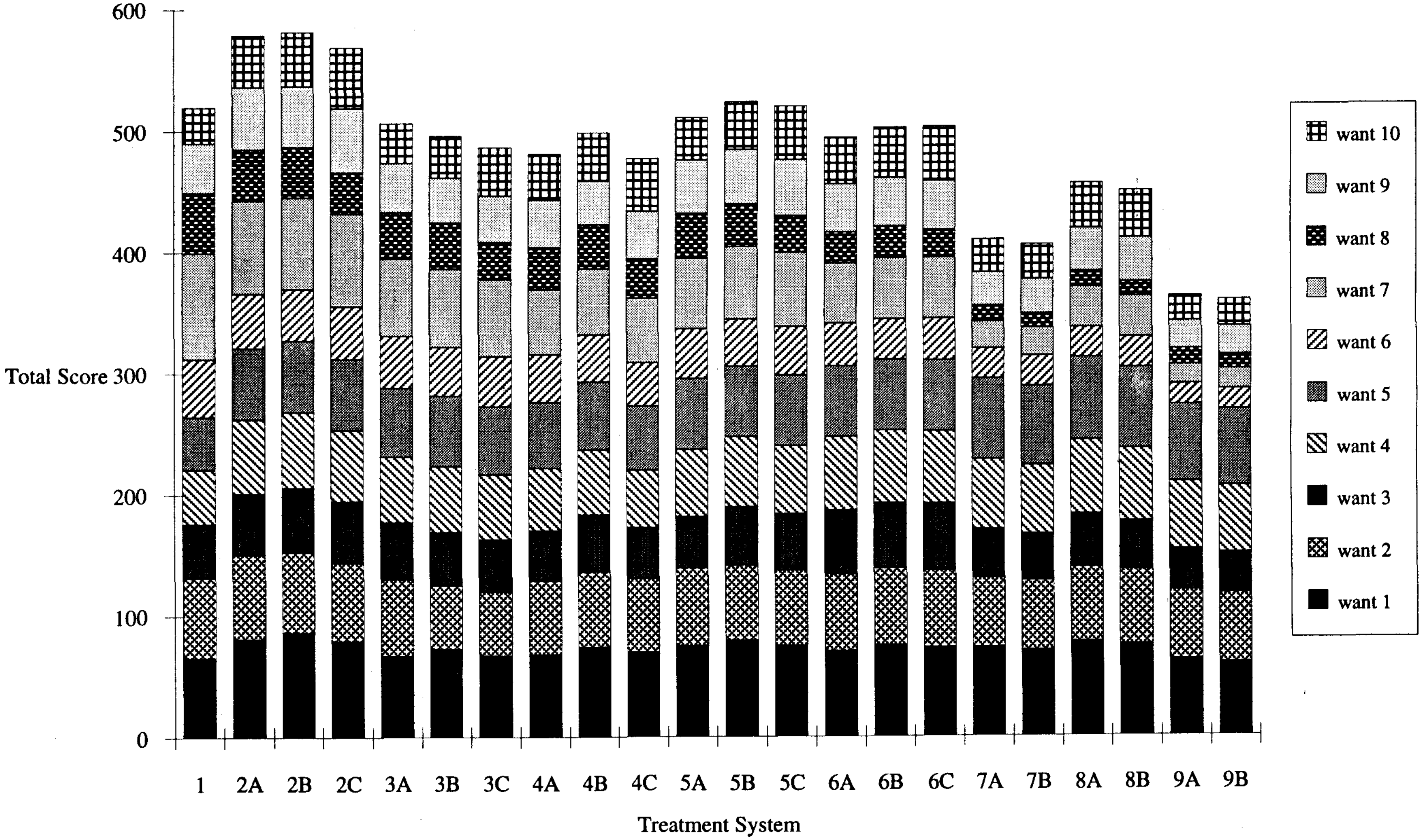

Fig. 5.3. Graphical illustration of Kepner-Tregoe analysis.

Table 5.6 Summary of Quade Multiple Comparison Test Results[a]

	Treatment System																					
	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
1		1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1	2	3	3
2A			0	0	0	1	2	3	2	3	2	0	1	3	2	2	3	3	3	3	3	3
2B				0	1	1	2	3	2	3	2	1	2	3	2	2	3	3	3	3	3	3
2C					1	1	2	3	2	3	2	0	1	3	2	2	3	3	3	3	3	3
3A						0	0	0	0	0	0	0	0	0	0	0	2	3	2	2	3	3
3B							0	0	0	0	0	0	0	0	0	0	2	3	1	2	3	3
3C								0	0	0	0	0	0	0	0	0	2	2	0	0	3	3
4A									0	0	0	0	0	0	0	0	0	1	0	0	2	3
4B										0	0	0	0	0	0	0	1	2	0	0	3	3
4C											0	0	0	0	0	0	0	0	0	0	2	2
5A												0	0	0	0	0	2	2	0	0	3	3
5B													0	0	0	0	3	3	2	2	3	3
5C														0	0	0	2	3	1	1	3	3
6A															0	0	0	1	0	0	3	3
6B																0	1	2	0	0	3	3
6C																	2	2	0	1	3	3
7A																		0	0	0	0	0
7B																			0	0	0	0
8A																				0	1	1
8B																					1	1
9A																						0
9B																						

[a] Intermediate results are presented in Appendix H. Number in matrix cell indicates significant level of differences between two treatment systems.

- 0 = significant at p values where $p > 0.1$ (i.e., up to 90% confidence that treatment processes are significantly different)
- 1 = significant where $0.05 < p < 0.1$ (i.e., 90% to 95% confidence that treatment processes are significantly different)
- 2 = significant where $0.01 < p < 0.05$ (i.e., 95% to 99% confidence that treatment processes are significantly different)
- 3 = significant where $p < 0.01$ (i.e., greater than 99% confidence that treatment processes are significantly different)

Table 5.7 Summary of Friedman Multiple Comparison Test Results[a]

	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
1		2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	2	3	3
2A			0	0	1	2	3	3	2	3	2	2	2	3	3	3	3	3	3	3	3	3
2B				0	2	2	3	3	2	3	2	2	2	3	3	3	3	3	3	3	3	3
2C					1	2	3	2	2	3	2	1	2	3	3	3	3	3	3	3	3	3
3A						0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	3	3
3B							0	0	0	0	0	0	0	0	0	0	1	2	1	2	3	3
3C								0	0	0	0	0	0	0	0	0	0	1	0	0	3	3
4A									0	0	0	0	0	0	0	0	0	1	0	1	3	3
4B										0	0	0	0	0	0	0	0	2	0	1	3	3
4C											0	0	0	0	0	0	0	0	0	0	3	3
5A												0	0	0	0	0	0	2	0	1	3	3
5B													0	0	0	0	1	2	1	2	3	3
5C														0	0	0	1	2	1	2	3	3
6A															0	0	0	0	0	0	3	3
6B																0	0	0	0	0	3	3
6C																	0	1	0	0	3	3
7A																		0	0	0	2	2
7B																			0	0	0	1
8A																				0	2	2
8B																					1	1
9A																						0
9B																						

[a] Intermediate results are presented in Appendix H. Number in matrix cell indicates significant level of differences between two treatment systems.

0 = significant at p values where $p > 0.1$ (i.e. up to 90% confidence that treatment processes are significantly different)

1 = significant where $0.05 < p < 0.1$ (i.e. 90% to 95% confidence that treatment processes are significantly different)

2 = significant where $0.01 < p < 0.05$ (i.e. 95% to 99% confidence that treatment processes are significantly different

3 = significant where $p < 0.01$ (i.e. greater than 99% confidence that treatment processes are significantly different

6. SUMMARY AND CONCLUSIONS

During 1994, a study was conducted by national laboratory staff affiliated with the Los Alamos Technology Office at Rocky Flats to identify, evaluate, and screen options for treatment and disposal of containerized sludges that had been recently removed from a series of solar evaporation ponds (OU4) at the DOE RFETS. The work was requested and supported by DOE/RFFO and intended to be an independent review and analysis that DOE could use in selecting and implementing an appropriate sludge treatment and disposal strategy. Completion of this work was therefore unconstrained in that a range of options could be considered, not just those that had been pursued to date. However, the work was appropriately focused so that the results would be consistent with the overall closure strategy and current waste management options available and feasible for RFETS.

The following principal work elements were conducted: (1) problem definition, including compilation of available sludge characterization information and treatment and disposal criteria; (2) computerized and manual searches of databases and open-literature sources for potentially viable sludge treatment and disposal systems; (3) a survey of sites with experience in treatment and disposal of sludges similar to those of OU4; (4) a survey of environmental technology industries (both developers and providers) to identify commercially available options; and (5) organization and coordination of an interdisciplinary, multi-institutional team to review, discuss, and rank each candidate treatment and disposal system. Based on the results of this work, the following conclusions were drawn:

- The solar pond sludges may be categorized into two distinct waste streams: a mineral sludge removed from ponds 207A and 207B and a chemical brine sludge removed from ponds 207C. The concentrations of solutes and particulates, including potential heavy metal, radionuclide, and salt contaminants, vary markedly between the two sludges, and this may affect overall treatment and disposal options.

- The sludge from both pond systems is classified as a low-level mixed waste. This classification is due to concentrations of various radionuclides (e.g., ^{235}U, ^{241}Am) and heavy metals (e.g., Cd, Ni).

- While there is a great deal of characterization data for the pond sludges, uncertainty exists about the character and composition of the current containerized sludges because of the transfer and mixing that occurred after completion of the existing sampling and analysis events upon which available characterization data are based.

- Sludges similar to those from solar evaporation ponds are typically treated prior to ultimate disposal. Based on practices to date across the DOE Complex and industrial facilities in general, S/S using cement-based processes is the most common strategy for sludge treatment.

- Numerous environmental technology firms claimed capability to treat the solar pond sludges such that the final waste form would meet land disposal restrictions. Vendors proposed various treatment schemes, which mainly use physical/chemical stabilization and solidification processes. Almost all vendors stated that some focused treatability studies would be required in order to select, design, and implement a full-scale sludge treatment process.

- Disposal of treated sludges includes both on-site and off-site options. While on-site options are increasingly being pursued due to stringent off-site disposal requirements and high costs, 75% of the DOE sites queried are still using or pursuing off-site disposal.

- A new regulatory approach involving corrective action management units, or CAMUs, was promulgated at the federal level by EPA in 1993 and at the state level by CDPHE during 1994 and offers potential for disposition of sludges back into the site of OU4 with far less stringent restrictions concerning waste form and composition. However, securing a CAMU permit in Colorado and actually implementing such a sludge treatment and disposal option are seemingly uncertain as there have been very few CAMU permits issued in the U.S. and none in Colorado. An attempt by Hanford to gain a CAMU permit was denied.

- Numerous sludge treatment processes were identified that had potential application to the solar pond sludges. All involved some form of stabilization, in some cases with pre-treatment and/or with solidification. The candidate processes included simple stabilization, cement S/S, biochemical stabilization, pressure S/S, biodenitrification with cement S/S, polymer S/S, vitrification S/S, microwave S/S, and plasma hearth S/S. Disposal options included on-site burial in OU4 or in a new disposal cell and off-site disposal at Envirocare of Utah, Inc.

- A total of 22 candidate treatment and disposal options were evaluated and screened by an ad hoc technology evaluation team of 11 scientists and engineers from ORNL, LANL, and EG&G/RF. This team included representatives intimately familiar with the DOE RFETS and representing diverse disciplines including environmental sciences, environmental and chemical engineering, radiological engineering, project engineering, industrial hygiene, and environmental regulations. Using a rational scoring and ranking process, the different treatment and disposal options were evaluated and screened. Of the systems considered, the one that ranked highest as the preferred alternative included sludge treatment by stabilization/solidification (cement-based process) with on-site disposal in OU4 or a new cell.

- The results of this study need to be reviewed and integrated with other past, present, and future activities related to solar pond sludge treatment and disposal. Prior to selection, design, and implementation of any treatment and disposal option for the containerized solar pond sludges, additional testing and treatability studies are necessary and appropriate.

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<u>8. APPENDICES</u>

Appendix A - Site Characterization Data

Appendix A: Site Characterization Data

The following tables summarize data from the May 1991 and August 1991 sludge and water sampling events conducted by Weston and Halliburton NUS respectively. Only values above the detection limits are included on the tables. A brief summary of the sampling procedures follows. Complete descriptions of the sampling events can be found in "Summary of R. F. Weston's Sampling and Analysis of Solar Pond Water and Sludge Report" (Dames and Moore 1991) and "Pond Sludge Waste Characterization Report and Clarifier Sludge Waste Characterization Report" (Halliburton 1992b).

Weston performed sampling of sludges and pond water separately (Dames and Moore 1991). Water samples were collected using a teflon dipper while a stainless steel dredge was used for sludge sampling. Particle size distributions were also reported by Weston.

Halliburton NUS (1992b) also performed sampling of sludges and pond water separately. Water samples were collected in stainless steel buckets prior to sludge sampling in an attempt to reduce sediments in the water. Sludge samples were collected using a coliwasa sampler which collects a sludge core. A change in sludge sampling procedures occurred around the 15th to 19th of August. At that time sludge samples were collected as dredge samples, which are expected to have a greater volume of water present, compared to cores. Field notes taken during sampling indicate that samples for chemical parameters were sampled in August 1991 while geotechnical samples were collected in a separate sampling event in September 1991.

Pond 207A Water[a] — Individual Pond Water Composition

Analyte	units	Detection Frequency	Concentration
Pesticides			
Atrazine	µg/L	1/4	3.5
Inorganics			
Arsenic	µg/L	3/4	188-224
Barium	µg/L	3/4	135-141
Boron	µg/L	4/4	1260-1460
Cadmium	µg/L	1/4	5
Calcium	µg/L	1/4	60,400
Chromium	µg/L	3/4	38-49
Lead	µg/L	1/4	3.9
Lithium	µg/L	1/1	1420
Magnesium	µg/L	4/4	120,000-124,000
Potassium	µg/L	4/4	376,000-397,000
Selenium	µg/L	1/4	14.9
Silicon	µg/L	1/1	846
Sodium	mg/L	4/4	1610-1870
Strontium	µg/L	1/1	2350
Zinc	µg/L	1/1	27.5
TCLP			
Arsenic	µg/L	3/3	233-246
Silver	µg/L	1/3	6
Miscellaneous			
Gross Alpha	pCi/L	4/4	300-790
Gross Beta	pCi/L	4/4	930-1000
Americium-241	pCi/L	1/1	0.42
Plutonium-239	pCi/L	1/1	0.71
Uranium-234	pCi/L	1/1	310
Uranium-235	pCi/L	1/1	11
Uranium-238	pCi/L	1/1	340
pH	units	4/4	9.6-9.9
Alkalinity (methyl orange)	mg/L	4/4	110-250
Alkalinity (phenolphthalein)	mg/L	3/3	84-89
Ammonia	mg/L	4/4	0.3-0.43
Bicarbonate	mg/L	1/1	35
Carbonate	mg/L	1/1	47
Chloride	mg/L	4/4	380-430
Conductivity at 25C	µmhos	1/1	8800
Cyanide - Total	mg/L	4/4	0.39-0.478
Nitrate	mg/L	3/3	970-1000
Nitrate as N	mg/L	1/1	1000
Nitrite	mg/L	1/1	39
Phosphorus (total as P)	mg/L	3/3	0.06-0.07
Specific gravity	none	3/3	1.010-1.012
Sulfate	mg/L	4/4	409-510
Total Organic Carbon	mg/L	4/4	68-70
Total Dissolved Solids	mg/L	4/4	7600-7900
Total Suspended Solids	mg/L	4/4	14-23

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207B–North Water[a] — Individual Pond Water Composition

Analyte	units	Detection Frequency	Concentration Range
Pesticides			
Atrazine	µg/L	1/6	1.1
Inorganics			
Arsenic	µg/L	3/5	60-63
Barium	µg/L	4/5	117-120
Boron	µg/L	5/5	149-173
Calcium	µg/L	5/5	137,000-189,000
Chromium	µg/L	2/5	10-16
Lithium	µg/L	1/1	332
Magnesium	µg/L	5/5	64,800-79,300
Potassium	µg/L	5/5	55,700-58,800
Selenium	µg/L	2/5	8.2-76
Silicon	µg/L	1/5	1020
Sodium	µg/L	5/5	254,000-403,000
Strontium	µg/L	1/1	2220
Zinc	µg/L	1/1	47.9
TCLP			
Barium	µg/L	4/4	215-230
Chromium	µg/L	1/4	16
Miscellaneous			
Gross Alpha	pCi/L	5/5	40-59
Gross Beta	pCi/L	5/5	75-510
Americium-241	pCi/L	1/1	0.14
Uranium-234	pCi/L	1/1	40
Uranium-235	pCi/L	1/1	1.7
Uranium-238	pCi/L	1/1	26
pH	units	5/5	8.3-8.5
Alkalinity (methyl orange)	mg/L	5/5	75-110
Alkalinity (phenolphthalein)	mg/L	3/4	2-3
Ammonia	mg/L	4/5	0.3-0.5
Chloride	mg/L	5/5	96-147
Conductivity at 25C	µmhos	1/1	3380
Cyanide, total	mg/L	5/5	0.016-0.043
Nitrate	mg/L	4/4	310-330
Nitrate as N	mg/L	1/1	39
Phosphorus (total as P)	mg/L	4/4	0.02-0.08
Phosphate, total	mg/kg	1/1	0.04
Specific gravity		4/4	1.008
Sulfate	mg/L	5/5	120-160
Total Dissolved Solids	mg/L	5/5	2700-3200
Total Organic Carbon	mg/L	5/5	7.6-37
Total Suspended Solids	mg/L	2/5	15-18

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207B–Center Water[a] — Individual Pond Water Composition

Analyte	Units	Detection Frequency	Concentration Range
Pesticides			
Atrazine	µg/L	1/6	9
Inorganics			
Arsenic	µg/L	5/5	13.8-330
Barium	µg/L	4/5	68-70
Boron	µg/L	5/5	2770-3530
Calcium	µg/L	5/5	22,600-27,700
Chromium	µg/L	5/5	22-93.8
Copper	µg/L	1/1	34.8
Lithium	µg/L	1/1	2600
Magnesium	µg/L	5/5	181,000-220,000
Nickel	µg/L	4/5	28-31
Potassium	µg/L	5/5	729,000-807,000
Selenium	µg/L	1/5	81
Silicon	µg/L	1/1	1410
Sodium	mg/L	5/5	2060-4060
Strontium	µg/L	1/1	2130
Tin	µg/L	1/1	109
TCLP			
Arsenic	µg/L	4/4	180-251
Barium	µg/L	2/4	214-258
Cadmium	µg/L	1/4	5
Chromium	µg/L	3/4	20-27
Nickel	µg/L	3/4	21-30
Miscellaneous			
Gross Alpha	pCi/L	5/5	1800-2400
Gross Beta	pCi/L	5/5	2700-3900
Americium-241	pCi/L	1/1	5.5
Plutonium-239	pCi/L	1/1	0.36
Uranium-234	pCi/L	1/1	780
Uranium-235	pCi/L	1/1	36
Uranium-238	pCi/L	1/1	900
pH	units	5/5	9.1-9.2
Alkalinity (methyl orange)	mg/L	5/5	1000-1400
Alkalinity (phenolphthalein)	mg/L	4/4	230-240
Ammonia	mg/L	5/5	0.2-0.5
Carbonate	mg/L	1/1	280
Chloride	mg/L	1/5	763
Conductivity at 25C	µmhos	1/1	1350
Cyanide - Total	mg/L	5/5	0.34-0.57
Fluoride	mg/L	1/1	73

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207B–Center Water (cont.)[a]

Analyte	Units	Detection Frequency	Concentration Range
Miscellaneous (cont.)			
Nitrate	mg/L	4/4	1900-2100
Nitrate as N	mg/kg	1/1	1600
Nitrite	mg/kg	1/1	75
Phosphorus (total as P)	mg/L	4/4	4.2
Phosphate, total	mg/kg	1/1	3.1
Specific gravity	none	4/4	1.016-1.018
Sulfate	mg/L	5/5	736-1000
Total Dissolved Solids	mg/L	5/5	13,000-16,000
Total Organic Carbon	mg/L	5/5	93-320
Total Suspended Solids	mg/L	3/5	11-16

[a] Pond water data from Halliburton NUS (1992) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207B–South Water[a] — Individual Pond Water Composition

Analyte	units	Detection Frequency	Concentration Range
Pesticides			
Atrazine	μg/L	1/6	13
Inorganics			
Arsenic	μg/L	6/6	16.4-276
Barium	μg/L	5/6	110-118
Boron	μg/L	6/6	2730-2800
Calcium	μg/L	6/6	18,900-52,700
Chromium	μg/L	4/6	14-22.8
Copper	μg/L	1/6	37.4
Lithium	μg/L	1/6	2670
Magnesium	μg/L	6/6	180,000-190,000
Manganese	μg/L	1/6	18.2
Mercury	μg/L	1/6	1
Molybdenum	μg/L	1/6	122
Nickel	μg/L	4/6	20-40
Potassium	μg/L	6/6	684,000-791,000
Silicon	μg/L	1/6	952
Sodium	mg/L	6/6	2010-2940
Strontium	μg/L	1/6	2370
Zinc	μg/L	1/6	37.1
TCLP			
Arsenic	μg/L	5/5	167-390
Barium	μg/L	5/5	269-319
Chromium	μg/L	2/5	10-87
Nickel	μg/L	3/5	21-24
Miscellaneous			
Gross Alpha	pCi/L	6/6	1500-2100
Gross Beta	pCi/L	6/6	2300-2900
Americium-241	pCi/L	1/1	0.13
Plutonium-239	pCi/L	1/1	0.14
Uranium-234	pCi/L	1/1	760
Uranium-235	pCi/L	1/1	31
Uranium-238	pCi/L	1/1	870
pH	units	6/6	9.1-9.2
Alkalinity (methyl orange)	mg/L	6/6	860-910
Alkalinity (phenolphthalein)	mg/L	5/5	140-160
Ammonia	mg/L	6/6	0.5-0.97
Carbonate	mg/L	1/1	190
Chloride	mg/L	1/6	745
Conductivity at 25C	μmhos	1/1	23,000
Cyanide - Total	mg/L	6/6	0.28-0.51
Fluoride	mg/L	1/1	72.5

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207B–South Water (cont.)[a]

Analyte	Units	Detection Frequency	Concentration Range
Miscellaneous (cont.)			
Nitrate	mg/L	5/5	1600-1800
Nitrate as N	mg/L	1/1	1800
Nitrite	mg/L	1/1	100
Phosphorus (total as P)	mg/L	5/5	2.6-2.8
Phosphate, total	mg/kg	1/1	2.6
Specific gravity	none	4/4	1.016-1.020
Sulfate	mg/L	6/6	540-784
Sulfide	mg/L	1/1	1
Total Dissolved Solids	mg/L	6/6	14,000-16,000
Total Organic Carbon	mg/L	6/6	58-297
Total Suspended Solids	mg/L	6/6	6-39

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207C Water[a] — Individual Pond Water Composition

Analyte	units	Detection Frequency	Concentration Range
Volatiles			
2-Butanone	µg/L	4/5	77-110
Methylene Chloride	µg/L	1/5	8
Pesticides			
Diazinon	µg/L	1/1	2.8
Simazine	µg/L	1/1	7.5
Inorganics			
Arsenic	µg/L	5/6	3350-4110
Barium	µg/L	5/6	110-150
Boron	µg/L	6/6	360,000-494,000
Cadmium	µg/L	6/6	312-560
Chromium	µg/L	6/6	2360-3940
Copper	µg/L	1/1	6790
Lead	µg/L	2/6	300
Magnesium	µg/L	5/6	1300-3870
Nickel	µg/L	6/6	2540-5090
Potassium	mg/L	6/6	54,500-78,700
Selenium	µg/L	2/6	600-3000
Silicon	µg/L	1/1	30,100
Sodium	mg/L	6/6	102,000-142,000
TCLP			
Arsenic	µg/L	5/5	4660-5510
Cadmium	µg/L	5/5	350-560
Chromium	µg/L	5/5	2240-9160
Nickel	µg/L	5/5	2330-4930
Silver	µg/L	5/5	150-430
Miscellaneous			
Gross Alpha	nCi/L	6/6	63-130
Gross Beta	nCi/L	6/6	170-230
Americium-241	pCi/L	1/1	8.6
Plutonium-239	pCi/L	1/1	670
Uranium-234	pCi/L	1/1	2600
Uranium-235	pCi/L	1/1	120
Uranium-238	pCi/L	1/1	3900
pH	units	6/6	10.0-10.2
Alkalinity (methyl orange)	mg/L	6/6	45,000-63,000
Alkalinity (phenolphthalein)	mg/L	5/5	25,000-32,000
Ammonia	mg/L	5/6	1.8-6.4
Bicarbonate	mg/L	1/1	4000
Carbonate	mg/L	1/1	25,000
Conductivity at 25C	µmhos	1/1	610,000
Chloride	mg/L	6/6	18,300-25,000
Cyanide - Total	mg/L	6/6	3.3-20

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207C Water[a] (cont.)

Analyte	units	Detection Frequency	Concentration Range
Miscellaneous (cont.)			
Nitrate	mg/L	5/5	57,000-66,000
Nitrate as N	mg/L	1/1	2600
Nitrite	mg/L	1/1	2500
Phosphorus (total as P)	mg/L	5/5	520-610
Phosphate, ortho	mg/L	1/1	390
Phosphate, total	mg/L	1/1	431
Specific gravity	none	5/5	1.316-1.348
Sulfate	mg/L	6/6	12,200-18,000
Sulfide	mg/L	1/1	10
Total Dissolved Solids	mg/L	6/6	300,000-510,000
Total Organic Carbon	mg/L	6/6	54.9-1600
Total Suspended Solids	mg/L	6/6	76-1400

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Clarifier Water[a] — Individual Pond Water Composition

Analyte	units	Detection Frequency	Concentration Range
Inorganics			
Arsenic	µg/L	4/4	272-342
Barium	µg/L	4/4	30-91
Boron	µg/L	4/4	23,300-34,700
Cadmium	µg/L	4/4	38-570
Chromium	µg/L	4/4	138-825
Lead	µg/L	2/4	34-46
Magnesium	µg/L	4/4	2580-6730
Mercury	µg/L	4/4	2.2-4.6
Nickel	µg/L	4/4	258-393
Potassium	µg/L	4/4	4860-7000
Silver	µg/L	4/4	66-110
Sodium	mg/L	4/4	9940-14,800
TCLP			
Arsenic	µg/L	4/4	1400-1800
Cadmium	µg/L	1/1	50
Chromium	µg/L	2/4	110-140
Nickel	µg/L	3/4	240-350
Miscellaneous			
Gross Alpha	nCi/L	4/4	16-19
Gross Beta	nCi/L	4/4	22-30
pH	units	4/4	9.9-10.1
Alkalinity (methyl orange)	mg/L	4/4	5500-8200
Alkalinity (phenolphthalein)	mg/L	4/4	2300-3100
Ammonia	mg/L	4/4	5-14
Chloride	mg/L	4/4	1600-3200
Cyanide - Total	mg/L	4/4	2.4-3
Nitrate	mg/L	4/4	5700-10,000
Phosphorus (total as P)	mg/L	4/4	78-84
Specific gravity	none	3/3	1.038-1.044
Sulfate	mg/L	4/4	2600-3200
Total Dissolved Solids	mg/L	4/4	46,000-68,000
Total Organic Carbon	mg/L	4/4	140-190
Total Suspended Solids	mg/L	4/4	68-180

[a] Pond water data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

Pond 207A Sludge[a] — Individual Pond Sludge Compositions

Analyte	units	Detection Frequency	Concentration Range
Volatiles			
1,1,1-Trichloroethane	µg/kg	1/1	24
Tetrachloroethene	µg/kg	1/1	290
Trichloroethene	µg/kg	1/1	29
1,1,2-Trichloro-1,2,2-trifluoroethane	µg/kg	1/1	260
Inorganics			
Ammonia	mg/kg	1/1	36
Arsenic	mg/kg	1/1	40.2
Barium	mg/kg	1/1	210
Boron	mg/kg	1/1	84.3
Cadmium	mg/kg	1/1	1300
Chloride[b]	mg/L	1/1	20
Cyanide - Total	mg/kg	1/1	1.6
Chromium	mg/kg	1/1	658
Lead	mg/kg	1/1	89
Magnesium	mg/kg	1/1	11,400
Nitrate[b]	mg/L	1/1	35
Nickel	mg/kg	1/1	102
Phosphorus (total as P)[b]	mg/L	1/1	0.1
Sodium	mg/kg	1/1	14,500
Sulfate[b]	mg/L	1/1	20
TCLP			
Arsenic	µg/L	1/1	185
Barium	µg/L	1/1	1710
Cadmium	µg/L	1/1	485
Miscellaneous			
Gross Alpha	pCi/g	1/1	570
Gross Beta	pCi/g	1/1	95
pH	units	1/1	8.9
Atterberg - Liquid Limit	none	1/1	83
Atterberg - Plastic Index	none	1/1	49
Atterberg - Plastic Limit	none	1/1	34
Moisture - Gravimetric	%	1/1	87.3
Moisture - Karl Fisher	%	1/1	34
Specific gravity	none	1/1	1.1
Swell Test	%	1/1	40
Total Organic Carbon	mg/kg	1/1	14,000
Total Dissolved Solids[b]	mg/L	1/1	480
% Recovery of solids	%	1/1	11.6

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–North Sludge[a] — Individual Pond Sludge Compositions

Analyte	units	Detection Frequency	Concentration Range
Semi-Volatiles			
Acenaphtene	µg/L	1/9	4500
4-Chloro-3-methylphenol	µg/L	1/5	7900
2-Chlorophenol	µg/L	1/5	7700
1,4-Dichlorobenzene	µg/L	1/9	4000
2,4-Dinitrotoluene	µg/L	1/9	3500
n-Nirtoso-di-propylamine	µg/L	1/9	3900
Phenol	µg/L	1/5	7400
Pyrene	µg/L	1/9	4600
1,2,4-Trichlorobenzene	µg/L	1/9	4300
Inorganics			
Aluminum	mg/kg	5/5	2600-4340
Barium	mg/kg	6/9	89.1-144
Boron	mg/kg	1/9	12.8
Cadmium	mg/kg	8/9	6.7-18.8
Calcium	mg/kg	5/5	20,700-26,300
Chloride[b]	mg/L	4/4	4-24
Chloride	mg/kg	5/5	927-1540
Chromium	mg/kg	9/9	7.9-70.6
Copper	mg/kg	2/5	15.3-18.9
Iron	mg/kg	5/5	2920-4800
Lead	mg/kg	9/9	9.6-21.3
Magnesium	mg/kg	8/9	3270-5070
Manganese	mg/kg	5/5	60.5-90.2
Mercury	mg/kg	2/4	0.7-0.8
Nickel	mg/kg	2/4	7.1-9.5
Nitrate[b]	mg/L	4/4	1.7-9.9
Nitrate as N	mg/kg	5/5	380-860
Nitrite	mg/kg	5/5	0.46-28
TKN-N	mg/kg	5/5	1140-5110
Phosphorus (total as P)[b]	mg/L	4/4	0.01-0.05
Phosphate, ortho	mg/kg	5/5	2.4-8.9
Phosphate, total	mg/kg	1/5	28
Silicon	mg/kg	5/5	1110-2670
Strontium	mg/kg	5/5	582-752
Sulfate[b]	mg/L	4/4	150-160
Sulfide	mg/kg	5/5	8-56
Thallium	mg/kg	1/5	7.3
Zinc	mg/kg	5/5	77.6-105
TCLP			
Barium	µg/L	4/4	1060-1210
Cadmium	µg/L	4/4	54-104
Chromium	µg/L	3/4	10-57
Nickel	µg/L	3/4	20-56

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only. All semivolatile compounds were detected in composite samples only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–North Sludge (cont.)[a]

Analyte	Units	Detection Frequency	Concentration Range
Miscellaneous			
Gross Alpha	pCi/g	9/9	5.2-38
Gross Beta	pCi/g	9/9	5.1-46
Plutonium-239	pCi/g	5/5	2-11
Uranium-234	pCi/g	5/5	13-19
Uranium-235	pCi/g	5/5	0.3-0.55
Uranium-238	pCi/g	5/5	8.4-12
pH	units	9/9	7.2-7.7
Alkalinity (total)	mg/kg	5/5	180-440
Ammonia	mg/kg	9/9	9.8-102
Atterberg - Liquid Limit	none	4/4	71-75
Atterberg - Plastic Index	none	4/4	34-40
Atterberg - Plastic Limit	none	4/4	33-37
Bulk Density (dried solids)	g/cc	4/4	0.84-0.90
Conductivity at 25C	µmhos	5/5	445-627
Moisture - Gravimetric	%	4/4	71.8-76.8
Moisture - Karl Fisher	%	4/4	23.5-27.9
Specific gravity	none	4/4	1.2
Swell Test	%	4/4	0-10
Total Dissolved Solids[b]	mg/L	4/4	160-220
Total Organic Carbon	mg/kg	4/4	3000-3400
Total Organic Carbon	mg/L	5/5	9,600-14,000
% Recovery of solids	%	4/4	16.6-25.8

[a] Sludge data from Halliburton NUS (March 1992) and Dames and Moore (October 1991) reports. Concentration range applies to detected values only. All semivolatile compounds were detected in composite samples only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–Center Sludge[a] — Individual Pond Sludge Compositions

Analyte	Units	Detection Frequency	Concentration Range
Volatiles			
Tetrachloroethene	µg/kg	4/9	37-180
Inorganics			
Aluminum	mg/kg	5/5	1350-3070
Barium	mg/kg	4/9	46.5-120
Beryllium	mg/kg	1/5	10.9
Boron	mg/kg	1/9	151
Cadmium	mg/kg	9/9	46.5-110
Calcium	mg/kg	5/5	74,300-153,000
Chloride[b]	mg/L	3/4	210-300
Chloride	mg/kg	5/5	9,900-18,200
Chromium	mg/kg	8/9	48.5-390
Copper	mg/kg	5/5	64.6-103
Cyanide - Total	mg/kg	5/9	0.34-15.1
Iron	mg/kg	5/5	1680-3470
Lead	mg/kg	5/9	10.2-14.4
Magnesium	mg/kg	9/9	7190-19,800
Manganese	mg/kg	5/5	80.7-208
Mercury	mg/kg	6/9	1.4-5.5
Nitrate[b]	mg/L	4/4	50-74
Nitrate as N	mg/kg	5/5	8,400-13,000
Nitrite	mg/kg	5/5	270-520
TKN-N	mg/kg	5/5	16,700-22,700
Phosphorus (total as P)[b]	mg/L	4/4	1.4-3.9
Phosphate, ortho	mg/kg	5/5	14-21
Phosphate, total	mg/kg	5/5	1400-2800
Potassium	mg/kg	5/9	9,420-15,400
Silicon	mg/kg	5/5	2550-3090
Sodium	mg/kg	9/9	28,800-54,200
Strontium	mg/kg	5/5	575-946
Sulfate[b]	mg/L	4/4	33-90
Sulfate	mg/kg	5/5	6,460-13,800
Zinc	mg/kg	5/5	110-277
TCLP			
Arsenic	µg/L	4/4	122-181
Barium	µg/L	4/4	2660-3690
Cadmium	µg/L	4/4	114-153
Chromium	µg/L	4/4	11-54
Nickel	µg/L	1/4	28

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–Center Sludge (cont.)[a]

Analyte	Units	Detection Frequency	Concentration Range
Miscellaneous			
Gross Alpha	pCi/g	9/9	13-130
Gross Beta	pCi/g	9/9	12-380
Americium-241	pCi/g	2/5	1.2-5.1
Plutonium-239	pCi/g	5/5	0.18-0.72
Uranium-234	pCi/g	5/5	69-86
Uranium-235	pCi/g	5/5	2-3
Uranium-238	pCi/g	5/5	75-94
pH	units	8/8	9.1-9.3
Alkalinity (total)	mg/kg	4/4	2700-3500
Ammonia	mg/kg	9/9	25-199
Atterberg - Liquid Limit	none	4/4	77-85
Atterberg - Plastic Index	none	4/4	20-40
Atterberg - Plastic Limit	none	4/4	45-65
Bulk Density (dried solids)	g/cc	4/4	0.81-0.88
Conductivity at 25C	µmhos	4/4	2900-4350
Moisture - Gravimetric	%	4/4	89.9-93.4
Moisture - Karl Fisher	%	4/4	42-53
Specific gravity	none	4/4	1.0
Swell Test	%	4/4	60-70
Total Dissolved Solids[b]	mg/L	4/4	670-770
Total Organic Carbon	mg/kg	4/4	5500-8800
Total Organic Carbon	mg/L	5/5	16,000-30,000
% Recovery of solids	%	4/4	9.3-13.7

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–South Sludge[a] — Individual Pond Sludge Compositions

Analyte	units	Detection Frequency	Concentration Range
Volatiles			
Tetrachloroethene	µg/kg	10/10	32-460
Trichloroethene	µg/kg	4/10	36-57
Xylenes	µg/kg	1/5	14
Inorganics			
Aluminum	mg/kg	5/5	1510-2390
Arsenic	mg/kg	1/10	59.7
Barium	mg/kg	5/10	62.2-134
Boron	mg/kg	3/10	138-349
Cadmium	mg/kg	5/10	7.4-30.4
Calcium	mg/kg	5/5	76,000-157,000
Chloride	mg/kg	5/5	8,600-17,200
Chromium	mg/kg	10/10	23.3-51.9
Copper	mg/kg	5/5	76.7-210
Cyanide - Total	mg/kg	9/10	0.46-74.1
Iron	mg/kg	5/5	2160-3690
Lead	mg/kg	4/10	9.4-61
Magnesium	mg/kg	10/10	5140-15,200
Manganese	mg/kg	5/5	75.2-204
Mercury	mg/kg	1/10	5
Nitrate[b]	mg/L	5/5	77-89
Nitrate as N	mg/kg	5/5	9,600-19,000
Nitrite	mg/kg	5/5	860-1700
TKN-N	mg/kg	5/5	12,100-16,400
Phosphorus (total as P)[b]	mg/L	5/5	0.09-1.7
Phosphate, ortho	mg/kg	5/5	3.8-42
Phosphate, total	mg/kg	5/5	68-5700
Potassium	mg/kg	6/10	6600-9580
Silicon	mg/kg	5/5	3750-5070
Silver	mg/kg	2/10	18.9-25.9
Sodium	mg/kg	9/10	23,800-44,600
Strontium	mg/kg	5/5	575-762
Sulfate[b]	mg/L	5/5	23-40
Sulfate	mg/kg	5/5	6,190-12,800
Zinc	mg/kg	5/5	80.6-300
TCLP			
Arsenic	µg/L	5/5	194-233
Barium	µg/L	5/5	1660-2770
Cadmium	µg/L	5/5	19-32
Chromium	µg/L	5/5	23-56

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207B–South Sludge (cont.)[a]

Analyte	Units	Detection Frequency	Concentration Range
Miscellaneous			
Gross Alpha	pCi/g	10/10	31-220
Gross Beta	pCi/g	10/10	21-730
Americium-241	pCi/g	4/5	0.75-2.4
Plutonium-239	pCi/g	5/5	1.9-23
Uranium-234	pCi/g	5/5	0.04-160
Uranium-235	pCi/g	5/5	1.6-5.1
Uranium-238	pCi/g	5/5	0.04-190
pH	units	5/5	9.1
Alkalinity (total)	mg/kg	5/5	1700-5500
Ammonia	mg/kg	9/10	17-585
Atterberg - Liquid Limit	none	4/4	70-101
Atterberg - Plastic Index	none	4/4	28-41
Atterberg - Plastic Limit	none	4/4	41-60
Moisture - Gravimetric	%	5/5	88.3-92.3
Moisture - Karl Fisher	%	4/4	39-50
Specific gravity	none	4/4	1.0-1.1
Swell Test	%	4/4	30-60
Total Dissolved Solids[b]	mg/L	5/5	740-790
Total Organic Carbon	mg/kg	5/5	6800-11,000
Total Organic Carbon	mg/L	5/5	15,000-23,000
% Recovery of solids	%	5/5	6.4-12.4

[a] Sludge data from Halliburton/NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207C Sludge[a] — Individual Pond Sludge Compositions

Analyte	units	Detection Frequency	Concentration Range
Volatiles			
2-Butanone	µg/kg	5/5	16-160
Benzene	µg/kg	2/5	7-31
Tetrachloroethene	µg/kg	5/5	8-73
Trichloroethene	µg/kg	2/5	5-7
1,1,2-Trichloro-1,2,2-triflouroethane	µg/kg	1/5	33
Semi-volatiles			
Pyrene	µg/kg	2/5	190-320
Inorganics			
Aluminum	mg/kg	5/5	69.5-1330
Antimony	mg/kg	1/5	13.8
Arsenic	mg/kg	7/10	2-37
Barium	mg/kg	5/5	13.2-61.4
Beryllium	mg/kg	2/5	1.1-17.6
Boron	mg/kg	10/10	78.9-1390
Cadmium	mg/kg	10/10	3.2-665
Calcium	mg/kg	1/5	1550
Chloride[b]	mg/L	5/5	660-990
Chloride	mg/kg	5/5	2420-6890
Chromium	mg/kg	10/10	216-960
Copper	mg/kg	4/5	4.3-78
Cyanide - Total	mg/kg	10/10	1.6-170
Fluoride	mg/kg	5/10	6,320-29,800
Iron	mg/kg	5/5	24.2-211
Lead	mg/kg	6/10	2-38.5
Lithium	mg/kg	5/5	24-108
Magnesium	mg/kg	5/10	1340-6250
Manganese	mg/kg	1/5	8.7
Mercury	mg/kg	8/10	0.11-1
Nickel	mg/kg	6/10	17.4-146
Nitrate[b]	mg/L	5/5	8900-11,000
Nitrate as N	mg/kg	5/5	65,000-130,000
Nitrite	mg/kg	5/5	480-1000
Phosphorus (total as P)[b]	mg/L	5/5	22-38
Phosphate, total	mg/kg	5/5	1300-3400
Potassium	mg/kg	10/10	16,900-365,000
Silicon	mg/kg	5/5	422-6990
Silver	mg/kg	6/10	4.4-73.6
Sodium	mg/kg	10/10	45,800-378,000
Sulfate[b]	mg/L	5/5	810-1300
Sulfate	mg/kg	5/5	28,800-141,000
Zinc	mg/kg	4/5	5.5-18.9

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only. Sample results include a composite berm sample.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Pond 207C Sludge (cont.)[a]

Analyte	units	Detection Frequency	Concentration Range
TCLP			
Arsenic	µg/L	5/5	447-538
Barium	µg/L	3/5	481-559
Cadmium	µg/L	5/5	342-5230
Chromium	µg/L	5/5	1840-3940
Lead	µg/L	2/5	33-52
Mercury	µg/L	1/5	0.4
Nickel	µg/L	5/5	563-2140
Silver	µg/L	5/5	9-23
Miscellaneous			
Gross Alpha	pCi/g	9/10	18-8700
Gross Beta	pCi/g	9/10	390-1200
Americium-241	pCi/g	5/5	0.01-1.7
Plutonium-239	pCi/g	3/5	2.8-16
Uranium-234	pCi/g	5/5	0.01-11
Uranium-235	pCi/g	5/5	0.02-0.84
Uranium-238	pCi/g	5/5	1.3-31
pH	units	5/5	10.2-10.5
Alkalinity (total)	mg/kg	5/5	17,000-24,000
Ammonia	mg/kg	2/10	2.7-4.5
Atterberg - Liquid Limit	none	4/4	NP
Atterberg - Plastic Index	none	4/4	NP
Atterberg - Plastic Limit	none	4/4	NP
Moisture - Gravimetric	%	5/5	34.8-48.8
Swell Test	%	4/4	0-10
Total Dissolved Solids[b]	mg/L	5/5	18,000-24,000
Total Organic Carbon	mg/kg	5/5	6400-9000
% Recovery of solids	%	5/5	9.2-18.8

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only. Sample results include a composite berm sample.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

NP: not possible to analyze based on nature of soil

Clarifier Sludge[a] — Individual Pond Sludge Compositions

Analyte	units	Detection Frequency	Concentration Range
Volatiles			
2-Butanone	µg/kg	4/4	87-180
Tetrachloroethene	µg/kg	4/4	280-1000
1,1,1-Trichloroethane	µg/kg	3/4	9-29
1,1,2-Trichloro-1,2,2-triflouroethane	µg/kg	4/4	45-150
Inorganics			
Arsenic	mg/kg	2/4	13.5-21.9
Barium	mg/kg	4/4	94.8-217
Boron	mg/kg	4/4	420-1380
Cadmium	mg/kg	4/4	2010-4660
Chloride[b]	mg/L	4/4	160-180
Chromium	mg/kg	4/4	1180-3190
Cyanide - Total	mg/L	4/4	21-190
Lead	mg/kg	4/4	83-191
Magnesium	mg/kg	4/4	10,400-24,200
Mercury	mg/kg	4/4	5-14
Nickel	mg/kg	4/4	339-902
Nitrate[b]	mg/L	4/4	410-450
Phosphorus (total as P)[b]	mg/L	4/4	33-52
Potassium	mg/kg	4/4	28,700-67,900
Silver	mg/kg	4/4	64.6-166
Sodium	mg/kg	4/4	39,200-96,300
Sulfate[b]	mg/L	4/4	210-280
TCLP			
Arsenic	µg/L	4/4	224-282
Barium	µg/L	1/4	530
Cadmium	µg/L	4/4	14,800-25,900
Chromium	µg/L	4/4	214-485
Lead	µg/L	1/4	34
Mercury	µg/L	2/4	0.9-4.9
Nickel	µg/L	4/4	6990-8300
Silver	µg/L	3/4	10-11
Miscellaneous			
Gross Alpha	pCi/g	4/4	3400-6600
Gross Beta	pCi/g	4/4	540-860
pH	units	4/4	9.7-9.8
Ammonia	mg/kg	4/4	28-84
Atterberg - Liquid Limit	none	3/3	69-72
Atterberg - Plastic Index	none	3/3	32-34
Atterberg - Plastic Limit	none	3/3	37-38
Moisture - Gravimetric	%	4/4	33.1-72.5
Swell Test	%	3/3	10
Total Dissolved Solids[b]	mg/L	4/4	4600-5400
Total Organic Carbon	mg/kg	4/4	3500-6400
% Recovery of solids	%	4/4	18-22.2

[a] Sludge data from Halliburton NUS (1992b) and Dames and Moore (1991) reports. Concentration range applies to detected values only. Sample results include a composite berm sample.

[b] ASTM leach analysis performed by analytical method ASTM D3987-85 (specifically EPA method 365.2 for phosphorus, EPA method 325.3 for chloride, EPA method 375.4 for sulfate, EPA method 352.2 for nitrate, and EPA method 160.1 for TDS)

Appendix B - Disposal Option Information

Appendix B: Disposal Option Information

This appendix contains NTS and Envirocare waste acceptance criteria. A brief discussion on Corrective Action Management Units (CAMUs) is presented in Section 2.2.4.

(2-92)

United States Government — Department of Energy
Oak Ridge Field Office

memorandum

DATE: March 18, 1994

REPLY TO ATTN OF: EW-913:Powell

SUBJECT: **NATIONWIDE MIXED WASTE COMMERCIAL DISPOSAL CONTRACT**

TO: Distribution List

Per EM-40 direction, the ORO office has contracted with Envirocare of Utah, Inc. for the disposal of DOE-generated mixed waste. The contract was signed March 17, 1994. Any DOE generated mixed waste that meets Envirocare licenses and permits are eligible for disposal under this contract.

Attached (Attachment 1) for your use is the disposal fee table. Prices for specific waste streams will be agreed to by Envirocare and the responsible generator before shipment.

Also attached for your information are the points of contact for DOE-ORO and Envirocare. (Attachment 2)

There are four areas for which documentation must be provided to the COR before shipment. These areas are: pre-acceptance and schedule agreement by Envirocare for the waste stream, NEPA compliance, approval for use of the DOE Order 5820.2A exemption, and funds transfer to ORO.

It is the responsibility of the generator to negotiate waste stream acceptance, schedule and disposal fee (based on the contract) with Envirocare. Documentation should be in the form of a letter from Envirocare to the generator stating preliminary acceptance, schedule and disposal fee. Attached for your use are the initial waste stream profile forms from Envirocare. (Attachment 3).

It is the responsibility of the generator to ensure NEPA compliance for any activities not already covered by NEPA. Documentation of NEPA compliance must be provided.

Documentation of operations office approval for use of the DOE Order 5820.2A exemption must be provided. This documentation could be a letter from the operations office manager approving shipment or similar written documentation.

Sufficient funds for the calculated annual disposal fee will be transferred to ORO before shipment. If disposal fees are less than calculated, the excess will be retained at ORO for future disposal fees.

After the documentation has been received by the COR and the funding transfer verified, the generator will receive written authorization to begin shipment. It is anticipated that COR review will take no more than five working days.

ORO is responsible for auditing Envirocare for environmental and contract compliance. Any generator that is or plans to ship waste to Envirocare within the following year, will be invited to participate in the annual ORO-led audit. Generators wishing to perform their own audit independent of ORO are subject to an administrative fee payable directly to Envirocare. Envirocare has the right to inspect generator documentation and facilities for waste disposed under this contract.

To aid planning for the use of the contract, generators are requested to transmit to the COR a two year forecast of waste shipments to Envirocare. These forecasts should be updated annually.

If schedule conflicts occur, the COR in consultation with Envirocare and the affected generators will resolve the conflict.

If a generator waste shipment fails Envirocare's license or permit requirements, shipments will be suspended. Any costs associated with this failure are the responsibility of the generator. For the first offense, there will be 30 days suspension; the second, 60 days suspension. If a third offense occurs, appropriate remedies will be decided by the COR and Envirocare. If the first offense is of sufficient magnitude a suspension and remedy will be decided upon by the COR and Envirocare.

If you need any further information, please call me at 615-576-7087.

Jane Powell

Jane Powell
ORO Technical Lead
Envirocare Contract

BCC:
Bill French, AD-42, ORO
Jill Albaugh, AD-42, ORO

Environmental Restoration Program
Operations Principal Contacts

Richard F. Sena
* Director, Environmental
  Restoration Project Office
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87115
Phone: 505-845-6307
Fax: 505-845-4239
Ver: 505-845-4887
• Effective 11/1/93

Albert R. Chernoff
Project Manager
Uranium Mill Tailings Remedial
  Action Project Office
U.S. Department of Energy
2155 Louisiana N.E.,
  Suite 4000
Albuquerque, NM 87117
Phone: 505-845-4628
Fax: 505-845-4023

Jay Hunze
Director, Environmental Restoration
Division
U.S. Department of Energy
Chicago Operations Office
9800 South Cass Avenue
Chicago, IL 60439
Phone: 708-252-2428
Fax: 708-252-2654
Ver: 708-252-2028

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P.O. Box 398705
Cincinnati, OH 45239-8705
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Projects Office
P.O. Box 2567
Grand Junction, CO 81502-2567
Phone: 303-248-6001
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U.S. Department of Energy
Idaho Operations Office
785 Doe Place
Idaho Falls, ID 83402
Phone: 208-526-1148
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Ver: 208-526-1952

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P.O. Box E
Oak Ridge, TN 37831
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Ver: 615-576-3534

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  Division
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Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, TN 37831
Phone: 615-576-0948
Fax: 615-576-0956

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Acting Project Manager
Battelle Columbus Laboratory
  Decommissioning Project
U.S. Department of Energy
505 King Avenue, 15-1-131
Columbus, OH 43201
Phone: 614-424-3990
Fax: 614-424-3951

Steve McCracken
Project Manager
Weldon Spring Site Office
U.S. Department of Energy
7295 Highway 94 South
St. Charles, MO 63303
Phone: 314-441-8978
Fax: 314-447-0803

Roger Freeberg
Director, Environmental
Restoration Division
U.S. Department of Energy
Richland Operations Office
825 Jadwin Avenue
P.O. Box 550
Richland, WA 99352
Phone: 509-376-7277
Fax: 509-376-7818

Rich Schassburger
Acting Director, Environmental
Restoration Division
U.S. Department of Energy
Rocky Flats Office
P.O. Box 928
Golden, CO 80402-0928
Phone: 303-966-4888
Fax: 303-966-4871
Ver: 303-966-4538

Alex Dong
Director, Environmental Restoration
and Waste Management Division
U.S. Department of Energy
San Francisco Operations Office
Lawrence Livermore National Lab
P.O. Box 808/L-574
Livermore, CA 94551
Phone: 510-422-0770
Fax: 510-422-0832

Lew Goidell
Director, Environmental
Restoration Division
U.S. Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken, SC 29808
Phone: 803-725-3966
Fax: 803-725-7548
Ver: 803-725-4611

ATTACHMENT 1

SECTION B
SUPPLIES OR SERVICES AND PRICES/COSTS
B.1
PRICE SCHEDULE - DISPOSAL SERVICES FOR DOE MIXED WASTES - DISPOSAL VOLUME

Delivery Mode	All Waste Under 15,000 CY	Between 15,000 & 25,000 CY	Above 25,000 CY
1) Base Rate - Bulk Truck	a) Unit Price: $1,539.00 Per CY	b) Unit Price: $1,107.00 Per CY	c) Unit Price: $864.00 Per CY
2) Containers in Truck	a) Add $38.00 Per CY to Unit Price	b) Unit Price: $38.00 Per CY	c) Add $38.00 Per CY to Unit Price
3) Bulk Rail	a) Add $2.62 Per CY to Unit Price	b) Unit Price: $2.62 Per CY	c) Add $2.62 Per CY to Unit Price
4) Containers by Rail	a) Add $38.00 Per CY to Unit Price	b) Unit Price: $38.00 Per CY	c) Add $38.00 Per CY to Unit Price
5) Winter Delivery	a) Add $30.00 Per CY to Unit Price	b) Unit Price: $30.00 Per CY	c) Add $30.00 Per CY to Unit Price
6) Less than 10% debris	a) Subtract $486.00 Per CY from Unit Price	b) Unit Price: $320.00 Per CY	c) Subtract $320.00 Per CY from Unit Price
7) Material over 10" in any dimension	a) Add $17.52 Per CY to Unit Price	b) Unit Price: $17.52 Per CY	c) Add $17.52 Per CY to Unit Price
8) Small Waste Streams (Under 100,000 CF)	a) Add $8.74 Per CY to Unit Price	b) Unit Price: $8.74 Per CY	c) Add $8.74 Per CY to Unit Price
9) Decontamination Services for "Unlimited Release" as defined in the Scope of Work	$87.50 per hour plus 115% of the cost of supplies.		

The rates stated herein are effective for the entire term of the contract, which includes the two-year base period and all option periods.

The numbered items under the heading titled "Delivery Mode" are defined as follows:

1. Lined trucks with waste material in bulk form.

2. and 4. Containers consist of:

- drums, i.e., 55, 89, 96 gallon
- boxes, i.e., steel or wood B-12 (2'x4'x7')
- boxes, i.e., steel or wood B-25 (4'x4'x7')
- boxes - steel and wood other than B-12s and B-25s
- rolloffs - 10, 20 cubic yards
- polyethylene bags - 1, 2, 3 yard bags

Containers should be within a weight of 12,000 lbs. All containers must be packaged in accordance with the Department of Transportation "strong tight" container specifications in 49 CFR 173.

3. Lined rail cars with waste material in bulk form.

5. The months of December through February.

6. Debris is defined as anything other than soil. Debris will be measured on a volumetric basis.

7. and 8. No further definition.

9. As defined in the scope of work, paragraph 4.B.6.

ATTACHMENT 2

ENVIROCARE CONTRACT POINTS OF CONTACT

ENVIROCARE
Sue Rice
46 West Broadway
Suite 240
Salt Lake City, Utah 84101
Phone No. 801/532-1330
Fax No. 801/537-7345

DOE-ORO
Contract Specialist
Jill Albaugh
U.S. Department of Energy
Oak Ridge Field Office
Post Office Box 2001
Oak Ridge, Tennessee 37831
Phone No. 615/576-0794
Fax No. 615/576-9188

PROPOSED CONTRACTING OFFICER'S REPRESENTATIVE
Jane Powell
U.S. Department of Energy
Environmental Restoration Division
105 Broadway
Oak Ridge, Tennessee 37831
Phone No. 615/576-7807
Fax No. 615/576-6074

FUNDS TRANSFER - ORO
Bruce Fitch
U.S. Department of Energy
Oak Ridge Field Office
Post Office Box 2001
Oak Ridge, Tennessee 37831
Phone No. 615/576-0657
Fax No. 615/576-5401

WASTE ACCEPTANCE CRITERIA SUMMARY

ENVIROCARE
OF UTAH

46 West Broadway, Suite 240, Salt Lake City, Utah 84101 (801) 532-1330

Acceptable Isotopes

ISOTOPE	CONCENTRATION
Silver-110m	5.6E+02 pCi/g
Americium-241	2.3E+02 pCi/g
Americium-243	1.7E+03 pCi/g
Berylluim-7	3.8E+04 pCi/g
Calcium-45	4.0E+08 pCi/g
Cadmium-109	4.6E+04 pCi/g
Cobalt-56	3.6E+02 pCi/g
Cobalt-57	1.9E+04 pCi/g
Cobalt-58	1.6E+03 pCi/g
Cobalt-60	3.6E+02 pCi/g
Chromium-51	6.8E+04 pCi/g
Cesium-134	1.2E+03 pCi/g
Cesium-137	5.6E+02 pCi/g
Europium-152	1.7E+03 pCi/g
Europium-154	1.4E+03 pCi/g
Iron-55	1.8E+06 pCi/g
Mercury-203	1.0E+04 pCi/g
Potassium-40	1.0E+04 pCi/g
Iridium-192	2.5E+03 pCi/g
Manganese-54	5.6E+03 pCi/g
Niobium-94	1.6E+02 pCi/g
Nickel-59	7.0E+02 pCi/g
Nickel-63	2.0E+06 pCi/g
Lead-210	2.3E+05 pCi/g*
Polonium-210	2.0E+04 pCi/g
Radium-226	2.0E+03 pCi/g*
Radium-228	1.8E+03 pCi/g
Radium-228 (1 yr)	1.2E+03 pCi/g*
Radium-228 (5 yrs)	6.7E+02 pCi/g*
Radium-228 (10 yrs)	5.6E+02 pCi/g*
Ruthenium-106	1.9E+04 pCi/g*
Antimony-124	7.9E+02 pCi/g
Antimony-125	5.3E+03 pCi/g
Tin-113	7.3E+05 pCi/g
Strontium-90	2.0E+04 pCi/g

ISOTOPE	CONCENTRATION
Thorium-230	1.5E+04 pCi/g
Thorium-232	6.8E+02 pCi/g*
Uranium-234	3.7E+04 pCi/g
Uranium-235	7.7E+02 pCi/g
Uranium-236	3.6E+04 pCi/g
Uranium-238	2.8E+04 pCi/g
Uranium-natural	1.8E+04 pCi/g
Uranium-depleted	1.1E+05 pCi/g
Zinc-65	1.1E+04 pCi/g
Curium-242	1.4E+06 pCi/g
Curium-242	8.1E+03 pCi/g*
Curium-243	1.5E+03 pCi/g
Curium-243	1.3E+03 pCi/g*
Curium-244	1.0E+04 pCi/g
Curium-244	7.4E+03 pCi/g*
Neptunium-237	2.0E+03 pCi/g
Plutonium-238	1.0E+04 pCi/g
Plutonium-238	8.2E+03 pCi/g*
Plutonium-239	9.9E+03 pCi/g
Plutonium-240	1.0E+04 pCi/g
Plutonium-241	3.5E+05 pCi/g
Plutonium-241	1.1E+03 pCi/g*
Plutonium-242	1.0E+04 pCi/g
Carbon-14	4.0E+05 pCi/g
Hydrogen-3	2.0E+07 pCi/g
Iodine-129	3.1E+03 pCi/g
Sodium-22	7.8E+02 pCi/g
Technetium-99	1.0E+05 pCi/g

* Daughters are assumed to be present at same concentrations in equilibrium

Acceptable Hazardous Waste Numbers

- D001-D043

- F001 F002 F003 F004 F005 F006 F007 F008 F009 F010 F011
  F012 F019 F024 F028 F039

- K011 K013 K050 K051 K052 K061 K069

- P002 P003 P004 P005 P010 P011 P012 P013 P014 P015 P017
  P020 P021 P022 P024 P027 P028 P029 P030 P034 P037 P039
  P046 P047 P048 P050 P051 P056 P059 P060 P071 P074 P075
  P077 P082 P085 P089 P094 P097 P098 P099 P101 P102 P104
  P105 P106 P107 P108 P111 P113 P114 P115 P119 P120 P121
  P122 P123

- U002 U003 U004 U005 U007 U009 U012 U018 U019 U021 U022
  U027 U028 U029 U030 U031 U032 U036 U037 U038 U039 U041
  U042 U043 U044 U045 U047 U048 U050 U052 U056 U057 U060
  U061 U062 U063 U064 U066 U067 U068 U069 U070 U071 U072
  U073 U074 U075 U076 U077 U078 U079 U080 U081 U082 U083
  U084 U085 U088 U089 U091 U093 U094 U095 U101 U102 U105
  U106 U107 U108 U109 U112 U115 U117 U118 U119 U120 U121
  U122 U123 U127 U128 U129 U130 U131 U132 U133 U134 U135
  U137 U138 U140 U141 U142 U144 U145 U146 U147 U149 U151
  U152 U154 U155 U157 U158 U159 U161 U162 U165 U166 U167
  U168 U169 U170 U171 U172 U174 U179 U180 U181 U182 U183
  U184 U185 U187 U188 U190 U191 U192 U194 U196 U197 U201
  U203 U204 U205 U207 U208 U209 U210 U211 U212 U214
  U215 U216 U217 U219 U220 U221 U223 U225 U226 U227
  U228 U230 U231 U232 U233 U234 U235 U237 U238 U239
  U240 U242 U243 U247 U328 U359

- All waste must meet RCRA treatment standards.

PRE-SHIPMENT ACCEPTANCE PROCESS
MIXED WASTE

ANALYSES REQUIRED (UTAH CERTIFIED LAB):
(See Section "SAMPLES" concerning Utah Certified Laboratories.)

- ☐ GAMMA SPECTROSCOPY (NATURAL & MAN-MADE ISOTOPES)
- ☐ ISOTOPIC ANALYSIS (IF NEEDED)
- ☐ TCLP (8 METALS, 32 ORGANICS)
- ☐ REACTIVE HYDROGEN CYANIDE/HYDROGEN SULFIDE
- ☐ SOIL PH
- ☐ PAINT FILTER LIQUIDS TEST
- ☐ PROCTOR TEST ASTM D-698
- ☐ TOX (TOTAL ORGANIC HALIDES)

PRE-SHIPMENT SAMPLES REQUIRED (SEND TO ENVIROCARE):
(See Section "SAMPLES" for complete information.)

- ☐ 5 2-POUND DIVERSE, REPRESENTATIVE SAMPLES
- ☐ 1 50-POUND REPRESENTATIVE SAMPLE

FORMS REQUIRED PRIOR TO WASTE SHIPMENT:
(See Section "FORMS" for forms and instructions.)

- ☐ MIXED WASTE PROFILE RECORD (EC-0175)
- ☐ PHYSICAL PROPERTIES FORM (EC-0500)
- ☐ RADIOLOGICAL EVALUATION (EC-0650)
- ☐ LAND DISPOSAL RESTRICTIONS (LDR) NOTICE AND/OR CERTIFICATION
- ☐ RADIOACTIVE WASTE SHIPMENT AND DISPOSAL RECORD (RSR) (Form #E 100)
- ☐ UNIFORM HAZARDOUS WASTE MANIFEST (8700-22)
- ☐ WEIGH BILL

PRE-SHIPMENT SAMPLES

Send samples via United Parcel Post (UPS) or Federal Express to:

Envirocare of Utah, Inc.
Attention: Sample Control,
Tooele County, US I-80, Exit 49
Clive, Utah 84029

Form EC-2000, Pre-Shipment Sample Profile Record, must accompany pre-shipment sample delivery to the Clive site.

THE FOLLOWING IS OF EXTREME IMPORTANCE!

Please send representative samples (number and quantity found on following page) that separately represent the diversity, possible extremes, and average of the waste stream(s). These samples will be analyzed for the following 10 incoming-shipment parameters:

Photoionizer "sniffer"	Pyrophoricity	Solid/Soil pH
Air Reactivity	Oxidizer/Reducer	Cyanide Test
Water Reactivity	Shock Sensitivity	Sulfide Test
Paint Filter Liquid Test or visual assurance		

These preliminary samples will be analyzed at the Envirocare site, and the results of these analyses will be used to establish the range of tolerances for your incoming shipments. If a shipment of the waste stream arrives and the results of the analysis of that sample is beyond the pre-shipment tolerance range, the shipment may be returned. Additional characterization may be required before the waste may be accepted.

THIS ISSUE IS VERY IMPORTANT! If additional samples, analytical results, and/or written confirmation are needed to fully correct discrepancies, acceptance of waste materials may be delayed.

NOTE: YOUR SHIPMENT WILL BE CONSIDERED TO BE NON-CONFORMING WASTE IF THE RESULTS ARE NOT WITHIN THE TOLERANCES ESTABLISHED USING THESE SAMPLES AND MAY BE REJECTED!

As you proceed through your clean-up process, if you discover a type of material different than that which was sent in pre-shipment samples, contact your Envirocare Customer Support Representative concerning the possible need for additional samples of the new material to establish new acceptance parameters. This will help avoid rejected shipments of new material.

PRE-SHIPMENT SAMPLE PROFILE RECORD

(EC-2000) (Rev. 03/94)

Generator Name: ______; Generator #/Waste Stream #: ______; Delivery Date ______

Contractor Name: ______; Waste Stream Name: ______; Volume of Waste Material: ______

Check appropriate boxes: Licensed ___; Non-Licensed ___; NORM ___; LARW ___; MW treated ___; MW needing treatment ___; FUSRAP ___; 11e.(2) ___

Original Submission: ___ Y; ___ N: Revision # ___; Date: ______

Name & Title of Person Completing Form: ______

This form is to be completed by the generator's chemical safety officer or equivalent and should accompany pre-shipment samples sent to Envirocare. Please read carefully and complete this form describing the samples sent for one waste stream. This information will be used to determine how to properly and safely manage, analyze and dispose of your samples. **This form should not be enclosed in the sample containers or package but should accompany the samples, attached to the sample package, if possible.** Should you have any questions while completing this form, contact Envirocare at (801) 532-1330. PRE-SHIPMENT SAMPLES CANNOT BE ANALYZED FOR THE INCOMING-SHIPMENT FINGERPRINT PARAMETERS OR OTHER ANALYSES UNLESS THIS FORM IS COMPLETED. Please mail this form with the samples to: Envirocare of Utah, Inc., Attn: Sample Control, Tooele county US I-80 Exit 49, Clive, Utah 84029.

1. CHEMICAL/SAFETY OFFICER INFORMATION

Chemical/Safety Officer ______

Title of Chemical/Safety Officer ______

Phone ______ Firm ______

2. Sample Return Address ______

______

______

3. SAMPLE COLLECTION

Sample Collection Contact Person ______

Title of Contact Person ______

Phone ______ Firm ______

4. Waste Stream Name ______

EPA Hazardous Waste Number(s) ______

Y N Is this a sample of Mixed Waste?

5. Indicate (Y or N) the expected or possible analytical results, characteristics or components of any sample of this waste stream below:

___ High pH	___ Low pH	___ Volatile Organics	___ Concrete	___ Alkaline Materials
___ Oxidizing Agents	___ Reducing Agents	___ Dissolved Metals	___ Organic Halides	___ Shock Sensitive Materials
___ Cyanides	___ Sulfides	___ Air Reactive	___ Free Liquids	___ Pyrophoric Materials
___ Acids	___ Caustic Materials	___ Organic Compounds	___ Inorganic Compounds	___ Water Reactive Materials
___ PCBs	___ Explosives	___ Solvents	___ Corrosives	___ Infectious Materials
___ Flash Point <60 C	___ Corrosive Materials	___ Reactive Materials	___ Manganese	___ Copper
___ Mercury	___ Others ______			

6. During analyses, our analysts will subject these samples to analytical environments including: heat, cold, stirring, shock impacts, caustics, acids (including nitric and glacial acetic), salt solutions (including potassium iodide, potassium nitrate, sodium thiosulfate, sodium sulfite), starch, iodine, and buffered pH solutions. Please list the associated hazards and safety precautions to be employed when analyzing any sample of this waste stream.

______

______

GENERATOR'S CERTIFICATION OF REPRESENTATIVE SAMPLES: I certify that samples representative of the waste described above are provided to Envirocare of Utah, Inc., for pre-shipment analyses.

GENERATOR'S AUTHORIZATION THAT SAMPLES MAY BE ANALYZED SAFELY: I further authorize that these samples may be safely analyzed using the precautions described in 6. above.

GENERATOR'S AUTHORIZATION AND CERTIFICATION TO RETURN SAMPLES AND PRIOR TO OR FOLLOWING ANALYSES: I hereby authorize that Envirocare of Utah, Inc., may return these samples to the address in 2. above prior to or following analysis and prior to disposal. I hereby certify that the generator and generator's applicable associates in this project understand that **pre-shipment samples may be returned if wastes are not sent to Envirocare for disposal within 3 months of sample delivery.**

Generator's Safety Officer's Signature ______ Title ______ Date ______

(Sign for the above certifications and authorizations.)

PRE-SHIPMENT SAMPLES

NUMBER AND QUANTITY REQUIRED

NORM, LARW, OR MIXED WASTE

5 2-pound diverse, representative samples

1 50-pound representative sample

UTAH CERTIFIED LABORATORIES

Contact the State of Utah Department of Health (below) to obtain a current list of Utah certified laboratories or to ask any questions concerning the current status of laboratories. The list provided may not include all certified laboratories.

State of Utah
Department of Health
Division of Laboratory Services
Bureau of Laboratory Improvement
46 North Medical Drive
Salt Lake City, Utah 84113-1105
(801) 584-8469

PACKAGING REQUIREMENTS

Envirocare is required to inspect each shipment arriving at its Clive, Utah, disposal facility for compliance with a number of provisions in its Radioactive Materials License. Acceptance of non-compliant waste shipments can result in violations and possible civil penalties for Envirocare.

A shipment which is not in compliance upon arrival can be returned to the generator for correction. It is imperative that the following items be met:

All shipments reaching Envirocare must meet DOT packaging requirements for Low Specific Activity (LSA) shipments (49 CFR 173.425 [Included in Appendix]), whether they are "radioactive materials" (DOT defined, see following page "Placarding") or not.

BULK SHIPMENTS

1. Bulk shipments must be covered. The top must be completely enclosed with no open areas along the sides or openings in the top.

2. Bulk shipments (rail cars, trucks, trailers or other conveyances used for bulk shipments) must also be tightly sealed to prevent waste or liquids from leaking out. Shipments containing free liquids will be rejected.

CONTAINERS

1. All containers must meet the standard of a "Strong, Tight Container." (49 CFR 173.24 [Included in Appendix])

2. Containers must be properly sealed to prevent load movements from "pumping" dust-laden air out of the container.

3. Containers must be clean. They must not have any waste material, or other material which can be mistaken for waste material, on the outside surfaces.

4. Containers in a shipment must be loaded and braced securely to prevent shifting and damage during transport.

5. Although desirable, containerized rail shipments need not be enclosed or covered.

6. Specification containers (49 CFR 173.425 [Included in Appendix]) are not required for exclusive use container shipments.

7. Do <u>**not**</u> modify containers, e.g., added vents or drain plugs.

8. Do not have unnecessary container closure, e.g., welding of clips or barrel rings.

9. Overpack containers only when necessary, e.g., potential for leaking, deteriorating, etc.

ADDITIONAL

1. Drums <u>must</u> be on pallets.

2. Pallets must be strong enough to withstand collapse during transit.

3. Do not stack barrels.

4. Truck or railcar beds must be free of all loose material -- waste or other material.

5. Bulk trucks must be tarped. Tarps must extend over the top and down the sides far enough to prevent access to the load, wind blowing through the load, or precipitation reaching the load.

6. Bottom dump rail cars are not permitted.

7. Do not use moving-van type trailers.

PLACARDING

The Department of Transportation (DOT) defines Radioactive Material as material which has a total radioactivity concentration of 2,000 pCi/g, including all radionuclides in any decay chain which are present, but not listed. For example, Radium-226 at 250 pCi/g will have sufficient daughter product activity to reach 2,000 pCi/g total. Thorium-232 at 190 pCi/g in equilibrium with its daughter products will also provide a total radioactivity of 2,000 pCi/g, as will natural uranium at 1,000 pCi/g due to the presence of the Protactinium-234m and Thorium-234 daughters of Uranium-238.

All bulk shipments or containerized shipments with at least one container meeting the DOT definition of "radioactive material" must be placarded [49 CFR 173.425 and 49 CFR 172, Subpart F. (included in Appendix)]. Individual containers of "radioactive material" must be stenciled or marked "Radioactive-LSA" and must be marked "Class A." Shipments or containers not meeting the definition of "radioactive material" <u>must not be</u> so marked or placarded. A shipment containing a reportable quantity (RQ) of radioactivity may be, but is not required to be, manifested as an "Environmentally hazardous substance, solid, n.o.s." and placarded Class 9, with an ID number of UN3077.

You may also want to contact the Department of Transportation to request additional information and/or documents.

SHIPPING REQUIREMENTS

Envirocare is required to inspect each shipment arriving at its Clive, Utah, disposal facility for compliance with a number of provisions in its Radioactive Materials License. Acceptance of non-compliant waste shipments can result in violations and possible civil penalties for Envirocare.

A shipment which is not in compliance upon arrival can be returned to the generator for correction. It is imperative that the following items be met:

All shipments reaching Envirocare must meet DOT packaging requirements for Low Specific Activity (LSA) shipments (49 CFR 173.425 [Included in Appendix]), whether they are "radioactive materials" (DOT defined, see following page "Placarding") or not.

Mixed Waste Shipments: The weight of incoming truck shipments must be within a specified range of the loaded weight at the point of departure. It is mandatory that a Weigh Bill accompany each truck shipment to verify this information and to avoid shipment rejection.

BULK SHIPMENTS

1. Bulk shipments must be covered. The top must be completely enclosed with no open areas along the sides or openings in the top.

2. Bulk shipments (rail cars, trucks, trailers or other conveyances used for bulk shipments) must also be tightly sealed to prevent waste or liquids from leaking out.

   Shipments containing free liquids will be rejected.

CONTAINERS

1. All containers must meet the standard of a "Strong, Tight Container." (49 CFR 173.24 [Included in Appendix])

2. Containers must be properly sealed to prevent load movements from "pumping" dust-laden air out of the container.

3. Containers must be clean. They must not have any waste material, or other material which can be mistaken for waste material, on the outside surfaces.

4. Containers in a shipment must be loaded and braced securely to prevent shifting and damage during transport.

5. Although desirable, containerized rail shipments need not be enclosed or covered.

6. Specification containers (49 CFR 173.425 [Included in Appendix]) are not required for exclusive use container shipments.

7. Do <u>not</u> modify containers, e.g., added vents or drain plugs.

8. Do not have unnecessary container closure, e.g., welding of clips or barrel rings.

9. Overpack containers only when necessary, e.g., potential for leaking, deteriorating, etc.

ADDITIONAL

1. Drums <u>must</u> be on pallets.

2. Pallets must be strong enough to withstand collapse during transit.

3. Do not stack barrels.

4. Truck or railcar beds must be free of all loose material -- waste or otherwise.

5. Bulk trucks must be tarped. Tarps must extend over the top and down the sides far enough to prevent access to the load, wind blowing through the load, or precipitation reaching the load.

6. Bottom dump rail cars are not permitted.

7. Do not use moving-van type trailers.

PLACARDING

The Department of Transportation (DOT) defines Radioactive Material as material which has a total radioactivity concentration of 2,000 pCi/g, including all radionuclides in any decay chain which are present, but not listed. For example, Radium-226 at 250 pCi/g will have sufficient daughter product activity to reach 2,000 pCi/g total. Thorium-232 at 190 pCi/g in equilibrium with its daughter products will also provide a total radioactivity of 2,000 pCi/g, as will natural uranium at 1,000 pCi/g due to the presence of the Protactinium-234m and Thorium-234 daughters of Uranium-238.

All bulk shipments or containerized shipments with at least one container meeting the DOT definition of "radioactive material" must be placarded (49 CFR 173.425 and 49 CFR 172, Subpart F.

[Included in Appendix]). Individual containers of "radioactive material" must be stenciled or marked "Radioactive-LSA" and must be marked "Class A." Shipments or containers not meeting the definition of "radioactive material" <u>must not be</u> so marked or placarded. A shipment containing a reportable quantity (RQ) of radioactivity may be, but is not required to be, manifested as an "Environmentally hazardous substance, solid, n.o.s." and placarded Class 9, with an ID number of UN3077.

You may also want to contact the Department of Transportation to request additional information and/or documents.

72-HOUR SHIPMENT NOTIFICATION

A completed copy of the "72-Hour Shipment Notification" (EC-2725) (your master copy is found in Section "FORMS") must be sent to Envirocare, "Attention: Scheduling Department," to set an arrival and acceptance date for each day's shipment. We recommend you fax this notice (fax # 801-532-0922) as soon as you know your schedule so that scheduling on our end will be able to accommodate your needs.

Please note that even though Envirocare may receive the "72-Hour Shipment Notification" form, we will <u>not necessarily</u> be able to accept your shipment on the day proposed. <u>Our scheduling department will confirm with you a scheduled day for your shipment's arrival and acceptance.</u>

Failure to comply with this shipment notification process may incur unnecessary demurrage charges as well as wages and salaries for additional personal to handle late-scheduled arrivals.

<u>COPIES</u> OF THE FOLLOWING PAGES IN THE SHIPPING SECTION MUST BE PROVIDED FOR TRUCK DRIVERS WHO MAY BE DELIVERING MATERIAL TO THE ENVIROCARE FACILITY TO PROVIDE FOR SMOOTH ACCEPTANCE OF YOUR SHIPMENT.

PLEASE REFER TO THE INFORMATION IN THESE PAGES AND RETAIN THE ORIGINALS IN THIS MANUAL.

CLIVE SITE WORKING HOURS

CLIVE SITE WORKING HOURS

Administrative Office: 8:00 a.m. through 4:30 p.m. Monday through Friday

Shipments may arrive for acceptance 7:00 am. through noon.

Shipments arriving after noon (even on a scheduled day) will not be guaranteed acceptance that day, but will most likely be accepted the following regular work day.

OBSERVED HOLIDAYS

January 1	New Year's Day
May, last Monday	Memorial Day
July 4	Independence Day
July 24	Pioneer Day
September, 1st Monday	Labor Day
November, last Thursday/Friday	Thanksgiving
December 25-31	Christmas

Non-problem shipments will be given priority in acceptance processing over problem shipments. Problem shipments may thus result in unexpected, cost-to-you delays. To avoid such delays, check carefully the checklists for "Acceptance Process," in "Pre-Shipment" section and the potential problem areas in the "Acceptance Checklist" section. Also, consult with your Envirocare Customer Support Representative with any questions you may have.

If you have questions concerning your arrival at the site, contact the site directly at (801) 521-9619.

NVO-325 (Rev.1)

Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements

June 1992

Prepared Jointly by:

U.S. Department of Energy
Nevada Field Office

and

Reynolds Electrical & Engineering Co., Inc.
Waste Management Department

5.5 Waste Acceptance Criteria Statements

Address each of the following waste acceptance criteria (WAC). Provide a brief statement of the NVO-325 criteria objective. State the regulatory or other reference(s) as provided in the WAC and provide a brief discussion of how each waste stream will comply with the individual criteria. In addition, where compliance is procedurally controlled, reference the applicable procedure(s). For example:

1) **Closure:** The package closure shall be sturdy enough that it will not be breached under normal handling conditions and will not serve as a weak point for package failure (per NVO-325, 5.5.1.3.A).

   Compliance Method: Waste containers shall be closed with metal clips and banding, per procedure XXXX, to prevent breaching under normal handling conditions.

2) **Free Liquids:** LLW disposed at the NTS waste management sites shall contain as little free liquids as is reasonably achievable, but in no case shall the liquid equal or exceed 0.5 percent by volume of the external waste container (per NVO-325, 5.5.1.1.C).

   Compliance Method: This criteria is evaluated by process knowledge, waste segregation, visual verification, and evaluation of the waste stream (e.g., contaminated soil) utilizing the Paint Filter Test, per procedure XXXX, XXXX, and XXXX. Absorbent will be added, per procedure XXXX, as a precautionary measure to absorb any moisture that may form due to condensation attributed to the variations in temperature and humidity from state-of-generation to NTS. Packages will also be reviewed by Real-Time Radiography (RTR) prior to package certification. Any packages suspected of having greater that 0.5 percent free liquids will be segregated and marked to prevent inadvertent shipment to NTS.

5.5.1 Low-level Waste Acceptance Criteria

Defense waste accepted at NTS must be radioactive and meet the waste form criteria outlined below. These requirements are minimum requirements for all types of wastes and are intended to facilitate handling and provide health and safety protection of personnel at the disposal site.

5.5.1.1 General Waste Form Criteria

These waste form criteria are based on current DOE LLW management policies and practices per DOE Order 5820.2A guidelines. Any waste streams not meeting these basic requirements must be evaluated on a case-by-case basis and must not compromise the performance objectives for the disposal site or violate any permit requirements.

A. **Transuranics:** LLW must have a transuranic nuclide concentration less than 100 nCi/g. The mass of the waste container, including shielding, shall not be used in calculating the specific activity of the waste.

B. **Hazardous Waste Components:** LLW offered for disposal at NTS waste management sites shall not exhibit any characteristics of, or be listed as, hazardous waste as identified in Title 40 CFR 261, "Identification and Listing of Hazardous Waste" or state-of-generation hazardous waste regulations.

C. **Free Liquids:** Free liquids mean liquids which readily separate from the solid portion of a waste under ambient temperature and pressure conditions.

   LLW disposed at the NTS waste management sites shall contain as little free liquids as is reasonably achievable, but in no case shall the liquid equal or exceed 0.5 percent by volume of the external waste container and shall meet the following criteria:

   - Bottles, cans, or other similar well-drained containers may contain residual liquids.
   - Where practicable, residual liquids in well-drained containers shall be mixed with absorbent or solidified so that free liquids are no longer observed.

- If absorbent materials are added to a waste for control of free liquids, the generator must calculate the volume of liquid in the waste and use a quantity of sorbent material sufficient to absorb a minimum of twice the calculated volume of the liquid. Please note when significant differences of temperature exist between the generating site and the disposing site, provisions for additional absorbent materials must be made for affected waste forms.
- To demonstrate compliance with the free liquids requirement, the generator may be required to use Method 9095 (Paint Filter Test) as described in "Test Methods For Evaluating Solid Wastes, Physical/Chemical Methods." (EPA Publication No. SW-846) The Paint Filter Test may not be applicable to certain waste forms; e.g., concrete. If the generator determines that the waste form is not conducive to the Paint Filter Test, documentation must be provided to substantiate the claim.

D. Particulates: Fine particulate wastes shall be immobilized so that the waste package contains no more than 1 weight percent of less-than-10-micrometer-diameter particles, or 15 weight percent of less-than-200-micrometer-diameter particles. Waste that is known to be in a particulate form or in a form that could mechanically or chemically be transformed to a particulate during handling and interim storage shall be immobilized.

When immobilization is impractical, other acceptable waste packaging shall be used, such as the following:

- Overpacking (i.e., 55-gallon drum inside 83- or 85-gallon drum);
- steel box with no liner;
- wooden box with a minimum of 6-mil sealed plastic liner;
- steel drum with a minimum of 6-mil sealed plastic liner.

E. Gases: LLW gases shall be stabilized or absorbed so that pressure in the waste package does not exceed 1.5 atmospheres at 20° C.

Compressed gases as defined by Title 49, CFR 173.300, including unpunctured aerosol cans, will not be accepted for storage or disposal. Aerosol cans will have puncture disfigurements recognizable by (RTR). Expended gas cylinders must have the valve mechanism removed.

F. **Stabilization:** Where practical, waste shall be treated to reduce volume, promote waste minimization, and provide a more structurally and chemically stable waste form.

Structural stability can be accomplished by crushing, shredding, and placing a smaller piece inside an opening of a larger piece, such as nesting pipes.

Chemical stability must be documented to show that significant quantities of harmful gases, vapors, or liquids are not generated. Wastes shall not react with the packaging during storage, shipping, and handling time.

Where stabilization is required for the waste to meet this waste acceptance criteria, it must be shown that the stabilization process is adequately controlled. Control is shown through the use of procedures, sampling, test plans, etc., and the results of such controls shall be made available for examination and approval.

G. **Etiologic Agents:** LLW containing pathogens, infectious wastes, or other etiologic agents as defined in Title 49, CFR 173.386 will not be accepted for disposal at NTS.

H. **Chelating Agents:** LLW containing chelating or complexing agents at concentrations greater than 1 percent by weight of the waste form will not be accepted.

I. **Polychlorinated Biphenyls (PCBs):** PCB-contaminated LLW will not be accepted for disposal at NTS unless the PCB concentration meets municipal solid waste disposal levels of 50 ppm or less. See Title 40, CFR 761.60 for PCB disposal requirements.

J. Explosives and Pyrophorics: LLW containing explosive and/or pyrophoric material in a form that may spontaneously explode or combust, if the container is breached, will not be accepted.

5.5.1.2 General Regulatory Waste Package Criteria

The NTS waste package criteria include regulatory criteria to meet applicable DOE, EPA, and DOT requirements and criteria established to meet site-specific requirements at NTS waste management sites. Defense waste shipped to NTS waste management sites for disposal or storage must be packaged in accordance with all DOE and DOT regulations. These include the requirements of DOE Order 1540.1, "Materials Transportation and Traffic Management"; Titles 49, CFR 173.448, "General Transportation Requirements"; 49 CFR 173.474, "Quality Control for Construction of Packaging," and 49 CFR 173.475, "Quality Control Requirements Prior to Each Shipment of Radioactive Materials."

A. Design: Type A packaging shall be designed to meet Title 49 CFR 173.411, "General Design Requirements," and Title 49 CFR 173.412, "Additional Design Requirements for Type A Packages." Type A packages must have been evaluated under the DOE Type A package Certification Program (see MLM-3245, "DOT 7A Type A Certification Document" or succeeding DOE publication). Type B packaging must meet the applicable requirements of Title 10 CFR 71. Strong, tight packaging used for shipping limited quantities and low specific activity LLW excepted by Titles 49 CFR 173.421 and 173.425, respectively, must be constructed so that it will not leak during normal transportation and handling conditions.

B. Nuclear Safety: The quantity of fissile radioactive materials shall be limited so that an infinite array of such packages will remain subcritical. This quantity shall be determined on the basis of a specific nuclear safety analysis, considering credible accident situations, and taking into account the actual materials in the waste. See Title 49 CFR 173.451, "Fissile Materials - General Requirements."

C. Nuclear Heating: The quantity of radioactive materials shall be limited for each waste matrix and package type so that the effects of nuclear decay heat will not adversely affect the physical or chemical stability of the contents or package integrity. See Title 49 CFR 173.442, "Thermal Limitations," for temperature limits of accessible external package surfaces.

D. Radiation Levels: The external radiation levels for packages shall not exceed 200 millirem per hour on contact during handling, shipment, and disposal unless specifically excepted by DOT regulations. See Title 49 CFR 173.441, "Radiation Level Limitations." Type B containers that will be unloaded by remote procedures will be addressed on a case-by-case basis.

E. External Contamination: Packages shall be within DOT contamination limits upon receipt at NTS. See Title 49 CFR 173.443, "Contamination Control." On-site generators refer to current NTS external contamination limits.

F. Activity Limits: The activity limits listed in Title 49 CFR 173.431, "Activity Limits for Type A and Type B Packages," shall be met. Where applicable, the activity limits of Titles 49 CFR 173.421, "Limited Quantities of Radioactive Materials," and 49 CFR 173.425, "Transport Requirements for Low-Specific Activity Radioactive Materials," shall be met for strong, tight packages. See Section 5.5.5.2 for additional requirements for activity limits outside of this range.

G. Multiple Hazards: Waste containing multiple hazards shall be packaged according to the level of hazard as defined in Title 49 CFR 173.2, "Classification of Material Having More than One Hazard."

5.5.1.3 NTS Specific Package Criteria

The use of properly designed packaging reduces the chance of radiological or occupational safety occurrences during transportation, handling, and disposal operations. In addition, preplanning the size and load of each package is essential to reducing the number of waste shipments to the NTS and the space required for disposal. DOE/NV has adopted the following criteria to assure that the NTS RWMSs are operated safely and efficiently. The criteria shall be incorporated in the design of all waste packaging, including strong, tight containers.

A. **Closure:** The package closure shall be sturdy enough that it will not be breached under normal handling conditions and will not serve as a weak point for package failure.

B. **Strength:** Except for bulk waste, waste packaged in steel drums or SEALAND® containers, the waste package (packaging and contents) shall be capable of supporting a uniformly distributed load of 19,528 kg/m2 (4,000 lbs/ft2). This is required to support other waste packages and earth cover without crushing during stacking and covering operations.

C. **Handling:** All waste packages shall be provided with permanently attached skids, cleats, offsets, rings, handles, or other auxiliary lifting devices to allow handling by means of forklifts, cranes, or similar handling equipment. Lifting rings and other auxiliary lifting devices on the package are permissible, provided they are recessed, offset, or hinged in a manner that does not inhibit stacking the packages. The lifting devices must be designed to a 5:1 safety factor based on the ultimate strength of the material. All rigging devices that are not permanently attached to the waste package must have a current load test based on 125 percent of the safe working load.

D. **Size:** 1.2- x 1.2- x 2.1-m (4- x 4- x 7-ft) or 1.2- x 0.6- x 2.1-m (4- x 2- x 7-ft) (width, height, length) boxes or 208-liter (55-gallon) drums are required to be used. Bulk waste container approval is discussed in Section 5.5.4. While these sizes allow optimum stacking efficiency in disposal cells, other dimensions are acceptable with approval from DOE/NV on a case-by-case basis.

E. Weight: In addition to the weight limits set for specific packaging designs, NTS imposes limits of 4,082 kg (9,000 pounds) per box and 544 kg (1,200 pounds) per 208-liter (55-gallon) drum. Packages exceeding 4,082 kg (9,000 pounds) require crane or large forklift removal and must be approved by REECo/WMD prior to shipment. Shipments of this type must be in a removable-top or removable-side trailer.

F. Loading: Waste packages shall be loaded to ensure that the interior volume is as efficiently and compactly loaded as practical. High density loading will allow efficient RWMS space utilization and provide a more stable waste form that will reduce subsidence and enhance the long-term performance of the disposal site.

G. Nonstandard Type A Packaging: Use of DOT Type A packages not previously evaluated under the DOE Type A Package Certification Program (see MLM- 3245, etc.) will not be permitted.

H. Package Protection: The generator shall take the following precautions to protect the waste package after closure.

1. The preshipment storage environment shall be controlled to avoid adverse influence from weather or other factors on the containment capability of the waste packaging during handling, storage, and transport. The generator preparing waste for preshipment storage shall take all reasonable precautions to preclude the accumulation of moisture on or in packages prior to their arrival at the NTS.
2. A form of Tamper Indicating Device (TID) shall be applied to each waste container, once certification actions have been completed.
3. Each waste package shall be prepared for shipment so as to minimize damage during transit. Minor damage incurred during transit, not attributable to poor packaging, will be repaired at the RWMS without charge to the waste generator. Costs for repairs of damage caused by waste generator or carrier negligence as well as any necessary decontamination to meet DOE Order 5480.11 will be charged to the waste generator.

5.5.2 Additional Criteria for Mixed Waste

In addition to meeting all of the LLW WAC, MW offered for disposal at the Area 5 RWMS Mixed Waste Management Unit (MWMU) must meet the criteria described below.

> **Note:** MW will not be accepted for bulk disposal in the Area 3 RWMS. MW containing asbestos will be handled on a case-by-case basis. State-of-generation requirements for identifying, treatment, and disposal will also apply.

A. **Free Liquids:** MW disposed at the NTS shall contain no free liquids.

- Residual liquids in well-drained containers shall be mixed with absorbent or solidified so that free liquids are no longer observed.
- If absorbent materials are added to a waste for control of free liquids, the generator must calculate the volume of liquid in the waste and use a quantity of sorbent material sufficient to absorb a minimum of twice the calculated volume of the liquid. Please note when significant differences of temperature exist between the generating site and the disposing site, provisions for additional absorbent materials must be made for affected waste forms.
- To demonstrate the absence of free liquids, the generator may be required to use Method 9095 (Paint Filter Test) as described in "Test Methods For Evaluating Solid Wastes, Physical/Chemical Methods." (EPA Publication No. SW-846) The Paint Filter Test may not be applicable to certain waste forms; e.g., concrete. If the generator determines that the waste form is not conducive to the Paint Filter Test, documentation must be provided to substantiate the claim.

B. Treatment: All MW accepted for disposal at the MWMU must comply with land disposal restrictions for the hazardous component(s) as specified under Title 40 CFR 268, "Land Disposal Restrictions" unless treated as specified under Title 40 CFR 268, Subpart D, "Treatment Standards."

C. Reactive Wastes: All reactive wastes must be treated in accordance with Title 40 CFR 268, Subpart D, "Treatment Standards."

D. Potentially Incompatible Wastes: Wastes must be identified by the most appropriate compatibility group listed in Title 40 CFR 264, Appendix V, "Examples of Potentially Incompatible Waste," to ensure that incompatible wastes are not shipped or disposed together. Incompatible MW shall be packaged in accordance with Title 40 CFR 264.177, "Special Requirements for Incompatible Wastes."

E. Marking and Labeling: MW packages of 110 gallons or less must be marked in accordance with Title 40 CFR 262.32(b). Intrasite shipments shall be marked and labeled in accordance with the above requirements as well as NV 54XG.1A, "DOE/NV Radiological Safety Manual." Marking and labeling of the waste packages shall be for the hazardous component in addition to the radioactive component. Limited quantity MW must be classified according to the requirements for hazardous components as defined by Title 49 CFR 173.2.

F. Package Protection: The requirements of Title 40 CFR 264, Subpart I, "Use and Management of Containers," shall be met for MW packages.

5.5.3 Additional Criteria for Transuranic/Transuranic Mixed Waste

Requests for storage of all TRU waste will be considered on a case-by-case basis.

TRU waste must meet all the LLW WAC including DOE/HQ designation, application to DOE/NV, and participation in the waste generator approval process. TRU waste is only accepted at the NTS for interim storage prior to shipment to the Waste Isolation Pilot Plant (WIPP). In addition, the generator

Appendix C - EPA Environmental Bulletin on Cement Stabilization/Solidification

United States Environmental Protection Agency | Office of Emergency and Remedial Response Washington, DC 20460 | Office of Research and Development Cincinnati, OH 45268
Superfund | EPA/540/S-92/015 | May 1993

EPA

Engineering Bulletin Solidification/Stabilization of Organics and Inorganics

Purpose

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the most current information available on selected treatment and site remediation technologies and related issues. They provide summaries of and references for this information to help remedial project managers, on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their Superfund or other hazardous waste site. Those documents that describe individual treatment technologies focus on remedial investigation scoping needs. Addenda are issued periodically to update the original bulletins.

Abstract

Solidification refers to techniques that encapsulate hazardous waste into a solid material of high structural integrity. Encapsulation involves either fine waste particles (microencapsulation) or a large block or container of wastes (macroencapsulation) [1, p. 2]*. Stabilization refers to techniques that treat hazardous waste by converting it into a less soluble, mobile, or toxic form. Solidification/Stabilization (S/S) processes, as referred to in this document, utilize one or both of these techniques.

S/S technologies can immobilize many heavy metals, certain radionuclides, and selected organic compounds while decreasing waste surface area and permeability for many types of sludge, contaminated soils, and solid wastes. Common S/S agents include: Type 1 Portland cement or cement kiln dust; lime, quicklime, or limestone; fly ash; various mixtures of these materials; and various organic binders (e.g., asphalt). The mixing of the waste and the S/S agents can occur outside of the ground (ex situ) in continuous feed or batch operations or in the ground (in situ) in a continuous feed operation. The final product can be a continuous solid mass of any size or of a granular consistency resembling soil. During in situ operations, S/S agents are injected into and mixed with the waste and soil up to depths of 30 to 100 feet using augers.

Treatability studies are the only means of documenting the applicability and performance of a particular S/S system. Determination of the best treatment alternative will be based on multiple site-specific factors and the cost and efficacy of the treatment technology. The EPA contact identified at the end of this bulletin can assist in the location of other contacts and sources of information necessary for such treatability studies.

It may be difficult to evaluate the long-term (>5 year) performance of the technology. Therefore, long-term monitoring may be needed to ensure that the technology continues to function within its design criteria.

This bulletin provides information on technology applicability, the limitations of the technology, the technology description, the types of residuals produced, site requirements, the process performance data, the status of the technology, and sources for further information.

Technology Applicability

The U.S. EPA has established treatment standards under the Resource Conservation and Recovery Act (RCRA), Land Disposal Restrictions (LDRs) based on Best Demonstrated Available Technology (BDAT) rather than on risk-based or health-based standards. There are three types of LDR treatment standards based on the following: achieving a specified concentration level, using a specified technology prior to disposal, and "no land disposal." Achieving a specified concentration level is the most common type of treatment standard. When a concentration level to be achieved is specified for a waste, any technology that can meet the standard may be used unless that technology is otherwise prohibited [2].

The Superfund policy on use of immobilization is as follows: "Immobilization is generally appropriate as a treatment alternative only for material containing inorganics, semi-volatile and/or non-volatile organics. Based on present information, the Agency does not believe that immobilization is an appropriate treatment alternative for volatile organic compounds (VOCs). Selection of immobilization of semi-volatile compounds (SVOCs) and non-volatile organics generally requires the performance of

*[reference number, page number]

a site-specific treatability study or non-site-specific treatability study data generated on waste which is very similar (in terms of type of contaminant, concentration, and waste matrix) to that to be treated and that demonstrates, through Total Waste Analysis (TWA), a significant reduction (e.g., a 90 to 99 percent reduction) in the concentration of chemical constituents of concern. The 90 to 99 percent reduction in contaminant concentration is a general guidance and may be varied within a reasonable range considering the effectiveness of the technology and the cleanup goals for the site. Although this policy represents EPA's strong belief that TWA should be used to demonstrate effectiveness of immobilization for organics, other leachability tests may also be appropriate in addition to TWA to evaluate the protectiveness under a specific management scenario. "To measure the effectiveness on inorganics, the EPA's Toxicity Characteristic Leaching Procedure (TCLP) should be used in conjunction with other tests such as TCLP using distilled water or American Nuclear Society (ANS) 16.1 [3, p. 2].

Factors considered most important in the selection of a technology are design, implementation, and performance of S/S processes and products, including the waste characteristics (chemical and physical), processing requirements, S/S product management objectives, regulatory requirements, and economics. These and other site-specific factors (e.g., location, condition, climate, hydrology, etc.) must be taken into account in determining whether, how, where, and to what extent a particular S/S method should be used at a particular site [4, p. 7.92]. Pozzolanic S/S processes can be formulated to set under water if necessary; however, this may require different proportions of fixing and binding agents to achieve the desired immobilization and is not generally recommended [5, p. 21]. Where non-pumpable sludge or solid wastes are encountered, the site must be able to support the heavy equipment required for excavation or in situ injection and mixing. At some waste disposal sites, this may require site engineering.

A wide range of performance tests may be performed in conjunction with S/S treatability studies to evaluate short- and long-term stability of the treated material. These include total waste analysis for organics, leachability using various methods, permeability, unconfined compressive strength (UCS), treated waste and/or leachate toxicity endpoints, and freeze/thaw and wet/dry weathering cycle tests performed according to specific procedures [6, p. 4.2] [7, p. 4.1]. Treatability studies should be conducted on replicate samples from a representative set of waste batches that span the expected range of physical and chemical properties to be encountered at the site [8, p. 1].

The most common fixing and binding agents for S/S are cement, lime, natural pozzolans, and fly ash, and mixtures of these [4, p. 7.86] [6, p. 2.1]. They have been demonstrated to immobilize many heavy metals and to solidify a wide variety of wastes including spent pickle liquor, contaminated soils, incinerator ash, wastewater treatment filter cake, and waste sludge [7, p. 3.1] [9]. S/S is also effective in immobilizing many radionuclides [10]. In general, S/S is considered an established full-scale technology for nonvolatile heavy metals although the long-term performance of S/S in Superfund applications has yet to be demonstrated [2].

Traditional cement and pozzolanic materials have yet to be shown to be consistently effective in full-scale applications treating wastes high in oil and grease, surfactants, or chelating agents without some form of pretreatment [11] [12, p. 122]. Pretreatment methods include pH adjustment, steam or thermal stripping, solvent extraction, chemical or photochemical reaction, and biodegradation. The addition of sorbents such as modified clay or powdered activated carbon may improve cement-based or pozzolanic process performance [6, p. 2.3].

Regulations promulgated pursuant to the Toxic Substances Control Act (TSCA) do not recognize S/S as an approved treatment for wastes containing polychlorinated biphenyls (PCBs) above 50 ppm. It is EPA policy that soils containing greater than 10 ppm in public/residential areas and 25 ppm in limited access/occupational areas be removed for TSCA-approved treatment/disposal. However, the policy also provides EPA regional offices with the option of requiring more restrictive levels. For example, Region 5 requires a cleanup level of 2 ppm. The proper disposition of high volume sludges, soils, and sediments is not specified in the TSCA regulations, but precedents set in the development of various records of decision (RODs) indicate that stabilization may be approved where PCBs are effectively immobilized and/or destroyed to TSCA-equivalent levels. Some degree of immobilization of PCBs and related polychlorinated polycyclic compounds appears to occur in cement or pozzolans [15, p. 1573]. Some field observations suggest polychlorinated polycyclic organic substances such as PCBs undergo significant levels of dechlorination under the alkaline conditions encountered in pozzolanic processes. Recent tests by the EPA, however, have not confirmed these results although significant desorption and volatilization of the PCBs were documented [13, p. 41] [14, p. 3].

Table 1 summarizes the effectiveness of S/S on general contaminant groups for soils and sludges. Table 1 was prepared based on current available information or on professional judgment when no information was available. In interpreting this table, the reader is cautioned that for some primary constituents, a particular S/S technology performs adequately in some concentration ranges but inadequately in others. For example, copper, lead, and zinc are readily stabilized by cementitious materials at low to moderate concentrations, but interfere with those processes at higher concentrations [12, p. 43]. In general, S/S methods tend to be most effective for immobilizing nonvolatile heavy metals.

The proven effectiveness of the technology for a particular site or waste does not ensure that it will be effective at all sites or that treatment efficiencies achieved will be acceptable at other sites. For the ratings used in Table 1, demonstrated effectiveness means that at some scale, treatability tests showed that the technology was effective for that particular contaminant and matrix. The ratings of "Potential Effectiveness" and "No Expected Effectiveness" are both based upon expert judgment. When potential effectiveness is indicated, the technology is believed capable of successfully treating the contaminant group in a particular matrix. When the technology is not applicable or will probably not work for a particular combination of contaminant group and matrix, a no expected effectiveness rating is given.

Table 1
Effectiveness of S/S on General Contaminant Groups for Soil and Sludges

	Contaminant Groups	Effectiveness Soil/Sludge
Organic	Halogenated volatiles	□
	Nonhalogenated volatiles	□
	Halogenated semivolatiles	■
	Nonhalogenated semivolatiles and nonvolatiles	■
	PCBs	▼
	Pesticides	▼
	Dioxins/Furans	▼
	Organic cyanides	▼
	Organic corrosives	▼
Inorganic	Volatile metals	■
	Nonvolatile metals	■
	Asbestos	■
	Radioactive materials	■
	Inorganic corrosives	■
	Inorganic cyanides	■
Reactive	Oxidizers	■
	Reducers	■

KEY:
■ Demonstrated Effectiveness: Successful treatability test at some scale completed.
▼ Potential Effectiveness: Expert opinion that technology will work.
□ No Expected Effectiveness: Expert opinion that technology will/does not work.

Another source of general observations and average removal efficiencies for different treatability groups is contained in the Superfund LDR Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions," (OSWER Directive 9347.3-06FS, September 1990) [16] and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions," (OSWER Directive 9347.3-06BFS, September 1990) [17]. Performance data presented in this bulletin should not be considered directly applicable to other Superfund sites. A number of variables such as the specific mix and distribution of contaminants affect system performance. A thorough characterization of the site and a well-designed and conducted treatability study are highly recommended.

Other sources of information include the U.S. EPA's Risk Reduction Engineering Laboratory Treatability Database (accessible via ATTIC) and the U.S. EPA Center Hill Database (contact Patricia Erickson).

Technology Limitations

Tables 2 and 3 summarize factors that may interfere with stabilization and solidification processes respectively.

Physical mechanisms that can interfere with the S/S process include incomplete mixing due to the presence of high moisture or organic chemical content resulting in only partial wetting or coating of the waste particles with the stabilizing and binding agents and the aggregation of untreated waste into lumps [6]. Wastes with a high clay content may clump, interfering with the uniform mixing with the S/S agents, or the clay surface may adsorb key reactants, interrupting the polymerization chemistry of the S/S agents. Wastes with a high hydrophilic organic content may interfere with solidification by disrupting the gel structure of the curing cement or pozzolanic mixture [11, p. 18] [18]. The potential for undermixing is greatest for dry or pasty wastes and least for freely flowing slurries [11, p. 13]. All in situ systems must provide for the introduction and mixing of the S/S agents with the waste in the proper proportions in the surface or subsurface waste site environment. Quality control is inherently more difficult with in situ products than with ex situ products [4, p. 7.95].

Chemical mechanisms that can interfere with S/S of cement-based systems include chemical adsorption, complexation, precipitation, and nucleation [1, p. 82]. Known inorganic chemical interferants in cement-based S/S processes include copper, lead, and zinc, and the sodium salts of arsenate, borate, phosphate, iodate, and sulfide [6, p. 2.13] [12, p. 11]. Sulfate interference can be mitigated by using a cement material with a low tricalcium aluminate content (e.g., Type V Portland cement) [6, p. 2.13]. Problematic organic interferants include oil and grease, phenols [8, p. 19], surfactants, chelating agents [11, p. 22], and ethylene glycol [18]. For thermoplastic micro- and macro-encapsulation, stabilization of a waste containing strong oxidizing agents reactive toward rubber or asphalt must also be avoided [19, p. 10.114]. Pretreating the wastes to chemically or biochemically react or to thermally or chemically extract potential interferants should minimize these problems, but the cost advantage of S/S may be lost, depending on the characteristics and volume of the waste and the type and degree of pretreatment required. Organic polymer additives in various stages of development and field testing may significantly improve the performance of the cementitious and pozzolanic S/S agents with respect to immobilization of organic substances, even without the addition of sorbents.

Volume increases associated with the addition of S/S agents to the waste may prevent returning the waste to the landform from which it was excavated where landfill volume is limited. Where post-closure earthmoving and landscaping are required, the treated waste must be able to support the weight of heavy equipment. The EPA recommends a minimum compressive strength of 50 to 200 psi [7, p. 4.13]; however, this should be a site-specific determination.

Environmental conditions must be considered in determining whether and when to implement an S/S technology. Extremes of heat, cold, and precipitation can adversely affect S/S applications. For example, the viscosity of one or more of the

Table 2.
Summary of Factors that May Interfere with Stabilization Processes *

Characteristics Affecting Processing Feasibility	*Potential Interference*
VOCs	Volatiles not effectively immobilized; driven off by heat of reaction. Sludges and soils containing volatile organics can be treated using a heated extruder evaporator or other means to evaporate free water and VOCs prior to mixing with stabilizing agents.
Use of acidic sorbent with metal hydroxide wastes	Solubilizes metal.
Use of acidic sorbent with cyanide wastes	Releases hydrogen cyanide.
Use of acidic sorbent with waste containing ammonium compounds	Releases ammonia gas.
Use of acidic sorbent with sulfide wastes	Releases hydrogen sulfide.
Use of alkaline sorbent (containing carbonates such as calcite or dolomite) with acid waste	May create pyrophoric waste.
Use of siliceous sorbent (soil, fly ash) with hydrofluoric acid waste	May produce soluble fluorosilicates.
Presence of anions in acidic solutions that form soluble calcium salts (e.g., calcium chloride acetate, and bicarbonate)	Cation exchange reactions - leach calcium from S/S product increases permeability of concrete, increases rate of exchange reactions.
Presence of halides	Easily leached from cement and lime.

* Adapted from reference 2

Table 3.
Summary of Factors that May Interfere with Solidification Processes *

Characteristics Affecting Processing Feasibility	*Potential Interference*
Organic compounds	Organics may interfere with bonding of waste materials with inorganic binders.
Semivolatile organics or poly-aromatic hydrocarbons (PAHs)	Organics may interfere with bonding of waste materials.
Oil and grease	Weaken bonds between waste particles and cement by coating the particles. Decrease in unconfined compressive strength with increased concentrations of oil and grease.
Fine particle size	Insoluble material passing through a No. 200 mesh sieve can delay setting and curing. Small particles can also coat larger particles, weakening bonds between particles and cement or other reagents. Particle size >1/4 inch in diameter not suitable.
Halides	May retard setting, easily leached for cement and pozzolan S/S. May dehydrate thermoplastic solidification.
Soluble salts of manganese, tin, zinc, copper, and lead	Reduced physical strength of final product caused by large variations in setting time and reduced dimensional stability of the cured matrix, thereby increasing leachability potential.
Cyanides	Cyanides interfere with bonding of waste materials.
Sodium arsenate, borates, phosphates, iodates, sulfides, and carbohydrates	Retard setting and curing and weaken strength of final product.
Sulfates	Retard setting and cause swelling and spalling in cement S/S. With thermoplastic solidification may dehydrate and rehydrate, causing splitting.

* Adapted from reference 2

Table 3
Summary of Factors that May Interfere with Solidification Processes * (continued)

Characteristics Affecting Processing Feasibility	*Potential Interference*
Phenols	Marked decreases in compressive strength for high phenol levels.
Presence of coal or lignite	Coals and lignites can cause problems with setting, curing, and strength of the end product.
Sodium borate, calcium sulfate, potassium dichromate, and carbohydrates	Interferes with pozzolanic reactions that depend on formation of calcium silicate and aluminate hydrates.
Nonpolar organics (oil, grease, aromatic hydrocarbons, PCBs)	May impede setting of cement, pozzolan, or organic-polymer S/S. May decrease long-term durability and allow escape of volatiles during mixing. With thermoplastic S/S, organics may vaporize from heat.
Polar organics (alcohols, phenols, organic acids, glycols)	With cement or pozzolan S/S, high concentrations of phenol may retard setting and may decrease short-term durability; all may decrease long-term durability. With thermoplastic S/S, organics may vaporize. Alcohols may retard setting of pozzolans.
Solid organics (plastics, tars, resins)	Ineffective with urea formaldehyde polymers; may retard setting of other polymers.
Oxidizers (sodium hypochlorite, potassium permanganate, nitric acid, or potassium dichromate)	May cause matrix breakdown or fire with thermoplastic or organic polymer S/S.
Metals (lead, chromium, cadmium, arsenic, mercury)	May increase setting time of cements if concentration is high.
Nitrates, cyanides	Increase setting time, decrease durability for cement-based S/S.
Soluble salts of magnesium, tin, zinc, copper and lead	May cause swelling and cracking within inorganic matrix exposing more surface area to leaching.
Environmental/waste conditions that lower the pH of matrix	Eventual matrix deterioration.
Flocculants (e.g., ferric chloride)	Interference with setting of cements and pozzolans.
Soluble sulfates >0.01% in soil or 150 mg/L in water	Endangerment of cement products due to sulfur attack.
Soluble sulfates >0.5% in soil or 2000 mg/L in water	Serious effects on cement products from sulfur attacks.
Oil, grease, lead, copper, zinc, and phenol	Deleterious to strength and durability of cement, lime/fly ash, fly ash/cement binders.
Aliphatic and aromatic hydrocarbons	Increase set time for cement.
Chlorinated organics	May increase set time and decrease durability of cement if concentration is high.
Metal salts and complexes	Increase set time and decrease durability for cement or clay/cement.
Inorganic acids	Decrease durability for cement (Portland Type I) or clay/cement.
Inorganic bases	Decrease durability for clay/cement; KOH and NaOH decrease durability for Portland cement Type III and IV.

* Adapted from reference 2

materials in the mixture may increase rapidly with falling temperatures or the cure rate may be slowed unacceptably [20, p. 27]. In cement-based S/S processes the engineering properties of the concrete mass produced for the treatment of the waste are highly dependent on the water/cement ratio and the degree of hydration of the cement. High water/cement ratios yield large pore sizes and thus higher permeabilities [21, p. 177]. This factor may not be readily controlled in environmental applications of S/S and pretreatment (e.g., drying) of the waste may be required.

Depending on the waste and binding agents involved, S/S processes can produce hot gases, including vapors that are potentially toxic, irritating, or noxious to workers or communities downwind from the processes [22, p. 4]. Laboratory tests demonstrate that as much as 90 percent of VOCs are volatilized during solidification and as much as 60 percent of the remaining VOCs are lost in the next 30 days of curing [23, p. 6]. In addition, if volatile substances with low flash points are involved, the potential exists for fire and explosions where the fuel-to-air ratio is favorable [22, p. 4]. Where volatization problems are anticipated, many S/S systems now provide for vapor collection and treatment. Under dry and/or windy environmental conditions, both ex situ and in situ S/S processes are likely to generate fugitive dust with potentially harmful impacts on occupational and public health, especially for downwind communities.

Scaleup for S/S processes from bench-scale to full-scale operation involves inherent uncertainties. Variables such as ingredient flow-rate control, materials mass balance, mixing, and materials handling and storage, along with the weather compared to the more controlled environment of a laboratory, all may affect the success of a field operation. These potential engineering difficulties emphasize the need for a field demonstration prior to full-scale implementation [2].

Technology Description

Waste stabilization involves the addition of a binder to a waste to immobilize waste contaminants effectively. Waste solidification involves the addition of a binding agent to the waste to form a solid material. Solidifying waste improves its material handling characteristics and reduces permeability to leaching agents such as water, brine, and inorganic and organic acids by reducing waste porosity and exposed surface area. Solidification also increases the load-bearing capacity of the treated waste, an advantage when heavy equipment is involved. Because of their dilution effect, the addition of binders must be accounted for when determining reductions in concentrations of hazardous constituents in S/S treated waste.

S/S processes are often divided into the following broad categories: inorganic processes (cement and pozzolanic) and organic processes (thermoplastic and thermosetting). Generic S/S processes involve materials that are well known and readily available. Commercial vendors have typically developed generic processes into proprietary processes by adding special additives to provide better control of the S/S process or to enhance specific chemical or physical properties of the treated waste. Less frequently, S/S processes combine organic binders with inorganic binders (e.g., diatomaceous earth and cement with polystyrene, polyurethane with cement, and polymer gels with silicate and lime cement) [2].

The waste can be mixed in a batch or continuous system with the binding agents after removal (ex situ) or in place (in-situ). In ex situ applications, the resultant slurry can be 1) poured into containers (e.g., 55-gallon drums) or molds for curing and then off- or onsite disposal, 2) disposed in onsite waste management cells or trenches, 3) injected into the subsurface environment, or 4) re-used as construction material with the appropriate regulatory approvals. In in situ applications, the S/S agents are injected into the subsurface environment in the proper proportions and mixed with the waste using backhoes for surface mixing or augers for deep mixing [5]. Liquid waste may be pretreated to separate solids from liquids. Solid wastes may also require pretreatment in the form of pH adjustment, steam or thermal stripping, solvent extraction, chemical reaction, or biodegradation to remove excessive VOCs and SVOCs that may react with the S/S process. The type and proportions of binding agents are adjusted to the specific properties of the waste to achieve the desired physical and chemical characteristics of the waste appropriate to the conditions at the site based on bench-scale tests. Although ratios of waste-to-binding agents are typically in the range of 10:1 to 2:1, ratios as low as 1:4 have been reported. However, projects utilizing low waste-to-binder ratios have high costs and large volume expansion.

Figures 1 and 2 depict generic elements of typical ex situ and in situ S/S processes, respectively. Ex situ processing involves: (1) excavation to remove the contaminated waste from the subsurface; (2) classification to remove oversize debris; (3) mixing; and (4) off-gas treatment. In situ processing has only two steps: (1) mixing; and (2) off-gas treatment. Both processes require a system for delivering water, waste, and S/S agents in proper proportions and a mixing device (e.g., rotary drum paddle or auger). Ex situ processing requires a system for delivering the treated waste to molds, surface trenches, or subsurface injection. The need for off-gas treatment using vapor collection and treatment modules is specific to the S/S project.

Process Residuals

Under normal operating conditions neither ex situ nor in situ S/S technologies generate significant quantities of contaminated liquid or solid waste. Certain S/S projects require treatment of the offgas. Prescreening collects debris and materials too large for subsequent treatment.

If the treated waste meets the specified cleanup levels, it could be considered for reuse onsite as backfill or construction material. In some instances, treated waste may have to be disposed of in an approved landfill. Hazardous residuals from some pretreatment technologies must be disposed of according to appropriate procedures.

Figure 1.
Generic Elements of a Typical Ex Situ S/S Process

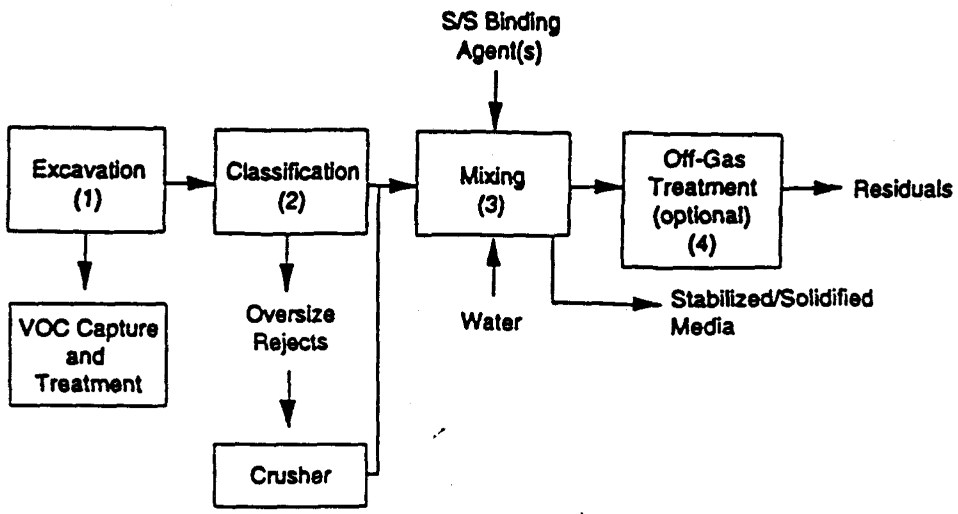
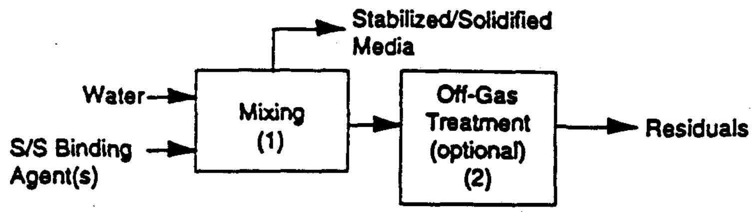


Figure 2.
Generic Elements of a Typical In Situ S/S Process



Site Requirements

The site must be prepared for the construction, operation, maintenance, decontamination, and ultimate decommissioning of the equipment. An area must be cleared for heavy equipment access roads, automobile and truck parking lots, material transfer stations, the S/S process equipment, set up areas, decontamination areas, the electrical generator, equipment sheds, storage tanks, sanitary and process wastewater collection and treatment systems, workers' quarters, and approved disposal facilities (if required). The size of the area required for the process equipment depends on several factors, including the type of S/S process involved, the required treatment capacity of the system, and site characteristics, especially soil topography and load-bearing capacity. A small mobile ex situ unit could occupy a space as small as that taken up by two standard flatbed trailers. An in situ system requires a larger area to accommodate a drilling rig as well as a larger area for auger decontamination.

Process, decontamination, transfer, and storage areas should be constructed on impermeable pads with berms for spill retention and drains for the collection and treatment of stormwater runoff. Stormwater storage and treatment capacity requirements will depend on the size of the bermed area and the local climate. Standard 440V, three-phase electrical service is usually needed. The quantity and quality of process water required for pozzolanic S/S technologies are technology-specific.

S/S process quality control requires information on the range of concentrations of contaminants and potential interferants in waste batches awaiting treatment and on treated product properties such as compressive strength, permeability, leachability, and in some instances, contaminant toxicity.

Performance Data

Most of the data on S/S performance come from studies conducted for EPA's Risk Reduction Engineering Laboratory under the Superfund Innovative Technology Evaluation (SITE) Program. Pilot scale demonstration studies available for review during the preparation of this bulletin included: Soliditech, Inc. at Morganville, New Jersey (petroleum hydrocarbons, PCBs, other organic chemicals, and heavy metals); International Waste Technologies (IWT) process using the Geo-Con, Inc. deep-soil-mixing equipment, at Hialeah, Florida (PCBs, VOCs); Chemfix Technologies, Inc., at Clackamas, Oregon (PCBs, arsenic, heavy metals); Im-Tech (formerly Hazcon) at Douglassville, Pennsylvania (oil and grease, heavy metals including lead, and low levels of VOCs and PCBs); Silicate Technology Corporation (STC), at Selma, California (arsenic, chromium, copper, pentachlorophenol and associated polychlorinated dibenzofurans and dibenzo-p-dioxins). The performance of each technology was evaluated in terms of ease of operation, processing capacity, frequency of process outages, residuals management, cost, and the characteristics of the treated product. Such characteristics included weight, density, and volume changes; UCS and moisture content of the treated product before and after freeze/thaw and wet/dry weathering cycles; permeability (or permissivity) to water; and leachability following curing and after the weathering test cycles. Leachability was measured using several different standard methods, including EPA's TCLP. Table 4 summarizes the SITE performance data from these sites [20] [24] [25] [26] [27] [28].

A full-scale S/S operation has been implemented at the Northern Engraving Corporation (NEC) site in Sparta, Wisconsin, a manufacturing facility which produces metal name plates and dials for the automotive industry. The following information on the site is taken from the remedial action report. Four areas at the site that have been identified as potential sources of soil, groundwater, and surface water contamination are the sludge lagoon, seepage pit, sludge dump site, and lagoon drainage ditch. The sludge lagoon was contaminated primarily with metal hydroxides consisting of nickel, copper, aluminum, fluoride, iron, and cadmium. The drainage ditch which showed elevated concentrations of copper, aluminum, fluoride, and chromium, was used to convey effluent from the sludge lagoon to a stormwater runoff ditch. The contaminated material in the drainage ditch area and sludge dumpsite was then excavated and transported into the sludge lagoon for stabilization with the sludge present. The vendor, Geo-Con, Inc., achieved stabilization by the addition of hydrated lime to the sludge. Five samples of the solidified sludge were collected for Extraction Procedure (EP) toxicity leaching analyses. Their contaminant concentrations (in mg/l) are as follows: Arsenic (<.01); Barium (.35 - 1.04); Cadmium (<.005); Chromium (<.01); Lead (<.2); Mercury (<.001); Selenium (<.005); Silver (<.01); and Fluoride (2.6 - 4.1). All extracts were not only below the EP toxicity criteria but (with the exception of fluoride) met drinking water standards as well.

Approximately three weeks later UCS tests on the solidified waste were taken. Test results ranged from 2.4 to 10 psi, well below the goal of 25 psi. One explanation for the low UCS could be due to shear failure along the lenses of sandy material and organic peat-like material present in the samples. It was determined that it would not be practical to add additional quantities of lime into the stabilized sludge matrix because of its high solids content. Therefore, the stabilized sludge matrix capacity will be increased to support the clay cap by installing an engineered subgrade for the cap system using a stabilization fabric and aggregate prior to cap placement [29].

The Industrial Waste Control (IWC) Site in Fort Smith, Arkansas, a closed and covered industrial landfill built in an abandoned surface coal mine, has also implemented a full-scale S/S system. Until 1978 painting wastes, solvents, industrial process wastes, and metals were disposed at the site. The primary contaminants of concern were methylene chloride, ethylbenzene, toluene, xylene, trichloroethane, chromium, and lead. Along with S/S of the onsite soils, other technologies used were: excavation, slurry wall, french drains, and a landfill cover. Soils were excavated in the contaminated region (Area C) and a total of seven lifts were stabilized with flyash on mixing pads previously formed. A clay liner was then constructed in Area C to serve as a leachate barrier. After the lifts passed the TCLP test they were taken to Area C for in situ solidification. Portland cement was added to solidify each lift and they obtained the UCS goal of 125 psi. With the combination of the other technologies, the overall system appears to be functioning properly [30].

Other Superfund sites where full scale S/S has been completed to date include Davie Landfill (82,158 yd^3 of sludge containing cyanide, sulfide, and lead treated with Type I Portland cement in 45 days) [31]; Pepper's Steel and Alloy (89,000 yd^3 of soil containing lead, arsenic, and PCBs treated with Portland cement and fly ash) [32]; and Sapp Battery and Salvage (200,000 yd^3 soil fines and washings containing lead and mercury treated with Portland cement and fly ash in roughly 18 months) [33], all in Region 4; and Bio-Ecology, Inc. (about 20,000 yd^3 of soils, sludge, and liquid waste containing heavy metals, VOCs, and cyanide treated with cement kiln flue dust alone or with lime) in Region 6 [34]. All sites required that the waste meet the appropriate leaching test and UCS criteria. At the Sapp Battery site, the waste also met a permeability criterion of 10^{-6} cm/s [33]. Past remediation appraisals by the responsible remedial project managers indicate the S/S technologies are performing as intended.

RCRA LDRs that require treatment of wastes based on BDAT levels prior to land disposal may sometimes be determined to be Applicable or Relevant and Appropriate Requirements (ARARs) for CERCLA response actions. S/S can produce a treated waste that meets treatment levels set by BDAT but may not reach these treatment levels in all cases. The ability to meet required treatment levels is dependent upon the specific waste constituents and the waste matrix. In cases where S/S does not meet these levels, it still may in certain situations be selected for use at a site if a treatability variance establishing alternative treatment levels is obtained. Treatability variances may be justified for handling complex soil and debris matrices. The following guides describe when and how to seek a treatability variance for soil and debris: Superfund LDR Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions" (OSWER Directive 9347.3-06FS) [16], and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions" (OSWER Directive 9347.3-06BFS) [17]. Another approach could be to use other treatment techniques in conjunction with S/S to obtain desired treatment levels.

Technology Status

In 1990, 24 RODs identified S/S as the proposed remediation technology [35]. To date only about a dozen Superfund sites have proceeded through full-scale S/S implementation to the operation and maintenance (O&M) phase, and many of those were small pits, ponds, and lagoons. Some involved S/S for off-site disposal in RCRA-permitted facilities. Table 5 summarizes these sites where full scale S/S has been implemented under CERCLA or RCRA [7, p. 3-4].

More than 75 percent of the vendors of S/S technologies use cement-based or pozzolanic mixtures [11, p. 2]. Organic polymers have been added to various cement-based systems to enhance performance with respect to one or more physical or

Table 4. Summary of SITE Performance Data

Site	Vendor Technology	Pretreatment	Post Treatment
Imperial Oil Co. / Champion Chemical Co. Morganville, NJ	Soliditech: Urrichem reagent, water, additives, Type II Portland cement	Bulk density: 1.14 to 1.26 g/cm^3 Permeability: Not determined UCS: Not determined Lead-TCLP Extract: 0.46 mg/l	Bulk density: 1.43 to 1.68 g/cm^3 Permeability: $8.9x10^{9}$ to $4.5x10^{7}$ cm/s UCS: 390 to 860 psi Lead-TCLP extract: <0.05 to <0.20 mg/l
GE Electrical Service Shop Hialeah, FL	IWT-DMS/Geo-Con: In situ injection of silicate additive	Bulk density: 1.55 g/ml Permeability: $1.8x10^{2}$ cm/s UCS: 1.2 to 1.85 psi	Bulk density: 1.88 g/ml Permeability: $0.24x10^{7}$ to $21x10^{7}$ cm/s UCS: 300 to 500 psi
Portable Equipment Salvage Co. Clackamas, OR	Chemfix: polysilicates and dry calcium containing reagents	TCLP-Extractable (Pb, Cu, Zn): 12 to 880 mg/l Hydraulic cond. (CSS-13): $2.4 x10^{4}$ to $2.7x10^{4}$ cm/s Bulk density: 2.0 to 2.6 g/cm^3	TCLP-Extractable (Pb, Cu, Zn): 0.024 to 47 mg/l Hydraulic cond. (CSS-14): $4.6x10^{7}$ to $1.2x10^{4}$ cm/s Bulk density: 1.6 to 2.0 g/cm^3 USC (14, 21, 28 days): 131, 136, 143 psi Immersion UCS (30, 60, 90 days): 177, 188, 204 psi
Douglasville Douglasville, PA	Imtech (Hazcon): Chloranan™, water and cement	Bulk density: 1.23 g/ml Permeability: 0.57 cm/s TCLP-Extractable Pb: 52.6 mg/l	Bulk density (7, 28 days): 1.95, 1.99 g/ml Permeability (7, 28 days): $1.6x10^{9}$, $2.3x10^{9}$ cm/s TCLP-Extractable Pb (7, 28 days): 0.14, 0.05 mg/l UCS (7,28 days): 1447,113 psi
Selma Pressure Treating Wood Preserving Site Selma, CA	Silicate Tech Corp.: alumino-silicate compounds	Arsenic-TCLP: 1.06 to 3.33 ppm Arsenic-Distilled H_20 TCLP: 0.73 to 1.25 ppm PCP-TWA: 1983 to 8317 ppm Bulk density: 1.42 to 1.54 g/cm	Arsenic-TCLP: 0.086 to 0.875 ppm Arsenic-Distilled H_20 TCLP: < 0.01 to 0.012 ppm PCP-TWA: 14 to 158 ppm Bulk density: 1.57 to 1.62 g/cm Permeability: $0.8x10^{7}$ to $1.7x10^{7}$ cm/s UCS: 259 to 347 psi

UCS - Unconfined Compressive Strength
TCLP - Toxicity Characteristic Leaching Procedure
TWA - Total Waste Analysis

Table 5. Summary of Full Scale S/S Sites

Site	Contaminant	Physical Form	Binder	Percentage Binder(s) Added	Treatment (batch/ continuous In Situ)
Independent Nail, SC	Zn, Cr, Cd, Ni	Solid/soils	Portland cement	20%	Batch Plant
Midwest, US Plating Company	Cu, Cr, Ni	Sludge	Portland cement	20%	In Situ
Unnamed	Pb/soil 2-100 ppm	Solid/soils	Portland cement and proprietary ingredient	Cement (15-20%) proprietary (5%)	In Situ
Marathon Steel, Phoenix, AZ	Pb, Cd	Dry-landfill	Portland cement and silicates	Varied 7-15% (cement)	Concrete batch plant
Alaska Refinery	Oil/oil sludges	Sludges, variable	Portland cement and proprietary ingredient	Varied 50+	Concrete batch plant
Unnamed, Kentucky	Vinyl chloride Ethylene dichloride	Sludges, variable	Portland cement and proprietary ingredient	Varied 25+	In Situ
NE Refinery	Oil sludges, Pb, Cr, As	Sludges, variable	Kiln dust (high CaO content)	Varied, 15-30%	In Situ
Velsicol Chemical	Pesticides and organics (resins, etc.) up to 45% organic	Sludges, variable	Portland cement and kiln dust, proprietary ingredient	Varied (cement 5-15%)	In Situ
Amoco Wood River	Oil/solids Cd, Cr, Pb	Sludges	Proprietary ingredient	NA, proprietary	Continuous flow (proprietary)
Pepper Steel & Alloy, Miami, FL	Oil saturated soil Pb-1000 ppm PCBs-200 ppm As-1-200 ppm	Soils	Pozzolanic and proprietary ingredient	~30%	Continuous feed (mixer proprietary design)
Vickery, Ohio	Waste acid PCBs (<500 ppm) dioxins	Sludges (viscous)	Lime and kiln dust	~15% CaO ~5% kiln dust	In Situ
Wood Treating, Savannah, GA	Creosote wastes	Sludges	Kiln dust	20%	In Situ
Chem Refinery, TX	Combined metals, sulfur, oil sludges, etc.	Sludges (synthetic oil sludges)	Portland cement and proprietary ingredient	NA	Continuous flow
API Sep. Sludge, Puerto Rico	API separator sludges	Sludges	Portland cement and proprietary ingredient	50% cement ~4 % proprietary	Concrete batch plant
Metaplating, WI	Al-9500 ppm Ni-750 ppm Cr-220 ppm Cu-2000 ppm	Sludges	Lime	10-25%	In Situ

chemical characteristics, but only mixed results have been achieved. For example, tests of standardized wastes treated in a standardized fashion using acrylonitrile, vinyl ester, polymer cement, and water-based epoxy yielded mixed results. Vinyl and plastic cement products achieved superior UCS and leachability to cement-only and cement-fly ash S/S, while the acrylonitrile and epoxy polymers reduced UCS and increased leachable TOC, in several instances by two or three orders of magnitude [36, p. 156].

The estimated cost of treating waste with S/S ranges from $50 to 250 per ton (1992 dollars). Costs are highly variable due to variations in site, soil, and contaminant characteristics that affect the performance of the S/S processes evaluated. Economies of scale likely to be achieved in full-scale operations are not reflected in pilot-scale data.

EPA Contact

Technology-specific questions regarding S/S may be directed to:

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U.S. Environmental Protection Agency
Municipal Solid Waste and Residuals Management Branch
Risk Reduction Engineering Laboratory
5955 Center Hill Road
Cincinnati, OH 45224
Telephone: (513) 569-7795 or (513) 569-7884

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Appendix D - Information on DOE, DOD, and Other Experiences

Appendix D: Information on DOE, DOD and Other Experiences

Information presented in this appendix is the result of a DOE, DOD, and other facility survey. Information was obtained through phone queries and literature reviews. DOE site information is compiled in the "DOE/DOD Survey Form" questionnaire format. Information on DOD and other facilities was compiled through literature reviews and is presented in a narrative case study format following the DOE survey responses.

Attempts were made in all cases to talk with site personnel from both waste management and environmental restoration. Much of the following information is the result of efforts currently being done under the Federal Facilities Compliance Act (FFCA). It should be noted that specific information on environmental restoration sludges was difficult to obtain as many sites are still conducting site characterization. Supporting literature and references received from various sites are on file.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Example Survey Form ____________ Address: ______________________

Contact: ______________________ ______________________

Phone No: ______________________ Date: ______________________

1. **Description of Sludge** *(volume, physical location, waste type, HLW, LLMW, hazardous only)*:

2. **Sludge Characteristics** *(primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content, etc.)*:

3. **Type of Treatment Selected** *(immobilization, vitrification, dewatering):*

4. **On-Site/Off-Site Disposal** *(rationale):*

5. **Performance Requirements** *(final waste form, constituent concentration, land disposal restrictions)*:

6. **Cost and Schedule for Treatment** *(total cost, estimate of total treatment time, current status)*:

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

8. **Regulatory Requirements** *(regulatory drivers, permits required, cleanup levels and criteria):*

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

10. **CAMU experience:**

11. **References** *(feasibility studies, treatment plans, personnel references)*:

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Argonne National Laboratory
Address: 9800 South Cass Avenue
Argonne, IL 60439

Contact: Hyo No
Phone No: 708-252-7401
Date: August 19, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   LLMW of unknown quantities (thousands of drums) and 100 yd^3 (375 55-gal. drums) of PCB mixed waste. The sludges are from retention tanks where the aqueous waste has settled out. The waste stream is evaporated concentrator bottom. The waste was HEPA filter media and tested as mixed waste.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content, etc.)*:

   Information on two types of sludges: (1) primary contaminants include radioactive (^{60}Co, ^{137}Cs) and heavy metals and (2) primary contaminants are PCBs and radionuclides (tritium).

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Two types of treatment for the first sludge are under consideration and study:

   a) *In situ* vitrification. Currently in the 2nd phase of study (bench scale testing). The results have been very satisfactory.

   b) Cementation for LL radioactive waste and metals (larger volumes must have TCLP testing).

   The treatments under consideration for the PCB sludge are solvent-washing, thermal adsorption or super critical CO_2 extraction.

4. **On-Site / Off-Site Disposal** *(rationale for decision if available)*:

   Plans for the mixed waste sludge are to convert waste to LLW and ship to Hanford, but is subject to change.

   Plans for the PCB sludge are to ship PCB liquid to a commercial facility and the radioactive waste to Hanford.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

MW sludge: treat to LDR standard
PCB sludge: remove PCBs down to 6 ppm (total PCBs) or 2 ppm Aroclor isomer.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Cost is unknown at this time, and the schedule indicates that completion will be near 2000 because of lengthy review cycles.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   In situ vitrification: 100 kg/day (100 kg of glass per day)

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Mixed waste sludge: RCRA, NEPA, EPA (currently seeking EPA treatability study approval (allowing the treatment of 1000 kg of waste)

   PCB sludge: TOSCA-mixed. Currently seeking demonstration permit. Must have a treatability study to build apparatus for treatment.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   The process of volume estimation and characterization for ER waste is in progress. Mixed-waste sludge: focus is on "locking-up" the heavy metals, so the sludge-waste can be transported as LL solid waste. This can be accomplished by containing the metals in the glass matrix and studies have shown this to be successful.

   PCB sludge: The major pitfall has been the fact that waste containing radioactives can not be incinerated. Radioactives cannot be "carried-over." Also, a tremendous amount of data is required to "prove" there are no radioactives in the final waste.

10. **CAMU experience:**

    August 29, 1994. Contacted Robert Swale to acquire information on the rationale for treatment selection. He wasn't familiar with CAMU and could not think of a reason they would implement it. Argonne's mission to remove the waste from the site. They are internally focused on off-site disposal. In lieu of this, the CAMUs would not be considered at Argonne.

11. **References**:

    Preliminary study, Second phase study, EPA treatability study, Conceptual Site Treatment Report (CSTR).

    Other contacts:
    Robert Swale 708-252-6526 *provided information on PCB sludge
    Mike Sodaro 708-252-6868 (referred Hyo No)
    Jim Cunnane (referred to the above contacts)

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Brookhaven National Laboratory

Contact: Paul Kald

Phone No: 516-282-7644

Address: 16 South Railroad Street

Upton, Ny 11973

Date: August 22, 1994

* August 29, 1994 contacted Glen Todzia (615-282-7488), as referenced by Peter Kwasychn. He provided most of the following information.

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Currently still in the characterization process and no decisions have been made. The technology demonstrations currently in process are for other waste streams besides the subject sludge (MLLW). They also have sewage and digestive bed sludge that they are storing in B-25 containers (Argonne bins) and will probably ship to Hanford.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Not provided during this survey.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Still in the characterization process. However, they have done the initial solidification of the waste.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   N/A

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   N/A

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Not provided.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Note: Paul Kald of Environmental and Waste Technology is in the process of developing options to treat waste including sludge. One option is thermal plastic encapsulation, which includes polyethylene and sulfur polymer. The binder material is melted, the mixed waste cools and forms a solid waste. Mr. Kald stated that their R & D work came out of the problems encountered when evaluating the cement grout option. The chemical interactions between waste and binder were found to contribute to the degeneration of the waste form over time. Therefore, the R & D was initiated. Thermal Plastic Encapsulation does not require chemical processing.

10. **CAMU experience:**

    Mr. Todzia had heard of CAMU, but it is premature to speculate on their selection. It is likely that it will not apply, as the latest sample analysis reveals that the sludge is not a mixed waste after-all, but only radioactive material. Therefore, it will not be subject to RCRA, or CAMU. This will be determined after the last samples are analyzed (currently in the laboratory).

11. **References**:

    A. J. Francis, 516-282-7813 (info. on citric acid, bioremediation, and photodegradation processes.
    Peter Kwaschyn, 516-282-4235, Waste Management (referred by Paul Kald).

DOE/DOD SURVEY FORM

Site: Colonie Interim Storage Site
Contact: Ed McNamea
Phone No: 615-576-4274

Address:

Date: September 2, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Two different sludges, each approximately 60 gal.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Specific details not provided.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   First batch of sludge was treated using "brute-force" oxidation. This sludge contained items such as rubber gloves and glass tubes. Therefore, it was ground to a fine material, then Nitric and Hydrocloric Acid were added to the mixture. It met LDRs after sampling and was shiped to Envirocare. Currently they are treating the second batch of sludge. This waste will require ferrous chloride and hydrogen peroxide. As with the first waste, they will solidify by cementation and ship to Envirocare.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site, Envirocare.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Final waste form was cement in drums.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   About 3 drums per day

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA regulated.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Lessons learned: Previous solidification tests ran used petro-cet which does not give a typical monolith like portland cement (it is more like a gel). If there is no concern about free liquids, this would be sufficient. However, the metals were low enough in this waste to use the portland cement, which was preferred. Noted that the volume of waste triples when using cement.

10. **CAMU experience:**

    They have heard of CAMUs, however it would not apply to this RCRA waste, nor do they have a large enough quantity to justify it.

11. **References**:

    Site Treatment Plan

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Fernald

Contact: Dave Rast, Manager

Phone No: 513-648-3138

Date: August 19, 1994

Address: U.S. DOE, ORO, Fernald
Environmental Projects
P. O. Box 398705
Cincinnati, OH 45239

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Six waste pits containing 720,000 yds^3 of sludge exist at the Fernald Site. Waste pit #4 is considered LLMW, however, much of the material has been removed from the mixed-waste listing. The sludge is currently stored on site in drums and containment. Pits 1 through 3, currently buried, have not been classified as mixed waste at this time. The pits were closed before the passage of RCRA and, therefore, cannot be classified until excavated.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Metals (Ba) and Radionuclides (U). No organics. Approximately 60 to 70% solids.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Chemical stabilization on site. Precipitation of barium components from barium chloride to barium sulfate.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Excavation, immobilization, bulk transport for disposal at Envirocare of Utah.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Must meet Envirocare waste acceptance criteria.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Treatment is scheduled to begin in 1997, and is a 5 year, $100 million process.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Unknown

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA and CERCLA. Does not intend to permit any mixed-waste facilities. The facility at Fernald is intended exclusively for treatment of mixed waste generated at Fernald. No treatment permit, no on-site storage. Although permits are an administrative requirement of CERCLA, Fernald will never have a standing permit. The program plans to operate under a work plan.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Constraints include being forbidden from taking mixed-waste off-site before permission from the Ohio EPA is granted.

10. **CAMU experience:**

    August 29, 1994. Contacted Mr. Rast regarding rationale for treatment options and information on CAMU. He stated that they have considered CAMU on some of their waste sites and are currently implementing it under the CERCLA "Area of Contamination" rules in some places. He said its implementation is a judgment call. They classified all solid waste landfills together using CAMUs. However, they will not put the waste back into the pits. They disposed sample material and soil cuttings back into the pits under this rule (i.e., ER waste). They will transport waste off-site because the pits are sitting on top of an aquifer and it is not an appropriate response to cap them and leave them in place. Some pits reach into the aquifer. This option would not be protective.

11. **References**:

    Feasibility Study (currently out for public comment)
    FFCA Compliance - Mixed Waste Treatment (recently published)

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: General Atomics
Contact: John Brock
Phone No: 619-455-3000

Address: P. O. Box 85608
San Diego, CA 92186-9784
Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   This facility has sludges from many different historical processes. They generate approximately 10 tons of liquid waste per year.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Detailed descriptions were not obtained in this survey.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   No treatment currently. They usually ship to a facility depending on the contaminants. The non-organics are processed through a filter for heavy metals and the water is discharged. The remaining filter cakes are disposed of in a landfill.

   Organic sludge is filtered, and filter cakes are sent to a landfill. Some compounds are recycled such as 1,1,-TCE.

   They are still in the process of looking at treatment/disposal options for mixed waste sludge. The Part A of CSTP is in process. The sludge first must be brought within anacceptable pH. They will probably not use concrete, but are looking into aqua sets or petri-set (Mike Dolphin).

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Plan to ship mixed waste off-site to Hanford.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not that far in the process yet. However, much of this will depend on what Hanford accepts.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   This information was not available.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   This is a RCRA facility.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   They are in the process of developing a scheme to deal with the flammable, corrosive properties of some hazardous sludge. Currently modifying a building to fire code. Attempting to find cost-effective technologies.

   Not using concrete because of the fact that ya better percentage can be obtained when you go to aqua-set versus concrete.

   Treatment Plan in preparation.

10. **CAMU experience:**

    N/A

11. **References**:

    Mike Dolphin: 619-455-2555

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Grand Junction Projects Office
Contact: Darlene DePinto
Phone No: 303-248-6576

Address: P.O. Box 2567
Grand Junction, CO 81502
Date: September 2, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   The only sludge stored at GJPO currently is the "Razo" sludge, a 5-gallon container.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Details not provided.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Information unavailable at the time of the survey.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Not provided.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not provided.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria)*:

   Not provided.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

Not provided.

10. **CAMU experience:**

Not provided.

11. **References:**

None provided.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Hanford
Contact: Owen Kruger
Phone No: 509-372-1463
Date: August 22, 1994

Address: Westinghouse Hanford
Hanford H-6-07
2440 Stevens Center Place
Richland, WA 99352

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Between 6,000 to 9,000 m^3 of sludges will be treated over an approximate 30 year period in the Waste Processing Facility at Hanford (on site). Currently the waste is stored in modules and buildings in the 200 area.

   Other sludges exist that will require thermal treatment which will be established through a commercial contract. The commercial company will treat through disposal. This material is currently undergoing study.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   In regard to the waste to be treated on-site, the primary contaminants are heavy metals and radionuclides.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Grout immobilization and polyethylene immobilization on-site.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   On-site RCRA trench.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   All RCRA requirements.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   The entire waste volume is 28,000 m^3 including Pb and Hg debris. The tentative start-up will be in 1999. Budgeting and scheduling are in process.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   The facility can process 29 ft^3/year per shift (3 shifts may be operated per day).

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Main regulatory driver is RCRA. Also driven by Tri-party agreement milestone (part of overall Hanford agreement). Hanford currently generates and stores MLLW and has an agreement that includes the State covering treatment and, therefore, they are not required to prepare a site-treatment plan.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not provided.

10. **CAMU experience:**

    Wade Fillingame (509-376-1589) provided the following valuable information:

    Hanford has opted not to follow the CAMU path, however, they were on a regulatory pathway to be permitted as a CAMU for waste from the remedial action by the river (amounts to millions of cubic yards). When EPA reviewed the option at Hanford, they decided not to go through with it. They felt that they could not defend it.

    Since they could not implement the CAMUs, things have been up in the air. Currently, they are doing more characterization to prove that there is less mixed waste than initially thought. They must prove that there is no hazardous constituent present in order to be able to say the waste is not LLMW. Based on costs assocatied with characterization, the idea of building a RCRA facility for MW is being pursued and they are now trying to apply CERCLA (DOE and EPA).

    CAMUs may have been a better idea. The waste must meet the 7 criteria for a CAMU. Hanford submitted the application, but EPA didn't know if they could defend it (not proven in court). Hanford has tried the CAMU route with no avail. CAMU's best selling point and danger is that you can use it to avoid full characterization and meeting LDRs with RCRA-type waste. They hoped to save money with this option, but were unable to do so.

    Finally, Mr. Fillingame referenced Connie Walker with A. T. Kearney in Denver (303-572-6175). Connie was one of the people who wrote the CAMU reg. for EPA and also worked for Hanford in preparation of their CAMU application.

11. **References:**

    Process Selection Summary, 1993. WAC-SD-W100-ES-006, Rev. 0, by R. A. Sexton, 1993.

    Darrel Duncan: 509-372-1013 (referred Owen Kruger - main contact).
    Dewey Burbank - (document references and papers on lessons learned) 509-372-0855.
    Barry Place: 509-372-1372, reference on waste held for thermal treatment - separate survey.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Idaho National Engineering Laboratory

Contact: Don Harrison

Phone No: 208-526-7514

Address:

Date: August 22, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   There are numerous sites with sludges that are currently undergoing characterization and assessment. Therefore, treatment options and information are incomplete. Waste Area Group 1 (WAG-1) is one example. Within this group there are 4.2 m^3 of LLW (metals and organics) that are scheduled for treatment under RCRA Subtitle C. There is also 15 m^3 of a sludge waste form. Treatment is not applicable as they plan to dispose of the material on-site.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Organics, metals.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Most of the sludges at INEL are scheduled for stabilization. The particular recipe for stabilization differs with each sludge. They have found that many of their sludges have high mercury concentrations. This has made it necessary for them to investigate the Mercury Retort Option, which they are currently evaluating.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   They have on-site and off-site options selected depending on material and volumes. Generally, off-site options are considered for RCRA waste at INEL. However, their ER waste (CERCLA) is treated differently.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not provided.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA, CERCLA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not provided.

10. **CAMU experience:**

    August 29, 1994, phone conversation with Bob Montgomery in Environmental Restoration (208-526-9339). Basically, no CAMUs are implemented at INEL, however there is a process that essentially does the same thing. In fact, Idaho has not adopted CAMU. Investigation-derived waste (CERCLA waste) is subject to a DOE policy that declares all of the INEL site to be one AOC. Basically, the RCRA CAMU supports this concept. The state of Idaho and EPA will not sign to this concept, but instead, will approve the same concept in their sampling and analysis plans that explain that residuals will be stored at INEL until a ROD is signed. EPA and the state will agree to this. The state of Idaho agreed that CERCLA waste generated during investigations can be taken to a RCRA facility, and will be subject to one year LDR requirements. This strategy has the same benefits of CAMUs. They have a strategy document that was the subject of a paper at "ER-93". However, they have no operational procedure. There is a final RCRA Part B - in action. They implement CERCLA in place of corrective action and avoid corrective action, whenever possible. All sites discovered by investigations are covered under CERCLA.

11. **References**:

    INEL's Draft Site Treatment Plan.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Institute for Toxicology, Environmental Health (former Laboratory for Energy Related Health)

Address

Contact: Alice Tackett

Date: August 31, 1994

Phone No: 916-752-1340

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Sludge is from animal feces processing. Most sludge has been previously disposed of at Hanford. There is a small volume left that is in the bottom of large septic tanks (about 2 m^3).

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Not discussed.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   The initial shipment of the waste was stabilized with magnesium-oxide flyash to a monolith.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site to Hanford.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Unknown.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not discussed.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   As of May, the site is listed with CERCLA. It used to be RCRA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   The site's RI work plan is currently undergoing review and approval. Therefore, the waste remaining has not been characterized. Thus, there are no experiences to share.

10. **CAMU experience:**

    N/A

11. **References:**

    Issue paper on stabilization.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Kansas City Plant
Contact: Joe Baker
Phone No: 816-997-7332
Date: August 22, 1994

Address: AlliedSignal, Inc.
2000 East 95th Street
Kansas City, MO 64141-6159

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Sludge was removed from two former lagoons, backfilled, and a RCRA clay cap was installed.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Metals, PCBs. The South Lagoon sludge was less aqueous and not dewatered. The North Lagoon was dewatered.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Dewatering on-site by belt filter press.

   Conditioned sludge was pumped to a recessed chamber press and dewatering occurred. Processed cake material was conveyed to trailers, 20 to 25 yd^3, for transportation. In order to facilitate the effectiveness of dewatering, hydrated lime was utilized as an additive in the raw sludge.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Disposal in permanent landfill.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   In 1985, RCRA requirements as in 40 CFR 265.310 (a)

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   No information is available on rates.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   The lagoons were decommissioned from 1985 to 1988. At this time, there were no landfill restrictions. This process would be more difficult today.

10. **CAMU experience:**

    N/A

11. **References**:

    Lagoon Site Closure Final Report, 1989.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Knolls Atomic Power

Address:

Contact: Ken Berta

Phone No: 203-244-7623

Date: August 29, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Total waste stream is 10 to 14 m^3 for the next five years.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Specific details not provided.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Knoll's approach is a simple RCRA solution. They will solidify and ship off-site. This was appropriate as the facility is only 10 acres and in the middle of a residential district. It is one of the smallest DOE facilities. Because of the small volume and limited space, this approach was the most reasonable and cost effective. Disposal will be at a larger facility.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not provided.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   The state of Connecticut has been very interested in the FFCA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   None

10. **CAMU experience:**

    Not appropriate for this small of a facility.

11. **References:**

    None provided.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Lawrence Berkeley Laboratory
Contact: Mark Lasrtemay
Phone No: 510-486-6825

Address: 1 Cyclotron Rd
Berkeley, CA 94720
Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   No radioactive or mixed waste sludges. Sludges from treatment of wastewater from electroplating operations.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   N/A

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   N/A

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   N/A

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   N/A

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   N/A

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   N/A

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

N/A

10. **CAMU experience:**

Not discussed.

11. **References:**

None provided.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Lawrence Livermore National Laboratory Address: P. O. Box 808, L-801
Livermore, CA 94550

Contact: John Bowers

Phone No: 510-422-7756 Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Filter cakes from the treatment of aqueos waste. Generates approximately 200 55-gal./drum per year of this LLMW. Not classified.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Metals, depleted uranium, 60% wet; diatomaceous earth.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Stabilization. Best demonstrated technology and simple to use.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Meet LDRs.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   200 drums per year.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   40 CFR 268

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

N/A

10. **CAMU experience:**

Not discussed.

11. **References**:

Draft treatment plan in preparation.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Los Alamos National Laboratory

Contact: Stan Zygumunt

Phone No: 505-667-8978

Address: P. O. Box 1663, MS E51
Los Alamos, NM 87546

Date: August 23, 1994

ER is in the early characterization process and very little information on any treatment options is available. Waste managment provided the following information obtained in this survey.

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Numerous drums of waste from operations: Uranium chip, plating, Pb brick decontamination and wastewater treatment. Mostly LLW.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Wastewater treatment sludge: lime
   Pb decontamination sludge: Pb and alumina
   Uranium chip sludge: U and heavy metals
   Plating operations sludge: metal sulfides

   Note that there are not "large" quantities of these sludges (except the wastewater treatment).

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Currently in process of evaluating options. The concept of portable treatment has ben suggested. The current plan is to build "skids" in the building providing the treatment rooms. Skids consist of several modules (treatment units built on metal frames). These portable treatment facilities may be shared between sites.

   It is currently planned that the wastewater treatment sludge (not a mixed waste) will be solidified by grout. Treatment for the other sludges is still under consideration.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   ER is planning to build a disposal facility on site for mixed waste. Options for non-RCRA waste include off-site disposal such as Envirocare or NTS.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   LDRs.

6. **Cost and Schedule for Treatment** *(te.g., otal cost, estimate of total treatment time, current status)*:

   Unknown at this time.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Uncertain at this time.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   The ER program at Los Alamos is scheduled to build a mixed-waste facility. The intent is for their site-wide EIS to include the disposal facility. Currently, the ER department will build the facility, but the WM department will run it. The critical question at this point is whether or not the facility will take the legacy waste and operating waste described in this survey. This has to do with public concept and the lengthy NEPA process.

10. **CAMU experience:**

    N/A

11. **References**:

    John Garry, Pantex, 806-477-6693 (given lead on evaluation committee for the process of stabilization and associated technologies).

    Ron Nakaoka, 505-667-7391

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Mound

Contact: Dan Capsch

Phone No: 513-865-4207

Address: P.O. Box 3000

Miamisburg, OH 45353-3000

Date: August 23, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Mound does not currently have any mixed waste sludge. However, they are still in the characterization process at some sites. They may potentially have some secondary waste streams that are considered mixed waste.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   The primary contaminant of the rad waste sludge from the treatment plant (called WD sludge) is U^{238}.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   They currently have an NPDES permit for rad waste (LL) from a water treatment facility (called WD sludge). The sludge from this operation is solidified in 55-gal. drums (26% solids).

4. **On-Site/Off-Site Disposal** *(rationale)*:

   Off-site to NTS.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not provided

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Not provided

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not provided

10. **CAMU experience:**

    N/A

11. **References**:

    Mary Alexander 513-865-3428
    Ron Henderson 513-865-4467

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Nevada Test Site

Contact: Doyle Anderson, Raytheon Services

Phone No: 702-295-3948

Address: P.O. Box 98518
Las Vegas, NV 89193

Date: August 23, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   The site is currently in the characterization process, and there has not been much LLMW identified. However, there are two potential LLMW sludges (1 drum and 1200 drums). The waste is from uranium ore reprocessing residue. Sampling and analysis is on-going. It is currently managed as mixed-waste and stored in compliance with RCRA.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Characterization in process.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Characterization in process.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Not provided

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not provided

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not provided

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not provided

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Not provided

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not provided

10. **CAMU experience:**

    N/A

11. **References:**

    None provided

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Oak Ridge National Laboratory

Contact: Lantz Meszca, Director
Central Waste Management

Phone No: 615-574-7258

Address: P. O. Box 2008
Oak Ridge, TN 37831

Date: August 13, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   On-site incinerator (TOSCA and RCRA permitted unit) generates ionizing wood-scrubber sludge. The waste is 90 to 95% water which is currently dewatered through a filter press, to obtain a sludge at 30 to 35% water.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   The low-level mixed waste contaminants are U, Tc, Np, and low levels of transuranics in addition to heavy metals. There are few organics left after the incineration process. However, since it is a listed waste from Y-12 and K-25 operations, it carries the code through after treatment.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   The Oak Ridge facilities are currently in the process of looking at treatment options. They have a mixed waste facility under the FFCA. They are evaluating several treatment options including low temperature thermal treatment for Hg and PCBs. Currently, a draft treatment study is evaluating options. Some options considered are privatization (request for proposals issued), on-site treatment facility (batch plant), or vitrification.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Not yet determined. However, dewatering is associated with the waste from the incinerator. They are hoping to ship the incinerator sludge off-site (Envirocare).

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   The incinerator waste must meet the requirements of Envirocare.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not determined.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not determined.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Had a compliance agreement with EPA Region IV requiring them to implement a treatment process. Currently evaluating options and will make a decision based on costs and performance.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Some of the lessons learned: sludge analysis is problematic from a chemical standpoint. Chemical extraction is difficult, especially when organics are present.

   Also, problems occurred when they were forced to excavate pond waste from an open basin. Experienced QA/QC problems with the concrete. They found liquid in the drums, perhaps from the phase separation water.

   *Note: ORNL has a biodenitrification unit that water is processed through; therefore, it does not have a high-nitrate problem.

10. **CAMU experience:**

    Not discussed.

11. **References**:

    Claude Buttram - preparation of treatment plan, 615-241-2112.
    Leslie Little - problems with concrete, 615-576-4034.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Oak Ridge, K-25 Address: P.O. Box 2008
Contact: Leslie Little Oak Ridge, TN 37831
Phone No: 615-576-4034 Date: August 24, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   K-1407-B, 1407-C Ponds (K-25 ponds): There was a decontamination facility at this site. The waste underwent crude neutralization and was discharged to settling ponds. The coal yard run-off also went to these settling ponds. There are currently 46,000 drums of LLMW (21,000 have not been cemented, i.e., raw sludge).

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Ni, Cd, Cr, U and some organics (no nitrates - eliminated with effluent).

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   During the mid 1980s the pond was dredged and put in 96-gal. drums and stored on a pad. The majority of sludge was fixed in flyash and concrete. In order to meet the regulatory deadline, some raw sludge was put in drums. Oak Ridge is currently working on this problem. They might be able to ship the raw sludge to Envirocare, where it will be treated (Envirocare working on facility).

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Ship off site, must meet LDRs. RCRA plating-type waste D-006.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Must meet LDRs.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown. Referred to Jane Powell. However, disposal cost is running \$56 to \$70 ft^3.

7. **Processing Capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Unknown.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA. DOE Order 5820.2A. Had to get an exemption from both the local DOE and HQ. NEPA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   This waste was generated in the early 1980s; RCRA was still "fluid" and, therefore, they chose to store the waste in tanks.

10. **CAMU experience:**

    Not discussed.

11. **References**:

    Terry Sams - further information - 615-241-2409.
    Jane Powell - cost information - 615-576-7807.

DOE/DOD SURVEY FORM

Site: Oak Ridge National Laboratory
Contact: Leslie Little/Chet Francis
Phone No: 615-576-4034

Address: P.O. Box 2008
Oak Ridge, TN 37831
Date: August 24, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   S-3 Ponds: The S-3 ponds were four interconnected ponds that received raw plating waste, caustic waste, and nitric acid. The pH of the ponds was 2. The ponds were roughly 1 acre apiece. In the early 1980s the state of Tennessee targeted the ponds for closure. There is currently a LLMW sludge associated with the ponds.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Organics, degreasers. Main rad component is U (enriched), and also Tc. High in nitrates.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   In the early 1980s the ponds were neutralized. Following this, *in situ* denitrification (biological, anaerobic process) was performed, followed by aerobic bio-oxidation. Then the decant was pumped off and put through a polishing process (filtration). The waste was discharged under the NPDES.

   The remaining sludge from this process was left in place. The ponds were filled with rock and a multi-layered cap was placed.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   On-site, *in situ*.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   RCRA closure (early 1980s), currently post-closure activities continue (referenced Jimmy Stone).

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown.

7. **Processing Capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Unknown.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   This was in the early 1980s and RCRA was still "fluid" at the time.

   Chet Francis provided the following information on 8-31-94:

   In September of 1987, MMES issued a RFP (SB096-22) for the "Technical Assessment, Closure Plan, and Stabilization/Fixation of the Old Hydrofracture Facility Surface Impoundment." Two contracts were implemented. One contract addressed the costs of implementing two processes: a cement stabilization process and an asphaltic stabilization process. The other contract addressed in situ stabilization by incorporating quick lime and other pozzolanic materials directly into the pond sediment. None of the three processes was implemented as priorities to reach an interim closure on SWSA6 became more important and funding to stabilize the OHF ponds was not available.

10. **CAMU experience:**

    Not discussed, closure prior to CAMU legislation.

11. **References**:

    Jimmy Stone, 615-574-6911 (Waste Management, will know about post-closure).

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Oak Ridge National Laboratory

Contact: Leslie Little

Phone No: 615-576-4034

Address: P.O. Box 2008

Oak Ridge, TN 37831

Date: August 24, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   West End Treatment Facility Sludge. This facility was built when the S-3 Ponds were closed during the 1980s. The residues of the facility have been collected and stored in four to five 500,000-gal. tanks.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Organics, metals, U, Tc (same as S-3 ponds) from plating operations, etc.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Currently out for bid to private vendors.

4. **On-Site/Off-Site Disposal** *(rationale if availble)*:

   Ship off-site, must meet LDRs.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Must meet LDRs.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown.

7. **Processing Capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Unknown.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Again, as this waste was being generated in the early 1980s, RCRA was still "fluid" and, therefore, they chose to store the waste in tanks.

10. **CAMU experience:**

    Not discussed.

11. **References:**

    Jimmy Stone, Y-12, 615-574-6911.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Paducah

Contact: George Johnston

Phone No: 502-441-6043

Address: P.O. Box 628, Paducah, KY 42002

Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   ER Mixed Waste Sludge (drilling muds, auger cuttings), LLMW. Paducah has approximately 6,000 drums of waste of which perhaps 2,000 drums are sludge. They have no means to treat this sludge, and no on-site filter press or centrifuge. If there is no RCRA waste involved, they solidify the sludge with absorbents. There are problems with this when the waste has a high solids content. This waste originates from their extensive groundwater investigation program.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   TCE, TC-99, no nitrates. Low detectable quantities of Np, Th and Pu.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   No treatment at the Paducah facility. They decant the water and solidify with the adsorbents (Radsorb). Will ship to Hanford after solidification. There is no limit for land disposal yet. They are currently in the process of sampling all the drums to classify. This waste has existed for some time, and they are just now "catching up".

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Plan to ship to Hanford.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Must meet WACs for Waste Management.

   Must be acceptable to Hanford.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA. Some of the earlier waste may be covered under CERCLA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not discussed.

10. **CAMU experience:**

    Not discussed.

11. **References**:

    Draft Site Treatment Plan - Currently in preparation.

    Referred to Richard Kuehn, 502-441-6878, in regard to "legacy waste" (inherited prior to their establishment) that is from the old processes and has been in long-term storage.

    Also referred to Leslie Little, at the Central Waste Management in Oak Ridge. Central Waste Management is probably overseeing all the WM activities at Paducah and Portsmouth (they track the volumes and type).

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Paducah Gaseous Diffusion Plant

Contact: Greg Shaie/Tom Connoly

Waste Management

Phone No: 502-441-5955

Address: P.O. Box 628

Paducah, KY 42002

Date: August 31, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Mixed-waste sludge. Unknown volume in drums.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Heavy metals, U-235, Tc may some TRU.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Stabilization. Treatability studies, demonstration testing, and evaluation are in progress. They are locked into their program through LDRs (FFCA).

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site disposal - perhaps Envirocare. This is up and coming.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not discussed, N/A.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not discussed, N/A.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not discussed, N/A.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   FFCA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not discussed.

10. **CAMU experience:**

    Not discussed.

11. **References:**

    The waste management contacts were referred by George Johnson in ER.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Pantex

Address:

Contact: John Garry

Phone No: 806-477-6693

Date: August 30, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   The sludges are a very small volume (<5 m^3). However, Pantex options for mixed waste in general were covered last year during treatment selection and are presented in the Albuquerque mixed-waste treatment plan. One of the only sludges Mr. Garry knew of at Pantex is from weapons production, a semi-solid sludge of about 1/2 m^3.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   N/A. Mr. Garry commented that they really have no "genuine" sludge at the site.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   The Treatment Plan (March 1994) indicates that they will use commercially available treatment for their mixed waste. There are currently 15 to 16 different methods under development. These are part of the "skid" units (see discussion with Los Alamos). These units and technologies will be shared between the sites. Most of the treatments include stabilization.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off site, Envirocare. Their philosophy is that off-site disposal was preferred. The legislature would probably disapprove of any on-site disposal.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not known.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not discussed.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not known yet.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   These are all RCRA wastes. LDRs will apply.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Too soon in the process to have experience.

10. **CAMU experience:**

    N/A, see discussion on disposal.

11. **References**:

    March 1994 Treatability Study.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Pinellas Plant

Contact: Gary Schmidke

Phone No: 813-545-6179

Address:

Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Pinellas Plant Waste-Water Sludge: In 1992, 116,000 lbs (58 tons) of raw sludge (listed F06 sludge) was shipped to Ladlaw Environmental Services in Pinewood, South Carolina. There will be more of this type of waste in the future. Problems occurred when the shipment arrived at the facility and it was determined that there was a tritium component. The state of South Carolina ordered a dose assessment, which proved negligible impact. There were no hazardous components in the waste.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Small amount of tritium, no hazardous components. (127 μCi Total)

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   The disposal facility did the solidification, and it was at that time that the rad component was discovered.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site hazardous waste disposal

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Requirements of the disposal facility.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   RCRA (listed waste)

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Their current strategy for upcoming potential mixed waste is to separate the rad component before they ship to the disposal facility. Will possibly use dewatering to get the tritium into liquid.

10. **CAMU experience:**

    N/A

11. **References**:

    Pinellas is preparing a treatment plan under the FFCA, but not for the sludge because they are unsure whether it will be classified as a mixed waste.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Portsmouth Gaseous Diffusion Plant	Address: P.O. Box 628
Contact: Doug Davenport	Piketon, OH 45661
Phone No: 614-897-3261	Date: August 24, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   X701-B: Excavated material from holding pond (a medium sized settling pond containing wash water from decontamination facilities of the gaseous diffusion plant).

   Currently storing 525 B-25 boxes (~1400 yd^3).

   Other: Portsmouth has sludges in storage at their hazardous waste facility. These are addressed in their treatment plan. They will probably be stabilized with a grout mix and disposed of off-site. Portsmouth has no disposal facility. They are still in the process of studying and sampling the material for treatability to find the most effective way to stabilize. The sludge includes heavy metals, Tc-99 and Uranium.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   X701-B: Wash water contained DNAPL TCE, PCBs, Uranium, Tc up to 10,000 pCi/g. Currently undergoing further characterization. The sludge was lime from pH neutralization; industrial sludge with a rad component.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   X701-B: Presently in RCRA storage.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   X701-B: Currently in evaluation process. Because the sludge is unique, they are unsure whether they want to treat it on site. Probably will stabilize and dispose of at Envirocare.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   In evaluation process.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

X701-B: Approximate cost for chemical destruction, and stabilization, is about $800/ton. Estimated cost in the range of $1.5 million.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

Regulated under DOE, TSCA (PCBs > 50 ppb), and RCRA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

X701-B: They are questioning whether they really want to attempt to treat this sludge on-site.

10. **CAMU experience:**

X701-B: Could not have used CAMUs for X-201B as the law was not in effect then. Also, it hasn't been adopted by Ohio to date. They are considering using it for other sites, however.

Other: Spoke to Rick Baldwin about the Cr sludge that was removed, dewatered, stabilized and put in a RCRA mono-cell, and whether or not a CAMU was considered. The sludge was treated by lime addition and some of the waste is still being characterized. He referred to Terry Acox who is responsible for the DRAFT Site Treatment Plan at Portsmouth (614-897-6415).

Terry Acox stated that the Cr sludge was not a hazardous waste after stabilization and therefore was put in a RCRA mono-cell and placed in a sanitary landfill. It was the most efficient method. It was generated during closure of sludge lagoons. He was not familiar with CAMU. He said that the Cr sludge was not subject to LDRs anyway. The lime treatment for the sludge was cost-effective and has worked well.

11. **References**:

Treatability Study for X-701-B Sludge Treatment.

Rick Baldwin, 614-897-2497.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Rocky Mountain Arsenal

Contact: Pat Silva

Phone No: 303-289-0381

Address:

Date: August 31, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Basin F. Brine salts. Not a true sludge, but wet solids. They generate approximately 1 drum per week (process waste). The waste is from cleaning out the strainers. Molten salt that has been glassified.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content, etc.)*:

   Brine salt from Basin F. Liquids. RQs for brine are based on copper. High Cu, 2000 to 4000 ppm. There are no radioactive components at the Arsenal.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Recycling because of copper. The copper recovery is performed at ENCYCLE in Corpus Cristi. The brine is delivered on two rail cars per day. The left-over salty water goes into the Gulf of Mexico.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site recycle.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   N/A

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   N/A

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Basin F is different from the other wastes on the site, because it is RCRA waste. The state of Colorado won jurisdiction over Basin F (Order of Consent from State). The rest of the site is CERCLA.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Conversation with Gary Anderson:
   The Arsenal also has approximately 2000 yd^3 of tank sludge. TCLP testing showed no hazardous constituents. It is a non-hazardous, industrial waste, and about 90% solids. They are planning to dispose of it at a Level D, landfill in Colorado (maybe CSI). This contract is in process.

10. **CAMU experience:**

    N/A

11. **References:**

    Pat was referred by Gary Anderson. She also referred to Larry Decet (303-289-0124) who is in charge of Waste Management.

    Larry Decet, 303-289-0124.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Sandia National Laboratory

Contact: Mary Baunge, Div. Director

Waste Management

Phone No: 505-845-6737

Address: P.O. Box 5800

Albuquerque, NM 87185

Date: August 14, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   The SNA waste management division oversees waste management at LANL, Pantex, Mound, KCP, and Pinnelas. There is no LLMW sludge at either of the Sandia Laboratories (New Mexico and California). There are lab packs and cut-up debris, but no true sludge waste stream.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   N/A

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   N/A

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   N/A

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   N/A

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   N/A

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   N/A

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   N/A

10. **CAMU experience:**

    Not discussed.

11. **References**:

    Referred to Gary Schmidke at Pinnelas, 813-545-6179.

Treatment of Low-Level Mixed Waste Sludges at DOE facilities

DOE/DOD SURVEY FORM

Site: Savannah River Site	Address: P.O. Box A
Contact: John Pickett	Aiken, SC 29801
Phone No: 803-725-3838	Date: August 22, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   250,000 to 500,000 gal. of waste from electroplating operations currently stored in tanks. Six different waste streams.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Primary contaminants are uranium and nickel. The waste is 50% water, 45% diatomaceous earth, and 5% other. Classified as 006 mixed waste.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Vitrification.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   De-list by petition, or transport to mixed-waste disposal facility.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Not discussed.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Not discussed.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   Not discussed.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Record of Decision.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   Not discussed.

10. **CAMU experience:**

    The waste at Savannah River would not apply, because it is a tank farm. Also, it is not covered under CERCLA. However, Savannah River did do something very similar to a CAMU, back in 1985 and 1986, before the regulations were finalized they stabilized waste in a settling seepage basin. It was an open impoundment and received wastes in the 50s to early 80s from tanks, ditch, and surface ponds. It was stabilized on-site and capped. However, they will be forced to monitor it forever. Mr. Picket noted that this sort of monitoring would also probably be required with a CAMU, just like a landfill.

11. **References:**

    Draft site treatment plan.
    Chris Langton (803-725-5806); referred John Pickett.

DOE/DOD SURVEY FORM

Site: Weldon Springs Site
Contact: Ken Lawyer
Waste Management
Phone No: 314-441-8978

Address: 7295 Highway 94 South
St. Charles, MO 63304
Date: August 24, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Two sludges referred to:

   1. Raffinates from uranium production processes (sludge-like material). Treated under FFCA (30 to 40 drums).
   2. Borderline RCRA sludge, 250 yd^3 in 4 pits (just barely meets RCRA - high As content).

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   1. FFCA material will be addressed under a treatment plan currently in progress. RCRA characteristic waste. Contains Hg, Radioactive components, PCBs.
   2. Borderline RCRA sludge has high As and Uranium (Th-230 chain).

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   1. FFCA material will be addressed under treatment plan in progress.
   2. The borderline RCRA sludge will undergo cement stabilization on site.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   1. Treatment plan in progress.
   2. On-site disposal cell.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   1. Probably to meet LDR
   2. RCRA - LDR

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown at this time; however, they hope to be operating the pilot plant for sludge #2 next year.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   2. Process in design. Pilot plant to process about 150 tons/hour.

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   2. Suspected RCRA (CERCLA site - No permit required).

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   2. Since they are in the process, there is not much to share. However, one problem they will encounter will be how to handle the radon after the cement stabilization process. The sludges will be in cells, however, radon will still be emitted. They are trying to capture as much as possible. Looking into technologies and designs that are in process. The pilot plant will be operating by next year.

10. **CAMU experience:**

    Not discussed.

11. **References**:

    1. Site treatment plan is currently in HQ review process.
    2. Currently in process.

Treatment of Low-Level Mixed Waste Sludges
at DOE facilities

DOE/DOD SURVEY FORM

Site: Westinghouse Bettis

Contact: Earl Shollenberger

Phone No: 412-476-7290

Address: ______

Date: August 31, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   Total volume of all waste is projected to be 20 m^3 over the next five years (minimum).

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Not provided during the survey.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Bettis is an R&D facility, and not a production facility, and therefore will not store waste nor have the capability.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Off-site disposal.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   N/A

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   N/A

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   N/A

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   FFCA mandated Draft Site Treatment Plan was just sent.

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   N/A

10. **CAMU experience:**

    N/A

11. **References:**

    None provided

DOE/DOD SURVEY FORM

Site: West Valley Project
Contact: April Howell, Manager
Operations Technical Support
Phone No: 716-942-4504

Address: 10282 Rock Springs Rd.
West Valley, NY 14171
Date: August 25, 1994

1. **Description of Sludge** *(e.g., volume, physical location, waste type, HLW, LLMW, hazardous only)*:

   High Level Waste-Water Tank Sludge. High level waste. Have processed over 19,000 drums of decontaminated supernate from waste tanks since 1988.

2. **Sludge Characteristics** *(e.g., primary contaminants, physical characteristics; percent solids, total dissolved solids, salt content)*:

   Cs-137 and others, Cr and other heavy metals, pH of 12.5.

3. **Type of Treatment Selected** *(e.g., immobilization, vitrification, dewatering)*:

   Currently processing by cementation on-site. Ion exchange rids of Cs-137.

4. **On-Site/Off-Site Disposal** *(rationale if available)*:

   Interim on-site storage.

5. **Performance Requirements** *(e.g., final waste form, constituent concentration, land disposal restrictions)*:

   Final waste form will be non-hazardous with just a rad component. They do confirmatory sampling to assure the constituent concentrations. Plan to capture the hazardous wastes and cesium.

6. **Cost and Schedule for Treatment** *(e.g., total cost, estimate of total treatment time, current status)*:

   Unknown, in process of planning.

7. **Processing capacities and Rates** *(applicable only if treatment has begun, range of equipment capacity and rates)*:

   300 drums in a 5-day week are processed in on-site cementation facility. (20 drums per shift with work conducted around the clock.)

8. **Regulatory Requirements** *(e.g., regulatory drivers, permits required, cleanup levels and criteria):*

   Under RCRA process Part A (for the tanks and facility).
   Cemented waste: 10 CFR 61

9. **Pitfalls and Problems Encountered and Miscellaneous Information:**

   They have experienced only normal operating problems. However, they have learned that there are many constituents that effect cementation such as sulfates, and especially pH. This affects the ability of the cement to harden in time.

10. **CAMU experience:**

    N/A

11. **References**:

    Site Treatment Plan (in process).
    April Howell was referred by Paul Klanian, 716-942-4382.

The following are brief case studies of the alternative analysis process were compiled by RUST Geotech, Grand Junction Office. All information used to develop these case studies was obtained from the EPA RODs database and does not reflect the technology that was actually implemented. The no-action alternative was developed and analyzed for each site, but limited discussion is presented for this alternative. The cost of the alternatives, given as the net present value, and implementation time were included when available. Some of the remedial actions were Interim Actions and did not have a formal alternatives analysis.

D.1 U.S. Department of Interior Sangamo Crab Orchard, Operable Unit 1.

The Sangamo Crab Orchard site is within the Crab Orchard National Wildlife Refuge, located near Carterville, Illinois, and is in EPA Region 5. The eastern portion of the refuge is used for manufacturing facilities. Site features of the eastern portion include a plating pond, a drainage pool, and an industrial landfill. The ROD for Operable Unit 1 focuses on the metal-contaminated soil, sediment, debris, and sludge in the plating pond, drainage pool, and landfill. The plating pond is an inactive pond containing 280 cubic yards of contaminated material. The drainage pool is a collection point for runoff and contains 5,200 cubic yards of contaminated material. The landfill contains 14,600 cubic yards of contaminated material. The COCs at the operable unit are metals, including chromium, cadmium, and lead. The site does not contain radioactive contaminants.

The Feasibility Study developed 22 site-specific alternatives. The Proposed Plan presented nine alternatives, all of which included stabilization. The selected alternative includes excavating contaminated soil, sediment, debris, and sludge; temporarily storing the excavated material on site until treatment; treating soil, debris, and sludge considered to be RCRA characteristic hazardous waste with stabilization; disposing of the treated and nontreated soil, debris, and sludge in an on-site RCRA landfill; capping the landfill; and filling the excavated areas with clean soil. Not all the soil, debris, or sludge require treatment before landfill disposal.

All the alternatives include stabilization, the only treatment option considered. The differences among the alternatives are the areas to include in the remediation effort and off-site versus on-site landfill. The selected alternative involves cleaning all contaminated areas identified in the operable unit.

Cleanup goals were based on the risk assessment and include cadmium levels of 10 milligrams per kilogram (mg/kg) and lead levels of 450 mg/kg. The ROD, which was signed on September 30, 1990, requires the removal of all soil and sludge with chromium levels above background.

D.2 U.S. Department of Interior Sangamo Crab Orchard, Operable Unit 2

The Sangamo Crab Orchard site is within the Crab Orchard National Wildlife Refuge, located near Carterville, Illinois, and is in EPA Region 5. The eastern portion of the refuge is used for manufacturing facilities. Operable Unit 2 focuses on the polychlorinated biphenyl (PCB)-contaminated soil and sludge at several landfills and in two drainage ditches. The landfill and drainage ditches contain approximately 36,000 cubic yards of contaminated material. COCs affecting the soil and sludge are organics that include primarily PCBs and metals (lead). The site does not contain radioactive contaminants.

The Feasibility Study developed 34 alternatives that used various combinations of 8 remedial technologies. The Proposed Plan presented four alternatives. The four alternatives in the Proposed Plan were called "consolidated remedial alternatives" because they were a combination of the technologies and alternatives presented in the Feasibility Study. Alternative 1 includes excavation of soil and sludges, stabilization of excavated material that requires treatment, and disposal in an on-site Toxic Substances Control Act (TSCA) landfill. The TSCA landfill would use an existing 5-million-gal. tank on site. The level of PCB contamination that require treatment was not specified but is assumed to be approximately 25 mg/kg on the basis of EPA cleanup criteria for PCBs. Alternative 1 had a net present value of $25.2 million and would take 2.5 to 5 years to implement.

Alternative 2 is the same as Alternative 1, except that only soil and sludges/sediments with PCB concentrations greater than 1,000 mg/kg would be stabilized and placed in a TSCA landfill. Alternative 2 had a net present value of $6.1 million and would take 2 years to implement.

Alternative 3 includes excavation of the soils and sludges/sediments, the same as Alternatives 1 and 2; on-site incineration for material that requires treatment and has "nonsorbed" PCBs and no metals; stabilization for all other excavated material that requires treatment; and disposal of all excavated material in an on-site TSCA landfill. The alternative had a net present value of $8.9 million and would take 2.5 to 3 years to implement. Alternative 4 is the same as Alternative 1, except the excavated material would be disposed of in an off-site TSCA landfill. Alternative 4 had a net present value of $23.9 million and would take 2 years to implement.

Alternative 3, which uses a combination of incineration and stabilization, was selected as the preferred alternative because it reduces toxicity and mobility of the PCBs by permanent destruction and does not increase the volume of waste. Stabilization would be used only for material that could not be effectively treated with incineration because stabilization reduces the toxicity and mobility but increases volume. The selected alternative also proposes testing in situ vitrification to determine if it could meet performance requirements. If in situ vitrification meets the performance requirements, it would be used instead of incineration. The ROD was signed on August 1, 1990.

D.3 Robbins Air Force Base, Georgia, Operable Unit 1

Robbins Air Force Base is located in Warner Robbins, Georgia, and is in EPA Region 4. Operable Unit 1 consists of Landfill 4 and a sludge lagoon. A wetlands area borders the site to the east, and part of the site lies within the 100-year floodplain. The sludge lagoon was used for disposal of wastewater treatment-plant sludge and other liquid wastes. Wastes known to have been disposed of in the landfill and sludge lagoon include electroplating wastes, organic solvents from cleaning operations, and pesticides. The primary COCs are VOCs (PCE and TCE) and metals (arsenic, chromium, and lead). There are no radioactive contaminants at the site. The primary media of concern are soils, sludges, and groundwater. Remediation of the groundwater will not be discussed here. The ROD was signed on June 26, 1991.

Alternatives were developed and presented separately for the landfill and sludge lagoon. Three alternatives were presented for the landfill. Alternative 1 includes limited action with institutional controls. Alternative 2 includes renovation of the existing landfill cover to reduce infiltration. Alternative 3 involves constructing a new multilayer cover over the existing landfill.

Three alternatives were presented for the sludge lagoon. Alternative 2 includes in situ soil vapor extraction to remove VOCs, followed by in situ solidification. The in situ soil vapor extraction was estimated to remove 75 to 90 percent of the VOCs. Alternative 3 involves excavation of the soils and sludges and then ex situ low-temperature volatilization, followed by solidification of the residue and disposal in an on-site landfill. Alternative 4 involves excavation and on-site incineration of the soils and sludges that contain VOCs, solidification of residual material left in the sludge lagoon, and disposal in an on-site landfill of the solidified soils and residue from incineration. The residue would require delisting as a hazardous waste.

The preferred alternative for the landfill is Alternative 2, renovation of the existing landfill cover. Alternative 2, soil-vapor extraction followed by solidification, was selected for the sludge lagoon. The alternative for the landfill was chosen because of its "overall effectiveness compared to its costs." Alternative 3 for the landfill was judged to provide better long-term effectiveness and reduce toxicity, mobility, and volume but was much more expensive. Alternative 2 was chosen for the sludge lagoon for similar reasons. It was judged to be sufficiently protective of human health and the environment and was substantially less expensive than the other treatment alternatives.

D.4 Ogden Defense Depot, Operable Unit 3

The Ogden Defense Depot is located in Ogden, Utah, and is in EPA Region 8. The site has burned oily liquid material and combustible solvents in pits since the 1940s. Solid materials were buried on site, burned, or removed for off-site disposal. During a 1988 U.S. Army site investigation, chemical warfare agents, VOCs (including TCE), and heavy metals were detected in an on-site burial area. Operable Unit 3 is composed of burial site 3-A, the water purification tablet burial area, and the World War II Mustard Storage Facility. Operable Unit 3 addresses the threats posed by the soil, debris, and sludges in these burial areas. The COCs for Operable Unit 3 are metals (arsenic), inorganics, and organics (primarily pesticides). There were no radioactive contaminants. The ROD is dated June 28, 1992.

Alternatives considered for remediation include Alternative 2, institutional controls; Alternative 3a, mechanical sieving to remove debris and off-site disposal in a RCRA landfill; Alternative 3b, mechanical sieving to remove debris and off-site incineration; Alternative 4a, off-site disposal at a RCRA landfill; and Alternative 4b, off-site disposal by incineration. The selected alternative is Alternative 3a. Solidification of soils and sludges not meeting the Toxicity Characteristic Leaching Procedure (TCLP) requirements was added to the selected alternative. Disposal in a RCRA landfill with some solidification was chosen rather than incineration because it was considered more cost effective, even though incineration was thought to be more protective of human health and the environment and provided better reduction of toxicity, mobility, and volume.

D.5 Maxey Flats Nuclear Disposal, Kentucky

The Maxey Flats nuclear disposal site, an inactive low-level radioactive waste disposal facility in Fleming County, Kentucky, is located in EPA Region 4. From 1962 to 1977, approximately 4,750,000 cubic feet of low-level radioactive waste was disposed of in a 45-acre area. The majority of waste was disposed of in unlined trenches, but concrete- capped "hot wells" consisting of coated steel pipe, tile, or concrete also were used for disposal of a small volume of wastes with a high specific activity. In 1988, EPA conducted a removal action that involved solidifying approximately 286,000 gal. of radioactive liquids stored in 11 tanks. The solidified blocks were disposed of in on-site trenches. This ROD, dated September 30, 1991, addresses final remediation of soil, debris, and some sludges. The primary contaminants of concern are metals (As and Pb), organics (benzene, TCE, and toluene), and radionuclides (including tritium).

The primary mechanism for release of contaminants to the environment is the migration of leachate from the disposal trenches, through the underlying fractured bedrock, to the hillslopes surrounding the site. The Feasibility Study developed 18 remedial alternatives, which were screened to 7 alternatives for detailed analysis. Except for the no-action alternative, all the alternatives involve some type of stabilization technology for the trenches as well as horizontal and vertical flow barriers. Discussion of the alternatives analysis for the horizontal and vertical flow barriers is excluded from this discussion.

The objective of trench stabilization is to achieve trench stability so that a cap, which would require minimum repair and maintenance for the life of the project, could be placed over the trench disposal areas. Three trench-stabilization technologies were considered: dynamic compaction, natural subsidence, and grouting. Dynamic compaction involves the repeated dropping of a large weight on each trench cover until the waste and trench cover are sufficiently consolidated. Backfill soil is added to the resulting depressions. The backfill soil is then compacted so that a stable cap can be constructed over the compacted trenches. Natural subsidence is the natural densification and consolidation of soils and waste materials in the trenches over time. It was not possible to accurately predict how long it would take for the trenches to naturally subside. Grouting would involve injecting grout (a mixture of materials such as cement, bentonite, or flyash and water) through specially inserted probes into the trenches to fill voids and other openings in the waste. The technology that would be used to insert the grout into the waste was considered to be only partially effective at filling the voids and preventing further collapse of the waste in the trenches.

The alternatives considered for the site include:

Alternative 1: No Action

Alternative 4: Dynamic compaction/structural cap/horizontal flow barrier
Net present value: $59.3 million

Alternative 5: Natural subsidence/initial cap and final engineered soil cap/horizontal flow barrier.
Net present value: $23.9 million

Alternative 8: Natural subsidence/engineered soil cap/horizontal flow barrier
Net present value: $34.3 million

Alternative 10: Dynamic compaction/engineered soil cap/horizontal barrier
Net present value: $39.6 million

Alternative 11: Trench grouting/engineered soil cap/horizontal flow barrier
Net present value: $61.9 million

Alternative 17: Dynamic compaction/engineered soil cap/horizontal flow barrier
Net present value: $51.9 million

Alternative 5 was selected as the preferred alternative. Additional subsidence after stabilization by dynamic compaction or grouting was considered likely. Use of either of these technologies would require that the final cap placed on the trenches be repaired periodically throughout the life of the project. Natural stabilization was chosen because it will reduce the redundancy of repairing the final cap. However, natural subsidence was estimated to require 100 years before the final cap was placed. Another reason cited for selection of Alternative 5 was that it would permit taking advantage of future technical advances during the subsidence period.

D.6 Teledyne Wah Chang, Oregon

The Teledyne Wah Chang site, located in Millersburg, Oregon, is an active plant used to produce nonferrous metals and products. The site is located in EPA Region 10. It consists of a 110-acre plant site that contains the plant's former sludge ponds and a 115-acre farm site that contains four active wastewater sludge ponds. Portions of the site are within the 100-year floodplain. The site operated under contract with the U.S. Atomic Energy Commission in the 1950s. The Lower River Solids Pond and Schmidt Lake Sludge Pond, which stored wastewater generated from the plant operations, are addressed in this ROD, dated December 28, 1989. Sludge in the solids pond and sludge pond contain heavy metals, organic compounds, and trace levels of radionuclides. Because the sludge is not a characteristic or listed hazardous waste under RCRA, Land Disposal Restrictions were not considered in evaluation of the alternatives.

The Feasibility Study developed seven alternatives that represent three different types of remediation: containment, on-site landfill, and off-site landfill. Four alternatives were included in the detailed analysis. Alternative 1 involves consolidation of the wastes, barrier wells, capping, and flood protection. Under this alternative, sludge from Schmidt Lake would be moved into the Lower River Solids Pond. Alternative 1 had a net present value of $1.8 million and would take 1 year to implement.

Alternative 5 involves removal of the sludges, solidification, and on-site disposal. The sludges removed from the ponds would be solidified with cement or a similar substance and then placed in an on-site landfill. Solidification is not required to meet Land Disposal Restrictions but was considered to reduce the mobility of the contaminants. This alternative had a net present value of $12.8 million and would take 2 years to implement.

Alternative 6 involves removal of the sludges and off-site disposal. The sludges would be removed from the ponds and placed on a concrete slab where they would be allowed to drain excess water. There would be no solidification of the sludges for this alternative. This alternative had a net present value of $8.5 million and would take 9 months to implement.

Alternative 7 involves removal of the sludges, solidification, and off-site disposal. The alternative is the same as Alternative 5, except that the solidified sludges would be disposed of in an off-site landfill. This alternative had a net present value of $10.7 million and would take 10 months to implement.

Alternative 7 was selected as the most appropriate remedy because it consistently ranked among the best choices under all the ranking criteria, except cost. It was considered the most effective to reduce the likelihood of contact with the sludges and to ensure that contaminants are not transported by removing them from the 100-year floodplain.

Appendix E - Vendor Request for Information and Example Responses

Appendix E: Vendor Request for Information

The following materials were sent to selected vendors (see Table 3.3 in the text) to solicit information on candidate technologies capable of treating SEP sludges. Two sample responses to this query are provided to show the form in which the information was being collected. Because of the volume, full responses are not included in this report but are on file.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

105 MITCHELL RD., ROOM 286
POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831 - 6495
TELEPHONE: (615) 574-0559
FACSIMILE: (615) 576-0327

April 25, 1994

Evaluation of Technologies for Treatment/Remediation of Contaminated Sludges

Oak Ridge National Laboratory is conducting an evaluation and screening of technologies for treatment/remediation of contaminated sludges at a Department of Energy (DOE) site located in the west as described in the enclosed project fact sheet. Although sludge treatment has general application to DOE sites throughout the west, this evaluation and screening of technologies is targeted to a specific waste stream. At a later date, it is probable that one or more of these technologies will be selected for treatability study and/or full scale treatment for the contaminated sludge.

If your company has one or more technologies that would be applicable for treating this contaminated sludge, and you would like them included in our evaluation, please complete and return the enclosed vendor/technology survey form by May 28, 1994. In order to ensure that your technology receives a comprehensive and fair evaluation, it is important that you answer each question on the survey form as it applies to your technology as completely as possible. Feel free to add additional sheets to the form as needed. Please submit a separate form for each technology you believe is appropriate and return them to:

Mr. Michael Morris
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6495

Should you have any questions concerning completion of the survey form or if you need additional information, please contact me at (615) 574-0559 or FAX (615) 576-0327.

Thank you for your participation in this technology evaluation. We look forward to receiving your completed survey form by May 28, 1994.

Very truly yours,

Michael I. Morris
Chemical Technology Division

MIM:rrs
Enclosures

Treatment of Low-Level Mixed Waste Sludges
from Solar Evaporation Ponds

VENDOR / TECHNOLOGY SURVEY FORM

Date:______________________________

Company:__________________________ Contact:__________________________

Telephone:__________________________ Position:__________________________

Address:____

City, State, Zip:____

1. **Name of Process Technology for Sludge Treatment** (Identify what type of process it is, such as dewatering, cement-based solidification, vitrificiation, electrochemical separation, etc.):

2. **Description** (Describe in detail, the process and its potential for treatment of the sludges as described in the Project Fact Sheet to achieve the performance goals listed in Tables 1 and 2. Please attach flowsheet and literature if available.):

3. **Treatment Efficiencies Expected and Reliability** (What are the expected treatment efficiencies and how robust is the process? Should the sludge be modified to improve operation of your process? For example, homogenized, screened, dewatered, etc.):

4. **Limiting Conditions and Interferences** (Describe any characteristics of the sludge that might adversely affect the treatment process (e.g., pH, solids content, salt content). Can the process handle fluctuations in waste character and composition?):

5. **Stage of Development** (Describe the stage of development the process is presently at: experimental, developmental, commercial, or other. Please elaborate as appropriate.):

6. **Approximate Number of Successful Installations / Remediations** (If applicable, list commercial applications that have been completed or are on going.):

7. **Processing Capacities and Rates** (List the range of equipment capacity and rates as well as the reaction rate of the process.):

8. **Pretreatment Requirements** (Describe any pretreatment or conditioning of the waste required for the process.):

9. **Chemicals or Other Treatment Agent Requirements** (List chemicals and quantities required per volume of waste treated.):

10. **Secondary Waste Stream Produced** (Identify types and quantities of secondary wastes the process may produce per unit waste volume treated.):

11. **Treatment of Secondary Wastes** (Describe treatment provided or required for secondary waste produced.):

12. **Final Waste Form** (List the physical characteristics of the final waste form such as the compressive strength, monolith, pellets, powder, etc., and include any volume change of the final waste form per volume of waste treated.):

13. **Permits Required** (List permits required to treat this waste.):

14. **Potential Safety Risks** (Identify (if any) safety risks that may be associated with process operations.):

15. **Potential Environmental Risks** (Identify any environmental risks that may be associated with the process operations, e.g., fugitive air emissions):

16. **Would a Treatability Study and/or a Field Demonstration be Required Before Full Scale Implementation** (If required, describe the types of treatability studies (bench scale, pilot scale and/or field scale) needed in order to determine and evaluate process applicability for treating this waste. Please also include estimated cost and time to complete these studies.):

17. **Equipment Availability** (Is this equipment readily available? If not, when might it be available?):

18. **Operation and Maintenance Requirements** (Does your process require on-line or frequent monitoring? Does your process require any special equipment for monitoring assuming that periodic samples are taken for measurement of contaminant concentrations. Overall, how much time would be required for operating and maintaining your process? What % of time is the process normally on-line?):

19. **Estimated Cost** (Provide an estimated cost per unit volume of waste treated ($/ton or yd^3) and estimated capital equipment costs.):

20. **Unusual Requirements** (Identify any out of the ordinary conditions or requirements not identified that are needed for successful process operation.):

21. **Case Histories** (Are there any case histories providing relevant information regarding the process for application to sludge treatment?):

20. **Other** (Describe any other process characteristics that could help in the evaluation.):

PLEASE RETURN COMPLETED FORM BY: MAY 28, 1994

Return form to:
Mr. Michael Morris
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6495

PROJECT FACT SHEET
Remediation Technologies for Containerized Contaminated Sludges

Background

Treatment options for contaminated sludges from evaporation ponds in the West are being evaluated and screened by Oak Ridge National Laboratory with funding provided by the U. S. Department of Energy (DOE). Although sludge treatment has general application to DOE sites located in the west, this evaluation and screening of technologies is for a specific, but anonymous site. It is probable that feasible technologies for this site may have further application within the DOE complex.

The waste streams requiring treatment for this technology evaluation and screening are sludges from evaporation ponds used for disposal of process wastewaters. The sludges contain a variety of constituents, including radioactive and hazardous materials. The ponds of interest were routinely used from the early 1950s to mid 1980s at which time efforts began to close the ponds in accordance with regulatory requirements and DOE commitments. Identification and evaluation of potential treatment options will lead to the most promising options for sludge treatment and disposal consistent with the current waste management options available and feasible for the site.

Site Characteristics

Sludges from the ponds have been blended into two different waste streams that have similar constituents at different concentration levels. Chemical analyses and physical characteristics of the sludges are summarized on Table 1. Samples were collected prior to blending the sludges and reflect the best available information. Variation of sludge composition in the tanks is expected; however, the data in Table 1 can be used as average expected concentration ranges. Volatile organic compounds have been sporadically reported but, due to the nature of the ponds (solar evaporation), significant concentrations have not been detected. Semivolatile organic compounds and pesticides have been reported sporadically at low levels in the sludge and the pond water respectively. PCBs have not been detected. Metals and radionuclides are present in both waste streams. Cadmium and nickel are of primary concern because they have been reported above land disposal requirement (LDR) constituent concentrations in the waste extract (CCWE) limits. Arsenic, chromium, cyanide (total), lead, and silver have also been detected in the pond water at concentrations above acceptable LDR constituent concentrations in waste (CCW) limits. Radioactive contamination is present but at low levels. Typically, total alpha and beta radiation ranges do not exceed 10 nCi/g. Salts (predominantly potassium nitrates and sodium nitrates with some phosphates, carbonates, and sulfates) are also present in both waste streams.

While still evolving, the present closure strategy for the ponds is to transfer the sludges from the ponds into 10,000-gal. double-wall polyethylene tanks while options are evaluated for final treatment and disposal. Presently, sludges are being removed (by vacuum truck) from the existing ponds and placed into 53 10,000-gal. double-wall polyethylene tanks for temporary storage. Due to space limitations excess water may be decanted after the tanks have been filled and the sludges have settled to allow for additional sludge to be added. The sludges will not be dewatered further prior to treatment. The vendor should consider this the starting point for the process.

Performance Criteria

The objective of this project is to identify feasible technologies for treatment of the containerized contaminated sludges. Process performance criteria are proposed, with metals as the target parameter for evaluation. For the purposes of this work, "metals" refers to the eight characteristic metals identified in 40 CFR 261, with the addition of nickel. Other potential contaminants are present within the sludge; however, metals were selected as targets based on their presence in the sludge above LDRs.

Effective treatment of the sludges should at a minimum result in:

1. Reduction or immobilization of metals so that the CCWE meets LDRs; or
2. Where LDRs are not applicable, TCLP concentrations in leachate that are below U. S.-stipulated hazardous waste criteria levels; and
3. Physical form that meets the waste acceptance criteria as listed in Table 2.

Technologies will also be evaluated based on other factors such as:

1. Overall protection of human health and the environment;
2. Compliance with applicable or relevant and appropriate requirements (ARARs);
3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, and volume through treatment;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. Regulatory agency acceptance; and
9. Community acceptance.

It should also be noted that the sludges of interest are considered listed wastes. It is not expected that delisting would be considered as part of a closure plan. Therefore, any secondary wastes that are produced from the treatment of this listed waste will also be listed. These secondary wastes will have to be disposed in the same manner and would be considered in the overall cost of the process.

Final disposition of the sludges has not been determined. Possible scenarios include both on-site (RCRA cell) disposal or off-site disposal at either the Nevada Test Site or Envirocare of Utah. Table 2 summarizes disposition and final waste form requirements. Other disposition criteria include cost and minimization of secondary waste. In any case, the sludge must be treated to meet LDRs at a minimum (Table 3).

Table 1. Representative Waste Stream Characterization

Characteristic	units	Waste 1	Waste 2
Volume (approximate)	gal. (ft^3)	350,000 (47,000)	230,000 (31,000)
1,1,1-Trichloroethane	µg/kg	24	9-29
Tetrachloroethene	µg/kg	32-460	8-1000
Trichloroethene	µg/kg	29-57	5-7
Benzene	µg/kg	-	7-31
Arsenic	mg/kg	39.6-60.0	2-37
Barium	mg/kg	46.5-210	13.2-217
Cadmium	mg/kg	6.7-1300	3.2-4660
Cadmium (TCLP leachate concentration)	mg/L	0.019-0.485	0.342-25.90
Chloride[a]	mg/L	20-300	160-990
Chloride	mg/kg	927-18,200	2420-6890
Chromium	mg/kg	7.9-658	216-3190
Cyanide - Total	mg/kg	0.34-74.1	1.7-190
Lead	mg/kg	9.4-89	2.0-191
Mercury	mg/kg	0.7-5.5	0.11-14
Nickel	mg/kg	7.1-102	17.4-902
Nickel (TCLP leachate concentration)	mg/L	0.02-0.056	0.563-8.30
Nitrate[a]	mg/L	1.7-89	410-11,000
Nitrate as N	mg/kg	380-19,000	65,000-130,000
Potassium	mg/kg	6,600-15,400	16,900-365,000
Silver	mg/kg	18.9-25.9	4.4-166
Sodium	mg/kg	14,500-54,200	39,200-378,000
Sulfate[a]	mg/L	20-160	210-1300
pH	none	7.2-9.3	9.7-10.5
Gross Alpha	pCi/g	5.2-570	2700-8700
Gross Beta	pCi/g	5.1-730	390-1200
Alkalinity (total)	mg/kg	180-5500	17,000-24,000
Atterberg - Liquid Limit	none	70-101	69-72
Atterberg - Plastic Index	none	20-49	32-34
Atterberg - Plastic Limit	none	33-65	37-38
Bulk Density (dried solids)	g/cc	0.81-0.90	-
Moisture - Gravimetric	%	71.8-93.4	33.1-72.5
Moisture - Karl Fisher	%	23.5-53	-
Particle Size, 4.75 mm (sand)	% finer	96.9-100	39.4-100
Particle Size, 0.075 mm(silt/clay)	% finer	59.1-88.3	0.1-100
Specific Gravity	none	1.0-1.2	-
% Recovery of solids[a]	%	6.4-25.8	9.2-22.2
Total Organic Carbon	mg/kg	3000-34,000	3500-9000
Total Dissolved Solids[a]	mg/L	160-790	4600-24,000

NOTE: Values reported in this table are based on sampling and analysis of sludges from the ponds. Composition may vary based on removal and transfer of sludges to the tanks.

[a] Following ASTM leach

\- Not detected

Additional Waste Stream Characteristics

Characteristic	units	Waste 1	Waste 2
Aluminum	mg/kg	1350-4340	69.5-1330
Ammonia	mg/kg	36	-
Antimony	mg/kg	-	13.8
Arsenic	mg/kg	39.6-60.0	2-37
Barium	mg/kg	46.5-210	13.2-217
Beryllium	mg/kg	10.9	1.1-17.6
Boron	mg/kg	12.8-349	78.9-1390
Cadmium	mg/kg	6.7-1300	3.2-4660
Cadmium (TCLP leachate concentration)	mg/L	0.019-0.485	0.342-25.90
Calcium	mg/kg	20,700-157,00	1550
Chloride[a]	mg/L	20-300	160-990
Chloride	mg/kg	927-18,200	2420-6890
Chromium	mg/kg	7.9-658	216-3190
Copper	mg/kg	15.3-210	4.3-78
Cyanide - Total	mg/kg	0.34-74.1	1.7-190
Fluoride	mg/kg	-	6,320-29,800
Iron	mg/kg	1680-4800	24.2-211
Lead	mg/kg	9.4-89	2.0-191
Lithium	mg/kg	-	24-108
Magnesium	mg/kg	3270-19,800	1340-24,200
Manganese	mg/kg	60.5-208	8.7
Mercury	mg/kg	0.7-5.5	0.11-14
Nickel	mg/kg	7.1-102	17.4-902
Nickel (TCLP leachate concentration)	mg/L	0.02-0.056	0.563-8.30
Nitrate[a]	mg/L	1.7-89	410-11,000
Nitrate as N	mg/kg	380-19,000	65,000-130,000
Nitrite	mg/kg	0.46-1700	480-1000
Phosphorus (as total P)	mg/L	0.09-3.9	22-52
Potassium	mg/kg	6,600-15,400	16,900-365,000
Silicon	mg/kg	1110-5070	422-6990
Silver	mg/kg	18.9-25.9	4.4-166
Sodium	mg/kg	14,500-54,200	39,200-378,000
Strontium	mg/kg	575-946	-
Sulfate[a]	mg/L	20-160	210-1300
Sulfide	mg/kg	8-56	-
Thallium	mg/kg	7.3	-
Zinc	mg/kg	77.6-300	5.5-18.9
Gross Alpha	pCi/g	5.2-570	2700-8700
Gross Beta	pCi/g	5.1-730	390-1200
Americium-241	pCi/g	0.75-5.1	0.01-1.7
Plutonium-239	pCi/g	0.18-23	2.8-16
Uranium-234	pCi/g	0.04-160	0.01-11
Uranium-235	pCi/g	0.3-5.1	0.02-0.84
Uranium-238	pCi/g	0.04-190	1.3-31

NOTE: Values reported in this table are based on sampling and analysis of sludges from the ponds. Composition may vary based on removal and transfer of sludges to the tanks.

[a] Following ASTM leach

- Not detected

Table 2. Sludge Disposition Options

Disposition Option	Waste Form	Waste Acceptance Criteria	Handling/Shipping
Off site[a]			
Nevada Test Site Las Vegas, Nevada	No free liquids. Immobilized waste (no more than 1 wt % of <10 μm particulates or 15 wt % <200 μm particulates). Mixed waste is not accepted for bulk disposal (i.e., must be immobilized). Waste and/or package must be capable of supporting a uniformly distributed load of 4000 lbs/ft^2 (28 psi).	Treatment standards expressed as constituent concentrations in waste extract (CCWE) as required by 40 CFR 268 land disposal requirements specifically for: cadmium: 0.066 mg/L, and nickel: 0.32 mg/L 49 CFR 173 activity limits and external radiation levels for packages < 200 mrem/h on contact.	If immobilization is impractical, acceptable waste packaging must be used (e.g., overpacking, steel box with no liner, or wooden box with plastic liner). Applicable DOT requirements.
ENVIROCARE of Utah, Inc. Tooele County, Utah	No free liquids. Volumetric bulky materials or debris (concentration of radionuclides must be homogeneous within physical form). Optimally, physical form should not be >10 inches in any dimension. Larger waste forms are accepted but are subsequently crushed to under this size limitation.	Treatment standards expressed as CCWE as required by 40 CFR 268 land disposal requirements specifically for: cadmium: 0.066 mg/L, and nickel: 0.32 mg/L If a single radionuclide is present the maximum average concentration shall not be exceeded (specifically): $Uranium^{234}$: 3.7E+4 pCi/L $Uranium^{235}$: 7.7E+2 pCi/L $Uranium^{238}$: 2.8E+4 pCi/L $Plutonium^{239}$: 9.9E+3 pCi/L If a mixture of radionuclides is present, the following relationship must be met: Σ(radionuclide concentration/maximum average waste concentration for disposal)$\leq$1.	Acceptable waste packaging (ranging from barrels, boxes, bags to bulk rail cars). Applicable DOT requirements. Transport by truck or rail available.
On site			
RCRA disposal cell	No free liquids. Volumetric bulky materials or debris.	To be negotiated with regulators at the time of permitting. At a minimum, 40 CFR 268 land disposal requirements (see above).	To be negotiated with regulators.

[a] Information was generated from Nevada Test Site and Envirocare waste acceptance criteria and may be subject to interpretation.

Table 3. Target Constituents and Treatment Requirements

Target analyte	Units	LDR (CCWE) [a]
Antimony	mg/L	0.23
Arsenic	mg/L	5.0
Barium	mg/L	52
Cadmium	*mg/L*	*0.066 (1.0)*
Chromium (total)	mg/L	5.2
Lead	mg/L	0.51
Mercury	mg/L	0.025
Nickel	*mg/L*	*0.32*
Selenium	mg/L	5.7
Silver	mg/L	0.072

[a] Sludges are considered to be listed as F001, F002, F003, F005, F006, F007, F009, F039 and D006. The value in parenthesis applies to D006 listed waste. LDR CCWEs are found in 40 CFR 268.41. Target constituents in the sludges above LDRs are identified by italics.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

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May 12, 1994

Evaluation of Technologies for Treatment/Remediation of Contaminated Sludges Follow-up Letter

This letter is a follow-up to the letter of April 28, 1994 concerning the evaluation of technologies for treatment/remediation of contaminated sludges at a Department of Energy (DOE) site located in the west. As part of this project, we plan to prepare a report based in part on information that you will be providing. We are asking for your approval for use of your information. We have enclosed a form giving options for use of the data you are providing. These are:

1. Consent to include all data as provided with reference to your company as the provider.

2. Consent to include all data as provided with no reference to your company as the provider.

Please return this form along with the completed technology survey form.

Thank you again for your participation in this important technology evaluation. We look forward to receiving the completed evaluation forms by May 28, 1994. In the mean time should you have any questions concerning completion of the survey form or if you need additional information, please contact me at (615) 574-0559 or FAX (615) 576-0327.

Very truly yours,

Michael I. Morris
Chemical Technology Division

MIM:rrs
Enclosures

Sample vendor response

Option A

1.0 Name of Process Technology for Sludge Treatment

Cement Admixture Stabilization (CAS) of nitrate salt sludge (Option A).

2.0 Description

These are interesting waste streams. From the analysis presented, the wastes contain significant amounts of sodium or potassium nitrates. The elevated concentrations of cations and anions preclude the use of Ordinary Portland cement (OPC) stabilization. An admixture of OPC with activated blast furnace slag, fly ash, and/or silica fume may successfully stabilize the waste. Relatively high loadings of additives, with a subsequent high volume increase, would have to be used to control the bleed of the freshly-made mixture and the leachability of the cured material. In addition, the elevated concentration of nitrate salts precludes the use of sulfur polymer cement on the waste.

The process consists of several processing steps. These include removing the waste from the tanks and transfer of sludge to dewatering equipment, dewatering of the sludge and stabilization of the dewatered material. In addition the aqueous streams removed from the sludges or generated in waste removal activities may need treatment to meet discharge requirements.

Excess water on top of the solid material in the tank will be pumped into a storage container(s). This water may require treatment to meet discharge requirements. We believe that the most likely removal option will be to pump the sludge from the tanks using a dredge type slurry pump. If the solid is not fluid enough to be pumpable, a hydraulic jet unit with mixers and/or grinders will be used to dislodge the solid chunks before pumping the waste. If necessary, part of the slurry liquid may be recycled back to the tank and mixed with the solids to improve the waste pumpability.

The solid material will be dewatered by processing it through either a filter press, centrifuge or a conical settling tank. Water that is not used in the subsequent stabilization process may need additional treatment to meet discharge requirements.

The dewatered sludge will be fed to a small cement batch plant for stabilization using admixtures, i.e., OPC combined with additives such as fly ash (FA), activated blast furnace slag (BFS), polysilicates, and adsorbents. The stabilized waste will be packaged to meet requirements for final disposal. The mix will probably be cured in the final package.

3.0 Treatment Efficiencies Expected and Reliability

The process can typically handle material with moisture contents between 10 and 70 percent. If the moisture content of the waste is too low, water will be added to enhance workability and to hydrate the cement admixture. From the limited data presented, the constituents and weight loadings of the cement based admixtures cannot be determined. The recommended stabilization reagent(s) can only be determined by a treatability study on the actual wastes, and this is recommended. We believe that it will be possible to develop formulations that meet the leachability requirements of the final disposal options but the long term durability of a formulation containing the highly soluble nitrate salts is questionable.

4.0 Limiting Conditions and Interferences

The data presented in Table 1 of your vendor survey indicate some significant differences in the two waste streams. These differences may be sufficient to cause process difficulties for the remediation of each one of the waste streams without initial pretreatment of the waste. For example, the LDR for amenable cyanides (F009) is 30 ppm. The high cyanide value for the ranges presented in Table 1 for Waste 1 is 74.1 ppm and that for Waste 2 is 190 ppm. Both of these values are in excess of the F009 LDR. If the average cyanide is well below the 30 ppm limit, the high cyanide sludge can probably be blended out. If not, additional treatment to destroy cyanide will be required before disposal can be implemented.

Both wastes contain very high levels of nitrate salts, with Waste 2 being the highest (130,000 ppm nitrate as N or 57.6 percent nitrate as NO_3). Without pretreatment of the waste, these high levels of nitrate salts preclude direct treatment by OPC stabilization; therefore cement admixtures will have to be used. Because of the high alkali nitrate in the waste, IT believes that the best chance of success will be through the use of large replacements of OPC with BFS and/or FA. The cement loading in the dry blend may constitute only 5 to 10 percent of the dry blend. Various options such as prehydration of the cement prior to addition to the waste should be considered. Also, the temperature rise of the hydrating material should be monitored since it is expected that BFS will be a major component of the dry blend.

Formulations can be developed that will pass the requirements listed in the letter, e.g., pass the TCLP. Devising cost-effective formulations that will pass the ANSI-16.1 test at Lx = 6 for all constituents of concern, e.g., nitrate, will be difficult. The long term durability of the treated material, particularly if exposed to water or to freeze/thaw conditions, is also questionable. If the treated materials are properly packaged, the detrimental effects of lower durability will be minimized.

5.0 Stage of Development

Cement stabilization processes have been tested at bench-, pilot-scales, and full-scale.

6.0 Approximate Number of Successful Installations/Remediations

IT knows of no full-scale remediation of high nitrate containing waste.

7.0 Processing Capacities and Rates

Cement batch plants are available in a wide range of capacities. For this waste we would probably use a small system with a 20 cubic yard batch capacity. This would give a processing rate of 30 to 60 cubic yards per hour of dewatered sludge.

8.0 Pretreatment Requirements

For nonpumpable slurries, it may be necessary to add a viscosity extender to the material. Large particles will be removed requiring a screening pretreatment. It may be advantageous to increase the pH if ammonia is present to facilitate its removal in the dryer. If the material in the tanks has set up, a pulverization step may be required.

9.0 Chemicals or Other Treatment Agent Requirements

Requirements (pound/pound waste)[1]	Chemical
Viscosity Extender	Minimal
Sodium Hydroxide	Minimal
OPC + FA + BFS on Dewatered Sludge[2]	1.0 - 2.5

[1]Estimated. Actual value is waste dependent and will be determined by treatability testing.
[2]OPC = Ordinary Portland Cement; FA = Fly Ash; BFS = Blast Furnace Slag.

10.0 Secondary Waste Produced

There may be some liquid decanted from the tanks or generated during the sludge removal activities.

Water use during the waste removal activities (dredging) will be minimized by recycling. This wastewater may contain some suspended solids, organics (if present in the original sludge) and dissolved or suspended metals (including radioactive materials).

11.0 Treatment of Secondary Waste

These wastewaters will be treated to meet discharge criteria. The solids and metals will be removed by chemical treatment with coagulants and metals scavenging additives. The resulting sludge will be mixed with the evaporation pond sludge for dewatering and stabilization. Any organics in the wastewater will be removed by adsorption on carbon. This carbon may be a low volume secondary waste requiring disposal.

12.0 Final Waste Form

The final waste form can be either monolithic or granular as required by the client. If monolithic, the compressive strength will be more than 500 psi. Either product will pass the TCLP leaching test. The volume increase/reduction of the final waste form per volume treated is strictly waste dependent and will have to be determined by treatability testing to determine the waste loading in the final form. Experience with the INEL material indicated that the final waste form had one-tenth the volume of the original waste. It is expected that the volume of the dewatered sludge will double or triple by this treatment.

13.0 Permits Required

The permits required are listed in the table below:

Operation	Permit Required
Treatability	Treatability Exemption, EPA ID Number, Radioactive Materials License
Processing	RCRA, CWA, CAA

14.0 Potential Safety Risks

The operation involves hot rotating equipment; therefore, risks associated with hot objects will be encountered. Caustic chemicals may be involved of pH adjustment is required. Poisons and radioactive hazards should be anticipated.

15.0 Potential Environmental Risks

Chemical spills during transfer can result in accidental discharge of heavy metals and radioactive substances.

16.0 Would A Treatability Study And/Or A Field Demonstration Be Required Before Full-Scale Implementation?

Treatability studies will most definitely be required before full-scale implementation. Dose/Response curves need to be determined as well as materials handling considerations. Questions, such as how much moisture can be decanted, how much remains behind, and can the material be pumped or does it need to be removed by other methods, need to be answered.

The normal duration of a cement based stabilization treatability study is about 5 months. The actual duration of any treatability test program is dependent on the performance criteria desired e.g., if a 90-day immersion test is required then the treatability program cannot be shorter than that.

Since this process will be a treatment train instead of a single unit operation, IT recommends that this concept be demonstrated on the pilot-scale. This normally will take from 2 to 3 months.

17.0 Equipment Availability

The equipment for this process is widely available. The dredge pumps for waste removal, dewatering equipment and cement batch plants can be purchased or rented and are available in a wide range of capacities. Some rental equipment, such as centrifuges, may be more difficult to decontaminate.

18.0 Operation and Maintenance Requirements

Waste composition will have to be monitored to adjust admixture composition and loading. On-line factor should be very high. A five- to seven-person crew will be required to operate the waste removal, dewatering and stabilization equipment.

19.0 Estimated Cost

We cannot provide more than an estimated cost range at this time. Further information on waste loading, admixture/formulation composition and packaging requirements is needed before the cost estimate can be firmed up.

For larger hazardous waste sites on typical contaminated sludges, the cost for waste removal, dewatering and cement stabilization range from $70 to $100 per cubic yard. For this small site, with high additive requirements, and higher costs for mobilization/demobilization, training and H&S oversight, we would expect cost for this option to range from $200 to $500 per cubic yard.

Costs for treatability studies and design of the full-scale system would add another $50 per cubic yard to the cost.

20.0 Unusual Requirements

High additive loadings as previously discussed.

21.0 Case Histories

IT has no experience with sludges with high nitrates.

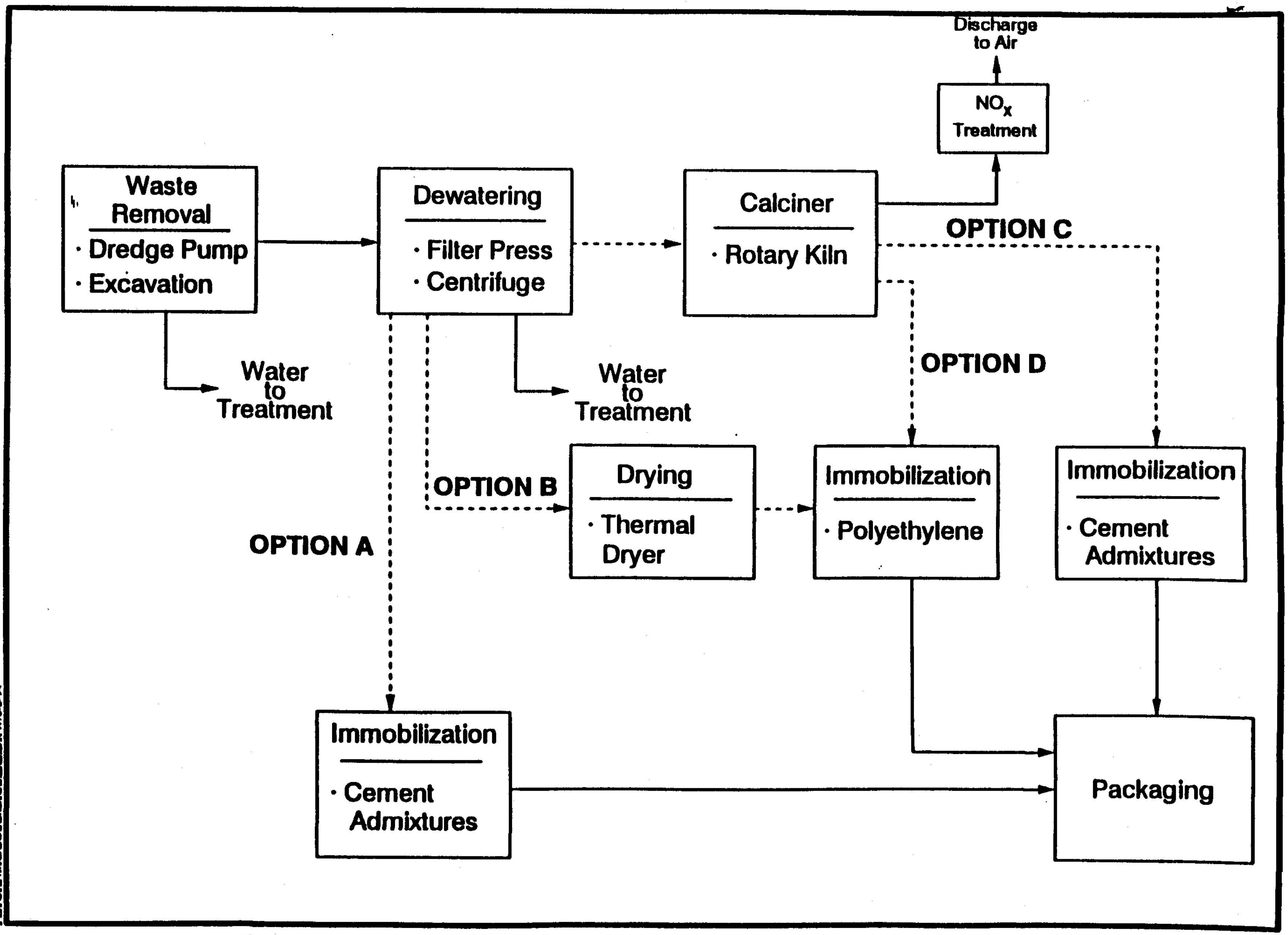


FIGURE 1. BLOCK FLOW FOR IMMOBILIZATION OF HIGH NITRATE SOLAR POND SLUDGES

Treatment of Low-Level Mixed Waste Sludges from Solar Evaporation Ponds

VENDOR / TECHNOLOGY SURVEY FORM

Date: May 27, 1994
Company: TIDE Co.
Telephone: (505) 856-0210
Address: 8325 Washington, NE
City, State, Zip: Albuquerque, NM 87113

Contact: M.S. Riddle
Position: President

1. Name of Process Technology for Sludge Treatment

Phoenix Ash Technology(PAT™); Fly-ash based solidification.
1

2. Description

The PAT™ process involves the compression of a mixture of fly ash and one or more other constituents, including waste materials, into a solid mass. The process has application for environmental remediation of the identified mixed waste materials in the Project Fact Sheet by providing a mechanism for the stabilization of the hazardous agents within the matrix specifically formulated for these materials. The solids from the materials, as described in the Project Fact Sheet, would be mixed with high grade(C) fly ash, adjusted for moisture content (12-14 % wt.) and then subjected to high pressure(1750 - 2000 psi.). The resulting block could then be immediately handled. The PAT™ achieved stabilization contains the hazardous materials and radionuclides by binding them with fly ash at the molecular level and in addition forms a physical barrier to leaching and migration.

3. Treatment Efficiencies Expected and Reliability

The PAT™ process is expected to be 100% efficient in treating the solids in the sludges described in the Project Fact Sheet and achieving the performance goals listed in Tables 1 and 2. In order to achieve these goals the sludges need to be dewatered so that the moisture content (% wt.) is not greater than 20% (e.g. solids = 80 % wt.) prior to being processed by the PAT™. The initial volume of waste is reduced by approximately 50% in the process. Even with the addition of C-grade fly ash, the total volume of the end product, as compared to the original volume of the dewatered waste materials, will show a reduction of approximately 30%. The PAT™ process and equipment are considered to be very robust and can operate effectively on a wide range of contaminants and over a wide range of concentrations. The equipment is capable of mobile operations and can operate in many environments.

4. **Limiting Conditions and Interferences**

The concentrations of salts(sulfates and nitrates) are significantly high in waste 1 & 2. However, due to the solubility of the salts, the necessary dewatering stage of treatment will reduce concentrations in the remaining solids to controllable levels. If residual levels are questionable for accommodation by the basic PAT™ process, proprietary additives will be used to neutralize the effects of the remaining salts. Fluctuations in levels of salts in the dewatered solids can be accommodated by varying amounts of additives.

5. **Stage of Development**

The PAT™ process is in an advanced developmental stage to accommodate large scale commercial applications. The experimental stage involved several bench scale experiments with different types of contaminants in soils and other mediums. Many of these experiments have been documented and range from battery reclamation sites to electro-plating sludge to mixed waste at a National Laboratory. A range of PAT™ formulations, as well as designs of the associated equipment for handling large volumes of different types of contaminated materials, are under development.

6. **Approximate Number of Successful Installations/Remediations**

Many successful bench scale remediations were initially accomplished during the initial experimental and early developmental stages. The first field application consisted of applying the basic process to lead contaminated mine tailings on an Oregon site. A modified rammed earth machine was used and because of the constrained mountainous terrain and other logistic considerations, portland cement was substituted as the pozzolanic material. At project completion, 980 tons of blocks had been produced which met Oregon DEQ criteria. The blocks were removed from the site by the client and were planned to be used in a construction project. The lessons learned during this project were incorporated into the design of the current full scale pre-production unit. Portland cement is acceptable to the PAT™ process, however the products have a longer set up time, they are difficult to handle after compression and the products have a shorter life expectancy as compared to those fabricated with fly ash.

Friedman Multiple Comparison Test Results, value >50.5 is considered to indicate that treatments are different at 95%, >42.2 at 90%, >66.3 at 99%, and >84.7 at 99.9%

	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
1	0	52.5	53.5	50.5	1.5	4	16	14	7.5	21	9	1	3.5	32	25.5	18	48	61	50	58	102.5	107
2A	52.5	0	1	2	51	56.5	68.5	66.5	60	73.5	61.5	51.5	56	84.5	78	70.5	100.5	113.5	102.5	110.5	155	159.5
2B	53.5	1	0	3	52	57.5	69.5	67.5	61	74.5	62.5	52.5	57	85.5	79	71.5	101.5	114.5	103.5	111.5	156	160.5
2C	50.5	2	3	0	49	54.5	66.5	64.5	58	71.5	59.5	49.5	54	82.5	76	68.5	98.5	111.5	100.5	108.5	153	157.5
3A	1.5	51	52	49	0	5.5	17.5	15.5	9	22.5	10.5	0.5	5	33.5	27	19.5	49.5	62.5	51.5	59.5	104	108.5
3B	4	56.5	57.5	54.5	5.5	0	12	10	3.5	17	5	5	0.5	28	21.5	14	44	57	46	54	98.5	103
3C	16	68.5	69.5	66.5	17.5	12	0	2	8.5	5	7	17	12.5	16	9.5	2	32	45	34	42	86.5	91
4A	14	66.5	67.5	64.5	15.5	10	2	0	6.5	7	5	15	10.5	18	11.5	4	34	47	36	44	88.5	93
4B	7.5	60	61	58	9	3.5	8.5	6.5	0	13.5	1.5	8.5	4	24.5	18	10.5	40.5	53.5	42.5	50.5	95	99.5
4C	21	73.5	74.5	71.5	22.5	17	5	7	13.5	0	12	22	17.5	11	4.5	3	27	40	29	37	81.5	86
5A	9	61.5	62.5	59.5	10.5	5	7	5	1.5	12	0	10	5.5	23	16.5	9	39	52	41	49	93.5	98
5B	1	51.5	52.5	49.5	0.5	5	17	15	8.5	22	10	0	4.5	33	26.5	19	49	62	51	59	103.5	108
5C	3.5	56	57	54	5	0.5	12.5	10.5	4	17.5	5.5	4.5	0	28.5	22	14.5	44.5	57.5	46.5	54.5	99	103.5
6A	32	84.5	85.5	82.5	33.5	28	16	18	24.5	11	23	33	28.5	0	6.5	14	16	29	18	26	70.5	75
6B	25.5	78	79	76	27	21.5	9.5	11.5	18	4.5	16.5	26.5	22	6.5	0	7.5	22.5	35.5	24.5	32.5	77	81.5
6C	18	70.5	71.5	68.5	19.5	14	2	4	10.5	3	9	19	14.5	14	7.5	0	30	43	32	40	84.5	89
7A	48	100.5	101.5	98.5	49.5	44	32	34	40.5	27	39	49	44.5	16	22.5	30	0	13	2	10	54.5	59
7B	61	113.5	114.5	111.5	62.5	57	45	47	53.5	40	52	62	57.5	29	35.5	43	13	0	11	3	41.5	46
8A	50	102.5	103.5	100.5	51.5	46	34	36	42.5	29	41	51	46.5	18	24.5	32	2	11	0	8	52.5	57
8B	58	110.5	111.5	108.5	59.5	54	42	44	50.5	37	49	59	54.5	26	32.5	40	10	3	8	0	44.5	49
9A	102.5	155	156	153	104	98.5	86.5	88.5	95	81.5	93.5	103.5	99	70.5	77	84.5	54.5	41.5	52.5	44.5	0	4.5
9B	107	159.5	160.5	157.5	108.5	103	91	93	99.5	86	98	108	103.5	75	81.5	89	59	46	57	49	4.5	0

rank, $R(X_{ij})$

Eval.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	2	1	5	7	4	3	6	8	9	14	20	21	22	17	19	11	10	18	12.5	12.5	16	15
2	4	3	1.5	1.5	10	8.5	8.5	18	15	13	17	16	14	6	6	6	19.5	19.5	11.5	11.5	21.5	21.5
3	2	2	2	6	10.5	10.5	13	4.5	4.5	7	8.5	8.5	12	14.5	14.5	16	21	22	17.5	17.5	19.5	19.5
4	20	3	1.5	1.5	19	21.5	21.5	17	16	18	10	4.5	4.5	15	8.5	8.5	6.5	6.5	13.5	13.5	11.5	11.5
5	10	2.5	6.5	8.5	1	4	5	16	14	15	2.5	6.5	8.5	11	12	13	17	18	19	20	21	22
6	18	5	1.5	1.5	17	21.5	21.5	14	9.5	9.5	6	3.5	3.5	11	7.5	7.5	12.5	12.5	15.5	15.5	19.5	19.5
7	9	4	3	8	20	19	22	6	5	10	16	15	17.5	12	11	14	1	2	7	13	17.5	21
8	18	14	11	6	7	3	2	21	15	22	10	4	1	13	12	5	16.5	16.5	9	8	19.5	19.5
9	16	12	10	11	1	2	5	3	9	6	7	4	8	14	13	15	17.5	19.5	17.5	19.5	21	22
10	6.5	6.5	10	2	11	13	12	4	8	1	5	9	3	16	19.5	19.5	14.5	14.5	17.5	17.5	21.5	21.5
11	2	2	2	4	5.5	5.5	7	10	10	13	14.5	14.5	17	10	10	10	19.5	19.5	17	17	21.5	21.5
sum, R_j	107.5	55	54	57	106	111.5	123.5	121.5	115	128.5	116.5	106.5	111	139.5	133	125.5	155.5	168.5	157.5	165.5	210	214.5
sum R_j^2	1555.25	456.5	412	405	1478.5	1705.25	1932.75	1751.25	1363.5	1843.25	1543.75	1392.25	1598	1867.25	1794	1636.75	2578.75	2957.75	2409.75	2625.75	4104	4293.75

Friedman Test Statistic, T_2

A_2	B_2	T_2
41705	35380.0455	42.1632207

Freidman Test Results:

data	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
Eval.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	589.4	616	545.6	488.8	554.1	565.2	490.6	481.3	471.1	452.3	435.1	418	397.7	442.2	436	453.7	438.4	438.4	453.6	453.6	445.6	451.9
2	610.6	615.2	634.7	634.7	503.6	506.5	506.5	434.5	462.2	471.3	444.4	453.5	462.6	552.7	552.7	552.7	371.9	371.9	496.3	496.3	290.5	290.5
3	661.6	661.6	661.6	591	535.9	535.9	516.4	595.2	595.2	575.7	551.2	551.2	531.7	485.7	485.7	466.2	265.3	197.1	406	406	268.8	268.8
4	353.4	581.8	584.1	584.1	357.8	280.5	280.5	486.7	489.3	474.3	554.5	564.3	564.3	536.2	561	561	561.4	561.4	540.7	540.7	553.3	553.3
5	537.1	596.2	586.1	581.8	597.9	595.8	591.5	370.4	387.3	377.7	596.2	586.1	581.8	505.6	504.6	500.3	355.3	345.7	320.5	310.9	339.4	329.8
6	421	608.2	663.2	663.2	422	360.7	360.7	488.6	534.1	534.1	581	655.5	655.5	515.7	570.3	570.3	496	496	482.4	482.4	405.7	405.7
7	522.8	553.1	557.9	536.6	468	472.8	464.1	548.1	552.9	516.3	489.7	494.5	473.2	508.8	513.6	504.9	591.2	582.5	541.7	507.8	473.2	464.5
8	436.2	524.1	549.5	583.4	566.9	600.3	611.9	372.3	498.4	330.4	549.7	598.8	716.2	535.4	548.2	589	453.2	453.2	554.5	560.7	376.4	376.4
9	418.5	443.5	462.7	455.5	490	489.5	476.1	482.7	463.3	469.4	465.3	476.9	463.5	434	443.1	429.7	393.7	360	393.7	360	232.3	209.6
10	546.4	546.4	526.9	564.1	515	487	511.8	554.7	535.2	572.4	553.4	533.9	558.7	425.5	412.5	412.5	440.9	440.9	419.4	419.4	392.6	392.6
11	621.6	621.6	621.6	571.4	556.5	556.5	537	491	491	471.5	425.5	425.5	406	491	491	491	209.5	209.5	406	406	209.5	209.5

Quade Multiple Comparison Test Results, value >347.8 is considered to indicate that treatments are different at 95%, >291 at 90%, >457.1 at 99%, and >583.96 at 99.9%

	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
1	0	302.5	343	315	14.5	1	61.5	189.5	101.5	219	71	26.5	13.5	175.5	113	58.5	440	489	341.5	351.5	646	655.5
2A	302.5	0	40.5	12.5	288	303.5	364	492	404	521.5	373.5	276	316	478	415.5	361	742.5	791.5	644	654	948.5	958
2B	343	40.5	0	28	328.5	344	404.5	532.5	444.5	562	414	316.5	356.5	518.5	456	401.5	783	832	684.5	694.5	989	998.5
2C	315	12.5	28	0	300.5	316	376.5	504.5	416.5	534	386	288.5	328.5	490.5	428	373.5	755	804	656.5	666.5	961	970.5
3A	14.5	288	328.5	300.5	0	15.5	76	204	116	233.5	85.5	12	28	190	127.5	73	454.5	503.5	356	366	660.5	670
3B	1	303.5	344	316	15.5	0	60.5	188.5	100.5	218	70	27.5	12.5	174.5	112	57.5	439	488	340.5	350.5	645	654.5
3C	61.5	364	404.5	376.5	76	60.5	0	128	40	157.5	9.5	88	48	114	51.5	3	378.5	427.5	280	290	584.5	594
4A	189.5	492	532.5	504.5	204	188.5	128	0	88	29.5	118.5	216	176	14	76.5	131	250.5	299.5	152	162	456.5	466
4B	101.5	404	444.5	416.5	116	100.5	40	88	0	117.5	30.5	128	88	74	11.5	43	338.5	387.5	240	250	544.5	554
4C	219	521.5	562	534	233.5	218	157.5	29.5	117.5	0	148	245.5	205.5	43.5	106	160.5	221	270	122.5	132.5	427	436.5
5A	71	373.5	414	386	85.5	70	9.5	118.5	30.5	148	0	97.5	57.5	104.5	42	12.5	369	418	270.5	280.5	575	584.5
5B	26.5	276	316.5	288.5	12	27.5	88	216	128	245.5	97.5	0	40	202	139.5	85	466.5	515.5	368	378	672.5	682
5C	13.5	316	356.5	328.5	28	12.5	48	176	88	205.5	57.5	40	0	162	99.5	45	426.5	475.5	328	338	632.5	642
6A	175.5	478	518.5	490.5	190	174.5	114	14	74	43.5	104.5	202	162	0	62.5	117	264.5	313.5	166	176	470.5	480
6B	113	415.5	456	428	127.5	112	51.5	76.5	11.5	106	42	139.5	99.5	62.5	0	54.5	327	376	228.5	238.5	533	542.5
6C	58.5	361	401.5	373.5	73	57.5	3	131	43	160.5	12.5	85	45	117	54.5	0	381.5	430.5	283	293	587.5	597
7A	440	742.5	783	755	454.5	439	378.5	250.5	338.5	221	369	466.5	426.5	264.5	327	381.5	0	49	98.5	88.5	206	215.5
7B	489	791.5	832	804	503.5	488	427.5	299.5	387.5	270	418	515.5	475.5	313.5	376	430.5	49	0	147.5	137.5	157	166.5
8A	341.5	644	684.5	656.5	356	340.5	280	152	240	122.5	270.5	368	328	166	228.5	283	98.5	147.5	0	10	304.5	314
8B	351.5	654	694.5	666.5	366	350.5	290	162	250	132.5	280.5	378	338	176	238.5	293	88.5	137.5	10	0	294.5	304
9A	646	948.5	989	961	660.5	645	584.5	456.5	544.5	427	575	672.5	632.5	470.5	533	587.5	206	157	304.5	294.5	0	9.5
9B	655.5	958	998.5	970.5	670	654.5	594	466	554	436.5	584.5	682	642	480	542.5	597	215.5	166.5	314	304	9.5	0

relative size statistic, S_{ij}

Eval.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	-28.5	-31.5	-19.5	-13.5	-22.5	-25.5	-16.5	-10.5	-7.5	7.5	25.5	28.5	31.5	16.5	22.5	-1.5	-4.5	19.5	3	3	13.5	10.5
2	-60	-68	-80	-80	-12	-24	-24	52	28	12	44	36	20	-44	-44	-44	64	64	0	0	80	80
3	-104.5	-104.5	-104.5	-60.5	-11	-11	16.5	-77	-77	-49.5	-33	-33	5.5	33	33	49.5	104.5	115.5	66	66	88	88
4	59.5	-59.5	-70	-70	52.5	70	70	38.5	31.5	45.5	-10.5	-49	-49	24.5	-21	-21	-35	-35	14	14	0	0
5	-7.5	-45	-25	-15	-52.5	-37.5	-32.5	22.5	12.5	17.5	-45	-25	-15	-2.5	2.5	7.5	27.5	32.5	37.5	42.5	47.5	52.5
6	39	-39	-60	-60	33	60	60	15	-12	-12	-33	-48	-48	-3	-24	-24	6	6	24	24	48	48
7	-2.5	-7.5	-8.5	-3.5	8.5	7.5	10.5	-5.5	-6.5	-1.5	4.5	3.5	6	0.5	-0.5	2.5	-10.5	-9.5	-4.5	1.5	6	9.5
8	58.5	22.5	-4.5	-49.5	-40.5	-76.5	-85.5	85.5	31.5	94.5	-13.5	-67.5	-94.5	13.5	4.5	-58.5	45	45	-22.5	-31.5	72	72
9	18	2	-6	-2	-42	-38	-26	-34	-10	-22	-18	-30	-14	10	6	14	24	32	24	32	38	42
10	-10	-10	-3	-19	-1	3	1	-15	-7	-21	-13	-5	-17	9	16	16	6	6	12	12	20	20
11	-95	-95	-95	-75	-60	-60	-45	-15	-15	15	30	30	55	-15	-15	-15	80	80	55	55	100	100
sum, S_j	-133	-435.5	-476	-448	-147.5	-132	-71.5	56.5	-31.5	86	-62	-159.5	-119.5	42.5	-20	-74.5	307	356	208.5	218.5	513	522.5
sum, S_j^2	33327.5	33314.2	35988	27420	14450.2	22215	20799.2	19903.2	9470.25	15253.5	8495	14920.8	18828.8	4501.25	5092	9567.25	26201	29709	10814.8	12130.8	35950.5	36752.8

Quade Test Statistic, T_1

A_1	B_1	T_1
445105	144563.455	4.8101

block rank, Q_i

Eval.	block range	block rank
1	218.3	3
2	344.2	8
3	464.5	11
4	303.6	7
5	287	5
6	302.5	6
7	127.1	1
8	385.8	9
9	280.4	4
10	179.8	2
11	412.1	10

rank, $R(X_{ij})$

Eval.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	2	1	5	7	4	3	6	8	9	14	20	21	22	17	19	11	10	18	12.5	12.5	16	15
2	4	3	1.5	1.5	10	8.5	8.5	18	15	13	17	16	14	6	6	6	19.5	19.5	11.5	11.5	21.5	21.5
3	2	2	2	6	10.5	10.5	13	4.5	4.5	7	8.5	8.5	12	14.5	14.5	16	21	22	17.5	17.5	19.5	19.5
4	20	3	1.5	1.5	19	21.5	21.5	17	16	18	10	4.5	4.5	15	8.5	8.5	6.5	6.5	13.5	13.5	11.5	11.5
5	10	2.5	6.5	8.5	1	4	5	16	14	15	2.5	6.5	8.5	11	12	13	17	18	19	20	21	22
6	18	5	1.5	1.5	17	21.5	21.5	14	9.5	9.5	6	3.5	3.5	11	7.5	7.5	12.5	12.5	15.5	15.5	19.5	19.5
7	9	4	3	8	20	19	22	6	5	10	16	15	17.5	12	11	14	1	2	7	13	17.5	21
8	18	14	11	6	7	3	2	21	15	22	10	4	1	13	12	5	16.5	16.5	9	8	19.5	19.5
9	16	12	10	11	1	2	5	3	9	6	7	4	8	14	13	15	17.5	19.5	17.5	19.5	21	22
10	6.5	6.5	10	2	11	13	12	4	8	1	5	9	3	16	19.5	19.5	14.5	14.5	17.5	17.5	21.5	21.5
11	2	2	2	4	5.5	5.5	7	10	10	13	14.5	14.5	17	10	10	10	19.5	19.5	17	17	21.5	21.5

Quade Test Results:

data

	1	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	8A	8B	9A	9B
Eval.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	589.4	616	545.6	488.8	554.1	565.2	490.6	481.3	471.1	452.3	435.1	418	397.7	442.2	436	453.7	438.4	438.4	453.6	453.6	445.6	451.9
2	610.6	615.2	634.7	634.7	503.6	506.5	506.5	434.5	462.2	471.3	444.4	453.5	462.6	552.7	552.7	552.7	371.9	371.9	496.3	496.3	290.5	290.5
3	661.6	661.6	661.6	591	535.9	535.9	516.4	595.2	595.2	575.7	551.2	551.2	531.7	485.7	485.7	466.2	265.3	197.1	406	406	268.8	268.8
4	353.4	581.8	584.1	584.1	357.8	280.5	280.5	486.7	489.3	474.3	554.5	564.3	564.3	536.2	561	561	561.4	561.4	540.7	540.7	553.3	553.3
5	537.1	596.2	586.1	581.8	597.9	595.8	591.5	370.4	387.3	377.7	596.2	586.1	581.8	505.6	504.6	500.3	355.3	345.7	320.5	310.9	339.4	329.8
6	421	608.2	663.2	663.2	422	360.7	360.7	488.6	534.1	534.1	581	655.5	655.5	515.7	570.3	570.3	496	496	482.4	482.4	405.7	405.7
7	522.8	553.1	557.9	536.6	468	472.8	464.1	548.1	552.9	516.3	489.7	494.5	473.2	508.8	513.6	504.9	591.2	582.5	541.7	507.8	473.2	464.5
8	436.2	524.1	549.5	583.4	566.9	600.3	611.9	372.3	498.4	330.4	549.7	598.8	716.2	535.4	548.2	589	453.2	453.2	554.5	560.7	376.4	376.4
9	418.5	443.5	462.7	455.5	490	489.5	476.1	482.7	463.3	469.4	465.3	476.9	463.5	434	443.1	429.7	393.7	360	393.7	360	232.3	209.6
10	546.4	546.4	526.9	564.1	515	487	511.8	554.7	535.2	572.4	553.4	533.9	558.7	425.5	412.5	412.5	440.9	440.9	419.4	419.4	392.6	392.6
11	621.6	621.6	621.6	571.4	556.5	556.5	537	491	491	471.5	425.5	425.5	406	491	491	491	209.5	209.5	406	406	209.5	209.5

where $$A_1 = \sum_{i=1}^{b} \sum_{j=1}^{k} S_{ij}^2$$

$$B_1 = 1/b \sum_{j=1}^{k} S_j^2$$

$$S_j = \sum_{i=1}^{b} S_{ij}$$

The null hypothesis is that there is no difference between candidate treatment and disposal systems. This null hypothesis is rejected at the level α, if T_1 exceeds the 1 - α quantile of the F distribution as listed in appropriate statistical tables with degrees of freedom equal to (k-1) and (b-1)(k-1). If the null hypothesis is rejected, multiple comparisons can be made. Treatment technologies i and j are considered different if the inequality below is satisfied:

$$| S_i - S_j | > t_{1-\alpha/2} [2b(A_1-B_1) / (b-1)(k-1)]^{1/2}$$

The Friedman test is an extension of the sign test and may be considered to be more powerful than the Quade test if the number of treatments is greater than five (Conover, 1981). Data are arranged and ranks within blocks R(Xij) are asigned in the same manner as in the Quade Test. However, the Friedman test does not use a block rank.

The Friedman Test Statistic is

$$T_2 = (b-1) [B_2 - bk(k+1)^2 / 4] / (A_2 - B_2) ,$$

where $$A_2 = \sum_{i=1}^{b} \sum_{j=1}^{k} [R(X_{ij})]^2$$

$$B_2 = 1/b \sum_{j=1}^{k} R_j^2$$

$$R_j = \sum_{i=1}^{b} R(X_{ij})$$

The null hypothesis is that there is no difference between candidate treatment and disposal systems. This null hypothesis is rejected at the level α, if T_2 exceeds the 1 - α quantile of the F distribution as listed in appropriate statistical tables with degrees of freedom equal to (k-1) and (b-1)(k-1). If the null hypothesis is rejected, multiple comparisons can be made. Treatment technologies i and j are considered different if the inequality below is satisfied:

$$| R_i - R_j | > t_{1-\alpha/2} [2b(A_2-B_2) / (b-1)(k-1)]^{1/2}$$

Numerical results from these tests are presented in the following tables.

Appendix H: Statistical Test Results

This appendix presents the results from nonparamteric statistical tests performed on the candidate technology scoring and ranking. A summary of the results are presented in Section 5. A brief discussion on the techniques used in this study follows.

Both the Quade and the Friedman tests were performed and are appropriate for cases of several related samples (i.e. experiments that are designed in blocks to detect differences in different treatments). The tests are typically called randomized complete block designs where the "block" is an individual scorer, and the "treatment" is the different treatment processes. Both tests have the following assumptions: 1) the weighting factors are constants and independent of the scoring, 2) the random variables are mutually independent (the results within one block do not influence the results within the other blocks), 3) within each block the observations may be ranked according to some criterion of interest, and 4) the sample range may be determined with each block so that the blocks may be ranked. Although some of the above assumptions maybe questionable for these data sets, the test results are helpful as a preliminary step in ranking the different treatment and disposal systems. Both tests are valid even if there are many ties in the rankings.

The Quade test is a nonparametric method that depends only on the ranks of the observations within each block and the ranks of the block to block sample ranges and may therefore be considered a two-way analysis of variance on ranks. The data are first arranged in blocks where block i is associated with treatment j as follows

Block	1	2	...	k
1	X_{11}	X_{12}	...	X_{1k}
2	X_{21}	X_{22}	...	X_{2k}
...	...	...	...	...
b	X_{b1}	X_{b2}	...	X_{bk}

The rank $R(X_{ij})$ is then assisgned a value from 1 to k within each block i. An average rank is assigned in the case of ties. The next step ranks the blocks (Q_i) based on the size of the sample range in each block by:

$$\text{Range in block } i = \max_j X_{ij} - \min_j X_{ij}$$

The smallest range is assigned a rank of 1, the second smallest a rank of 2 , and so on. Again an average rank is assigned in the case of ties.

Finally the block rank, Q_i, is multiplied by the difference between the rank within block i, ($R(X_{ij})$) and the average rank within blocks, $(k+1)/2$, to get the relative size, S_{ij}.

$$S_{ij} = Q_i\,[\,R(X_{ij}) - (k+1)/2]$$

Finally the Test Statisic is determined by:

$$T_1 = (b-1)B_1 / (A_1 - B_1)\ ,$$

Appendix H - Statistical Test Results

Table G.25 Summary of Individual Team Member Comments During Scoring (*continued*)

System	Comment
General (*continued*)	Disposal of effectively treated sludge (i.e., to meet LDRs) beneath the OU4 cap is far more reasonable as a conservative but reasonable compromise. However, the method of disposition beneath the cap should be scrutinized. For example, rather than simply dispersing the sludge throughout the entire subcap region, treatment and containerization in a small cell within the cap may be more logical and credible.
	The prior "bad" experience with cement-based solidification may constrain what will be acceptable to DOE, regulators, and public during treatment of the current sludges.
	Waste form size limits of 3 in. for OU4 and 10 in. for Envirocare are significant constraints and for some processes with require post-treatment size reduction that adds costs and hazards. For a new engineered cell onsite, size limits conceivably would not exist.
	Assumed that the "overall protection of public health and environment" want includes consideration of the risk of adverse impacts during handling, transportation, treatment and disposal.
	For all systems and processes, it was assumed that ARARs and ALARA would be met and thus the same score was given. The only deviation was for plasma hearth where fugitive emissions may cause problems.
	Long-term effectiveness was presumed to be high for all treated wastes that are disposed of in an engineered disposal site.
	Reduction in toxicity, mobility, and volume of the waste arises out of any treatment train, but volume reductions is the waste disposed of do not occur with any of the cement solidification or any other process that adds excessive binder agents.
	Assumed that short-term effectiveness for ES&H was not a critical want since the sludges are stored in double-wall tanks onsite. However, due to changes in waste form that may occur during prolonged storage, rapid removal and management of the containerized waste is desired.
	The fugitive emission potential for all high energy/temperature processes is considered significant and will require added ES&H precautions, monitoring/measurement, etc. that will slow down waste processing and disposal.

Table G.25 Summary of Individual Team Member Comments During Scoring

System	Comment
Simple Stabilization	Adequate isolation cell is particularly important.
Cement S/S	Most manageable treatment system.
Biochemical Stabilization	HCN evolution possible. Depends on hydroxide/sulfide solubility for protectiveness.
Pressure S/S	Assumed lower short-term effectiveness, regulatory acceptance and public acceptance because technology is not "proven". Process might not be applicable to Pond C sludges.
Biodenitrification and cement S/S	
Polymer S/S	Protectiveness needs to be demonstrated. Assumed that final waste form would "last" longer than cement S/S. Cost of treatment may overwhelm the disposal fee savings for OU4 burial.
Vitrification	Technology not "proven". Potentially greater risks to workers. Protectiveness needs to be demonstrated. May have off-gas compliance issue.
Microwave	Technology not "proven" and may require development. High volume reduction is attractive. Potentially greater risks to workers. Protectiveness needs to be demonstrated. May have off-gas compliance issue.
Plasma Hearth	Technology not "proven". High volume reduction is attractive. Potentially greater risks to workers. Protectiveness needs to be demonstrated. May have off-gas compliance issue.
General	Increased transportation risks may be associated with Envirocare disposal option. The health risks will increase with the amount of equipment used in treatment. Out-of-State disposal may always be more acceptable to the regulators and public. Treatment assumed to be more acceptable to public than non-treatment. Assumed that regulators would be more amenable to treated waste and proven processes. Time to create disposal site was not included for consideration of disposal options: OU4 and Envirocare about the same availability, new cell on-site years away. ARARs exceed for OU4 burial for all treatment systems. Assumed lower short-term effectiveness and implementability (i.e. lower scores) for developmental processes. Disposal of untreated or limited treated sludge beneath the cap in OU4 is likely the fastest option to implement <u>if acceptable/permitted</u>, but it may jeopardize the entire CAMU project either during the review and approval stage or after construction if deficient performance results (whether or not it is due to the sludge emplacement).

Table G.24 Summary of Solar Ponds Kepner-Tregoe Results for Plasma Hearth, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	7	8	9	3	2	2	8	8		
2	7	8	0	10	9	1	0	2	0	0		
3	4	4	4	4	4	4	4	2	4	3		
4	10	10	9	10	10	5	1	2	10	10		
5	5	10	5	7	9	1	1	2	2	2		
6	10	10	5	9	10	2	1	2	2	2		
7	7	10	6	8	9	4	5	2	7	5		
8	2	8	9	10	10	10	1	2	1	1		
9	4	4	1	4	4	1	2	2	3	3		
10	8	10	10	10	10	0	0	0	2	2		
11	3	3	3	3	3	3	3	2	3	3		
Ave score	6.3	7.5	5.4	7.5	7.9	3.1	1.88	1.8	3.8	3.5		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	60.2	56.6	33.8	55.1	63.3	16.4	16.5	11.8	23.7	22.0	359.3	347.5

Table G.23 Summary of Solar Ponds Kepner-Tregoe Results for Plasma Hearth, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	6	8	9	3	2	2	8	8		
2	7	8	0	10	9	1	0	2	0	0		
3	4	4	4	4	4	4	4	2	4	3		
4	10	10	9	10	10	5	1	2	10	10		
5	6	10	5	7	9	1	1	2	2	2		
6	10	10	5	9	10	2	1	2	2	2		
7	8	10	6	8	9	5	5	2	7	4		
8	2	8	9	10	10	10	1	2	1	1		
9	5	4	2	5	5	1	1	4	2	2		
10	8	10	10	10	10	0	0	0	2	2		
11	3	3	3	3	3	3	3	2	3	3		
Ave score	6.5	7.5	5.4	7.6	8.0	3.2	1.7	2.0	3.7	3.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	62.8	56.6	33.8	55.7	64.0	16.9	15.7	13.0	23.1	20.9	362.5	349.5

Table G.22 Summary of Solar Ponds Kepner-Tregoe Results for Microwave Melter, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	6	8	10	3	2	2	8	8		
2	9	9	9	8	5	8	7	2	5	6		
3	6	6	6	6	6	6	6	2	6	6		
4	10	10	7	10	10	5	1	2	10	10		
5	5	10	2	7	9	1	1	2	2	2		
6	10	10	6	10	10	4	2	2	4	7		
7	8	10	4	9	10	4	5	2	8	9		
8	10	8	9	10	10	10	6	2	6	6		
9	5	5	5	6	6	4	4	2	6	7		
10	8	10	10	10	10	1	1	0	3	3		
11	6	6	6	6	6	6	6	2	6	6		
Ave score	7.8	8.2	6.4	8.2	8.4	4.7	3.7	1.8	5.8	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	75.1	61.4	40.1	59.7	66.9	25.1	33.9	11.8	36.1	39.4	449.5	437.6

Table G.21 Summary of Solar Ponds Kepner-Tregoe Results for Microwave Melter, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	6	8	10	3	2	2	8	8		
2	9	9	9	8	5	8	7	2	5	6		
3	6	6	6	6	6	6	6	2	6	6		
4	10	10	7	10	10	5	1	2	10	10		
5	6	10	2	7	9	1	1	2	2	2		
6	10	10	6	10	10	4	2	2	4	7		
7	9	10	8	9	10	5	5	2	8	8		
8	10	8	9	10	10	10	6	2	6	5		
9	6	5	7	8	8	2	3	4	5	6		
10	8	10	10	10	10	1	1	0	3	3		
11	6	6	6	6	6	6	6	2	6	6		
Ave score	8.1	8.2	6.9	8.4	8.5	4.6	3.6	2.0	5.7	6.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	77.7	61.4	43.5	61.1	68.4	24.6	33.1	13.0	35.5	37.8	455.9	442.9

Table G.20 Summary of Solar Ponds Kepner-Tregoe Results for Vitrification, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	8	6	9	2	2	2	7	9		
2	10	9	0	10	10	8	0	2	0	0		
3	3	3	3	3	3	3	3	2	3	1		
4	10	10	8	10	10	6	2	2	10	10		
5	5	10	5	7	9	4	1	2	2	2		
6	10	10	7	10	10	6	3	2	4	5		
7	8	10	9	10	10	5	7	2	9	10		
8	10	8	9	10	10	10	1	2	1	1		
9	5	5	5	6	6	4	4	2	6	7		
10	8	10	10	10	10	1	2	0	5	3		
11	3	3	3	3	3	3	3	2	3	3		
Ave score	7.4	7.6	6.1	7.7	8.2	4.7	2.5	1.8	4.5	4.6		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	70.7	57.3	38.4	56.4	65.4	25.1	23.2	11.8	28.2	28.7	405.2	393.3

Table G.19 Summary of Solar Ponds Kepner-Tregoe Results for Vitrification, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	6	8	6	9	2	2	2	7	9		
2	10	9	0	10	10	8	0	2	0	0		
3	3	3	3	3	3	3	3	2	3	1		
4	10	10	8	10	10	6	2	2	10	10		
5	6	10	5	7	9	4	1	2	2	2		
6	10	10	7	10	10	6	3	2	4	5		
7	9	10	9	10	10	6	7	2	9	9		
8	10	8	9	10	10	10	1	2	1	1		
9	6	5	7	8	8	2	3	4	5	6		
10	8	10	10	10	10	1	2	0	5	3		
11	3	3	3	3	3	3	3	2	3	3		
Ave score	7.6	7.6	6.3	7.9	8.4	4.6	2.4	2.0	4.4	4.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	73.3	57.3	39.5	57.7	66.9	24.6	22.3	13.0	27.6	27.6	409.9	396.9

Table G.18 Summary of Solar Ponds Kepner-Tregoe Results for Polymer S/S, Envirocare

	Wants Criteria											Totals
Evaluator	1	2	3	4	5	6	7	8	9	10	Total score	score w/o cost
1	9	8	8	8	8	5	3	2	4	7		
2	9	9	10	10	7	7	7	2	7	8		
3	7	7	7	7	7	6	7	2	7	7		
4	8	10	10	8	8	7	4	5	10	9		
5	6	10	9	9	9	8	4	5	5	5		
6	8	10	10	9	8	8	5	5	7	10		
7	6	9	8	7	5	7	9	5	6	8		
8	10	8	9	8	6	10	8	5	9	9		
9	6	5	8	7	7	6	5	2	7	7		
10	8	10	10	10	8	1	2	0	3	3		
11	7	7	7	7	7	7	7	5	7	7		
Ave score	7.6	8.4	8.7	8.2	7.3	6.5	5.5	3.4	6.5	7.3		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	73.3	63.4	55.0	59.7	58.2	34.7	50.5	22.4	40.6	45.1	502.9	480.4

Table G.17 Summary of Solar Ponds Kepner-Tregoe Results for Polymer S/S, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	8	7	8	8	4	3	2	4	6		
2	9	9	10	10	7	7	7	2	7	8		
3	7	7	7	7	7	6	7	5	7	7		
4	8	10	10	8	8	7	4	5	10	9		
5	7	10	9	9	9	7	4	5	5	5		
6	8	10	10	9	8	8	5	5	7	10		
7	7	9	8	7	5	8	9	5	6	7		
8	9	8	7	8	6	10	8	5	9	6		
9	7	5	8	8	7	4	5	5	6	6		
10	8	10	10	10	8	1	2	0	3	3		
11	7	7	7	7	7	7	7	5	7	7		
Ave score	7.8	8.4	8.4	8.3	7.3	6.3	5.5	4.0	6.4	6.7		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	75.1	63.4	53.3	60.4	58.2	33.2	50.4	26.0	40.0	41.7	501.7	475.7

Table G.16 Summary of Solar Ponds Kepner-Tregoe Results for Polymer S/S, OU4 Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	8	7	8	8	4	3	2	5	6		
2	9	9	10	10	7	7	7	2	7	8		
3	7	7	7	7	7	6	7	5	7	7		
4	8	10	10	8	8	7	4	5	10	5		
5	6	10	9	9	9	9	4	5	5	5		
6	8	10	7	10	8	7	3	2	7	10		
7	5	9	8	7	5	9	10	5	6	7		
8	7	8	9	8	6	10	8	5	9	5		
9	7	5	8	7	7	6	5	5	5	5		
10	8	10	10	10	8	1	2	2	3	3		
11	7	7	7	7	7	7	7	5	7	7		
Ave score	7.4	8.4	8.4	8.3	7.3	6.6	5.4	3.9	6.4	6.2		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	70.7	63.4	52.7	60.4	58.2	35.2	49.6	25.4	40.0	38.3	493.9	468.5

Table G.15 Summary of Solar Ponds Kepner-Tregoe Results for biochemical S/S, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	6	8	6	5	7	5	4	2	6	6		
2	9	9	7	7	5	7	6	4	5	4		
3	8	8	8	8	8	7	8	2	8	8		
4	7	8	10	7	6	9	7	8	10	8		
5	8	10	9	9	8	9	9	8	5	5		
6	10	10	9	9	10	8	7	8	10	10		
7	6	9	6	8	5	6	6	5	8	7		
8	10	8	8	10	10	10	7	5	9	9		
9	7	5	6	7	8	8	7	2	7	7		
10	9	10	6	9	7	8	7	5	8	8		
11	6	6	6	6	6	6	6	2	6	6		
Ave score	7.8	8.3	7.4	7.7	7.3	7.5	6.7	4.6	7.4	7.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	75.1	62.0	46.4	56.4	58.2	40.0	61.2	30.1	46.2	44.0	519.6	489.5

All other remediation activities have been at the bench scale level with a wide range of successes. Results of these efforts have been verified not only by independent laboratories but through monitoring of DOE and EPA organizations. No commercial scale applications have been attempted to date.

7. **Processing Capacities and Rates**

The prototype equipment was designed to process mine tailings or contaminated soils and is capable of processing ten tons per hour of output material. The process and the equipment is scalable and could be designed for almost any processing rate that was appropriate for the other project factors involved (e.g. logistics). The rate of solidification/stabilization is very rapid and starts when moisture is added to the fly ash mixture. It is essentially complete when the solid form leaves the compression operation with a total elapsed time range of a few seconds to a couple of minutes. The strength of the final material continues to increase over time, even though it is strong enough to be handled immediately following the compression operation.

8. **Pretreatment Requirements**

As described above, the waste materials will need to be dewatered such that the moisture content does not exceed 20 %wt. prior to initiating the PAT™ process. The largest particle size acceptable for processing is 3/8" and most dewatering processes will more than accommodate this requirement.

9. **Chemicals or Other Treatment Agent Requirements**

The primary treatment agent is C-grade fly-ash, as defined by ASTM C618. The only other agent that may be required is the neutralizer for the residual salts after the dewatering, as mentioned in (4) above.

10. **Secondary Waste Stream Produced**

The PAT™ process does not produce any secondary wastes. All materials entering the process will become part of the treated product stream.

11. **Treatment of Secondary Wastes**

Not applicable.

12. **Final Waste Form**

The products that result from the application of the PAT™ are in a solid form with exceptional strength characteristics that can be handled immediately after being formed. The dimensions of the solid product can be varied in the equipment design over a wide variety of shapes and sizes to accommodate logistics and storage requirements. Based on formulations, PAT™ products typically exhibit compressive strengths of 2000 to 3500 psi. with some products as high as 7000 psi. Products exhibit extremely high resistance to freeze thaw cycles and the resulting spalling and physical deterioration. Low absorption and high specific heat are other basic characteristics.

13. **Permits Required**

There are no "special permits" required for the PAT™ process. All required permits would be associated with the handling and custody of radioactive materials.

14. **Potential Safety Risks**

The PAT™ process does not pose any unique safety risks within itself. The process entails operation of a large piece of hydraulically operated equipment with the associated high pressures and moving components. This is no different than many similar pieces of equipment in the manufacturing or construction industries today. Any unique risks come from the handling of the mixed wastes and are covered by standard handling procedures.

15. **Potential Environmental Risks**

Since there are no secondary wastes produced by the PAT™ process, there are no inherent risks posed to the environment by the process. Good quality control procedures will preclude those risks associated with handling of the mixed wastes. Adequate planning and design of the project should have no problem in completely containing all contaminants throughout the PAT™ entire treatment process.

16. **Would a Treatability Study and\or a Field Demonstration be Required Before Full Scale Implementation**

Because of the stage of development of the PAT™ process, it is highly recommended that both a bench scale and pilot program be conducted prior to implementation of full scale remediation efforts.

17. **Equipment Availability**

The required equipment for a bench scale test is currently available. If the program schedule is such that a bench scale press is not available at program initiation, four weeks would be required to fabricate a new piece of equipment. Full scale equipment is currently available for a pilot program although it may not provide optimum waste material handling capabilities because the unique handling characteristics of the two dewatered waste streams are unknown at this time. Most of the relevant characteristics would be determined during the bench scale test. Modifications may or may not be required to the existing full scale equipment prior to the pilot program. Results of the bench scale and pilot programs would provide the necessary information for design of the specifically tailored full scale remediation equipment. Design and fabrication of the production equipment would be approximately 90 days or less.

18. **Operation and Maintenance Requirements**

The equipment design is such that the equipment operator monitors all of the PAT™ processed products as they pass through the process. Indications are provided to the operator of mixture ratios and flow rates. Additional personnel monitor and maintain reservoir levels of constituents. Equipment operation is automatic and the operator is part of the quality control process. Based on results of the bench scale and pilot programs, testing frequencies will be established. For a typical 8 hr. shift, the equipment is on line 100% of the time. Two 8 hr. shifts per day can be easily accommodated. Normal equipment maintenance and servicing is accomplished at the end of each shift.

19. **Estimated Cost**

Cost of the full scale production equipment will be specifically designed to the material characteristics of the two specified waste streams. A full scale production piece of equipment to accept the dewatered wastes and produce a stabilized and solidified block for final disposal is currently base priced at $257,000. Necessary modifications, based on the results of the bench-scale and pilot programs, could affect that base price. Processing costs cannot be determined without additional information such as would be available from bench scale and pilot programs.

20. **Unusual Requirements**

No unusual requirements can be foreseen at this time.

21. Case Histories

A brief history of the PAT™ process was provided in (6) above. Test data from those efforts can be made available upon request.

22. Other

Many benefits can be realized through the application of the PAT™ process to these identified mixed waste sludges. They include:

- No external heat or power other than that necessary to run the equipment.
- Process can accept a limited but reasonable amount of moisture in the waste streams.
- Process provides overall volume reduction to the constituents.
- Process produces no secondary by-products.
- Processed materials can be handled immediately.
- Processing equipment is self contained and mobile.
- Product has demonstrated extended longevity over other encapsulation products (i.e. polymers, cement, etc.).
- Much more cost effective than other remediation treatments.
- Uses a waste form to treat a waste form.
- Potential for declassifying mixed waste material for final disposition.

Appendix F - Technology Description Fact and Flowsheets

Appendix F: Technology Description Fact and Flowsheets

Table F.1 summarizes information from several sources on technologies potentially capable of treating the containerized solar pond sludges. No attempt was made to screen or evaluate the technologies. This summary table was complied from; "In Situ Physical/Chemical Treatment Technologies Subarea Program Plan" (DOE 1994), "Technical Area Status Report for Chemical/Physical Treatment" (DOE 1993), "Preliminary Analysis of Treatment and Disposal Options for Solar Ponds Wastes. Solar Evaporation Ponds Rocky Flats Plant (Operable Unit 4)" (EG&G 1993), "Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites" (EPA 1989), "VISITT: Vendor Information System for Innovative Treatment Technologies, Version 2.0" (EPA 1993), "Remediation Technologies Screening Matrix and Reference Guide, A Joint Project of the U. S. Environmental Protection Agency and the U. S. Air Force" (EPA 1993), "Accessing Federal Data Bases for Contaminated Site Clean-up Technologies" (Federal Remediation Technologies Roundtable 1991).

Screening of this list as discussed in Sect. 4.2 resulted in a candidate technology list for scoring and ranking. Technology Description fact and flowsheets were developed for the candidate technology list. Treatment and disposal systems were concured on by the evaluation team as appropriate for scoring and ranking. These fact and flowsheets were prepared based on information obtained through lietrature reveiws, team member knowledge and experience, and vendor query responses. Following Table F.1 treatment and disposal system flowsheets are presented first followed by the associated technology description fact sheet.

Table F.1 Summary of Potential Technologies for Sludge Treatment

Technology	Phase[a]	Waste Stream[b]	Applicable Contaminants	Limitations/Comments	Applicability[c]	Implementation	Possible Vendors
Biological Treatment							
Anaerobic Bioremediation (De-nitrification)	A	sludge, aqueous	nitrate and nitrite anions	residual sludge requires trt, requires consistent stable operating conditions	As potential pretreatment	high	Martin Marietta Energy Systems
Slurry Phase Biological	A	soil, sediment, sludge	organics (aerobically degraded compounds)	rate of oxygen transfer, temperature, pH, secondary liquids generation	no		Bogart Environmental Services, Inc. OHM Corporation Praxair, Inc.
Chemical Treatment							
Oxidation-Reduction	A	aqueous, soil, solid, sludge	volatile organics, metals, and radionuclides	reaction kinetics and thermodynamics of oxidants and reducers may require better definition		high	ETUS, Inc. Environmental Technologies, Inc. Oak Ridge National Laboratory
Physical Treatment							
Adsorption	A	aqueous	organics, metals, radionuclides	selectivity and efficiency of sorbents		medium	Dynaphore, Inc.
Decanting/ Dewatering	A	sludges		residual sludge requires trt	As potential pretreatment		Filter Flow Technology RUST Geotech
Electrical Separation	A, I	soils, sludges	fuel hydrocarbons, PAHs, metals, radionuclides	may depend on compound solubility, pH, requires low hydraulic permeability, complex mixtures may reduce removal efficiency		low	Electrokinetics, Inc. Electro-Petroleum, Inc. Isotron Corporation
Ion Exchange	A	soils, sludges	metals, and radionuclides	low permeability soils	no	high	Scientific Ecology Group, Inc.
Mechanical Soil Aeration	A	sludge	organics	may require further trt	no	high	
Sludge Washing	A	soils, sludges	nonhalogenated organics, fuels hydrocarbons, PAHs, metals	complex mixtures make fluid formulation difficult (e.g. metals and organics), requires <20-30% silts and clays for economical volume reduction	no	high	Northwest Enviroservices Inc. On-Site Technologies Westinghouse Remedial Services,

[a] A: available
I: innovative
E: emerging

[b] waste stream applicable to treatment technology (e.g. anaerobic bioremediation is applicable to both aqueous and sludge waste streams)

[c] Applicability as a stand alone treatment process

References: DOE 1993c, 1994b, c, d, and e
EG&G 1993a
EPA 1986a and b, 1987, 1989, and 1993b and f
Federal Remediation Technologies Roundtable 1991
LATO/RF 1993

Table F.1 Summary of Potential Technologies for Sludge Treatment *(continued)*

Technology	Phase[a]	Waste Stream[b]	Applicable Contaminants	Limitations/Comments	Applicability[c]	Implementation	Possible Vendors
Physical Treatment (cont.)							
Soil Flushing	I	soil, sediment, sludge	organics, inorganics	low permeability soils inhibits fluid transfer, secondary liquids residuals	no	medium	Scientific Ecology Group Inc.
Solvent Extraction	A, I	aqueous, sludge	organics, oils, metals	sludges must have <20 wt % solids, Solvent must be immiscible and of different density (for gravity separation), handling of solvents	As potential pretreatment	medium	Terra-Kleen Corp.
Vacuum Filtration	A	sludges	organics, inorganics, hydroxide sludges	dewatering, no real trt			
Containment							
Barriers (e.g. slurry walls, grout curtains, sheet piling, pneumatic seals, synthetic membranes, ground freezing, extraction/ injection wells)	A	aqueous, soil, sediment, sludge	organics, and inorganics	Sludges will still require trt, assumes in place disposal of sludges	no	high	
Caps and liners	A	sludge, soils, sediments	organics, inorganics	Sludges will still require trt, assumes in place disposal of sludges.	yes	high	
Cement-based Stabilization	A	sludge	metal cations, radionuclides, solid organics	long term stability/ leachability is unknown; dissolved sulfate salts, borates, and arsenates must be limited	yes	high	ETAS Corporation IT Corporation OHM Corporation
Macro-Encapsulation, over packing, thermoplastic and Thermosetting Techniques	A	sludge	stabilized organics, inorganics, radionuclides	Encapsulating matrix must be compatible, unknown long-term leachability, requires specialized equipment. Oxidizing agents may not be compatible with organic encapsulants if exposed to a stimulant.	yes	low	Diversified Technologies IT Corporation
Magnetic Separation	I	soil, sediment, sludge	metals, inorganic cyanides, radionuclides	particles with staining or inclusions may behave as non-magnetic	no	medium	S. G. Franz Company, Inc.

Table F.1 Summary of Potential Technologies for Sludge Treatment (*continued*)

Technology	Phase[a]	Waste Stream[b]	Applicable Contaminants	Limitations/Comments	Applicability[c]	Implementation	Possible Vendors
Containment (cont.)							
Pozzolanic-based Fixation	A	sludge	metals, oils, solvents, and radionuclides	borates, sulfates and carbohydrates interfere, unknown long-term stability/leachability. Not useful for oils and solvents unless sorbents are used.	yes	high	
Precipitation	A, I	aqueous, sludge	metals, cyanides	requires optimization of reaction pH, residual sludge requires trt, geochemistry of injected agents; heterogeneous media, and cross-reactivity may occur	yes	high	Geochem Nuclear Fuel Services
Sorptive Clay Stabilization	I	sludge	halogenated organics and metals	long term leaching so must consider storage	yes	high	TIDE
Thermal Treatment							
Thermal Desorption	A	soil, sediment, sludge	organics, fuel hydrocarbons	dewatering may be required, frequently used in combination with solidification	no	high	
Pyrolysis	I	soil, sediment, sludge	salts, metals, and halogenated waste	dewatering required. requires homogeneous waste, metals and salts in residue can be leachable, high energy requirements, and nature and extent of incomplete combustion byproducts	yes	low	Bio-Electrics, Inc. Electro-Pyrolysis, Inc.
Vitrification	A, I	soil, solid, sludge	organics, inorganics, and radionuclides	soils must have high silica content and alkali fluxes, access to sufficient power supply	yes	low	Babcock & Wilcox Diversified Technologies Geosafe Corporation GTS Duratek Pacific Northwest Laboratory Retech Inc. SAIC (Plasme Process) Western Product Recovery Group Inc.
Rotary Kiln	A	aqueous, sludge	organics	high inorganic salt or heavy metal waste require special consideration, must limit fine particulate matter	no	low	IT Corporation RUST Geotech Weston

Table F.2. Ad hoc review committee and comments[a]

Name	Affiliation and expertise	Comments
Edwin F. Barth	U.S. Environmental Protection Agency Risk Reduction Engineering Lab Residuals Management Branch Stabilization	From information and data presented, it appears that the following technologies may prove useful even without salt level reduction: 1) vitrification (after combining the sludge and pondcrete), 2) inorganic gel coating, 3) acid extraction (process similar to Barth/Taylor process presented at Purdue Industrial Waste Conference), and 4) room-temperature molten salt extraction (developed by Soudarajan/Argonne for Hanford tank waste). Other technologies would be able to treat or manage the metals if the slats were previously removed. Nitrates can be biologically or physically removed (reverse osmosis). High nitrates and sulfates in pond C sludge may cause problems with type I cement. A washing pretreatment step or chemical precipitation step is suggested. The high TOC in pond A/B sludge should be reduced. Otherwise, the same pondcrete (non hardening) will likely occur. The sludge may be treated more effectively if other additives are added in addition to cement. The Ni and Cd may be less soluble if complexed with sulfide, as opposed to hydroxide, if the redox is controlled during disposal. However, optimal sulfide precipitation is at a lower pH than the pond sludges are, possibly favoring cement stabilization.
Mark Bricka	U.S. Army Corps of Engineers Waterways Experiment Station Stabilization	None.
Dr. Chet Francis	Oak Ridge National Laboratory Environmental Sciences Division Chemical treatment, biodenitrification, solidification	% solids information for the sludges in the 10,000-gal. tanks needs to be provided. If Cd and Ni are the drivers with regard to treatment, there is not a big problem for treatment.

[a] Comments summarized in this table represent the essence of comments made by ad hoc reviewers at various stages of report preparation. Other comments not reflected in this table and comments received by other reviewers resulted in revisions made directly to the text.

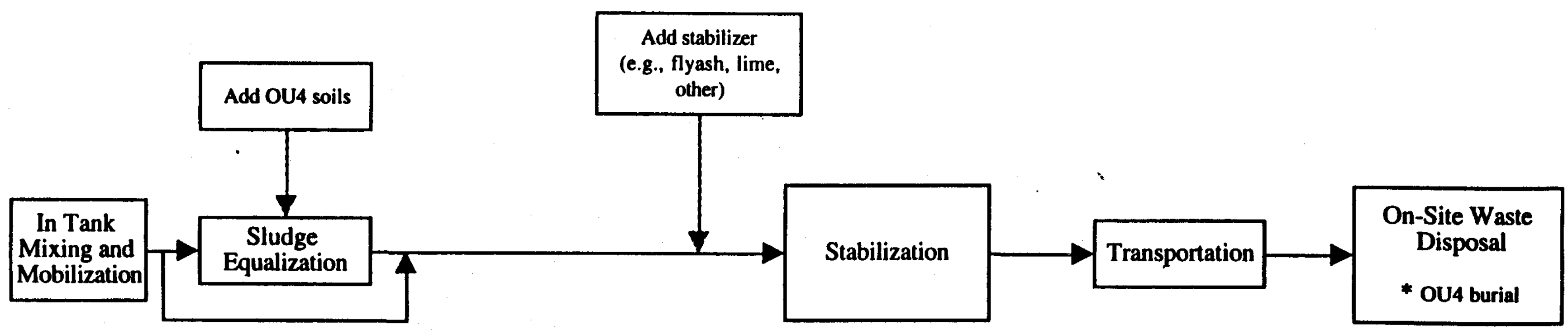
Table F.2. Ad hoc review committee and comments[a] *(continued)*

Name	Affiliation and expertise	Comments
Dr. Bernard Scheiner	U.S. Bureau of Mines Dewatering, separations	There is no assurance that cement admixture stabilization can handle the high sulfates and nitrates. The effect of high nitrates and sulfates may need to be researched for the TIDE PAT process. Treatability studies will be required for any treatment process. It appears that precipitation followed by dewatering to produce a sludge suitable for disposal may be the easiest way to treat the material. In highly concentrated salt solutions, the precipitation of Cd and Ni may cause some problems.
T. Michael Gilliam	Oak Ridge National Laboratory Chemical Technology Division Solidification/stabilization	S/S is "accepted" as treatment for inorganics but not for organics. However, it is also accepted that S/S technologies are OK for treatment of inorganic wastes co-contaminated with trace organics. Questions that arose when reviewing the report included the following: Is the sludge thixotropic (assumed yes)? If the sludge water is decanted in place, can the "settled" solids still be vacuumed out or will slurry water need to be added? Were other lessons learned during the previous pondcrete operations that might translate into the need for additional performance criteria, such as freeze/thaw or thermal cycling resistance? Do F codes apply to secondary waste streams at Rocky Flats?

a Comments summarized in this table represent the essence of comments made by ad hoc reviewers at various stages of report preparation. Other comments not reflected in this table and comments received by other reviewers resulted in revisions made directly to the text.

Conceptual Treatment System Flowsheet No. 1

"Simple Physical/Chemical Stabilization and On-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Simple Physical/Chemical Stabilization (Flowsheet No. 1).

2. **Process description:** The sludges are removed from the tanks and flyash, lime, and/or OU4 soils are added for stabilization. Soils may be added for water absorption to yield a solid. Flyash and or lime may also be added for stabilization. The metals and radionuclides are immobilized in the matrix.

3. **Potential vendors, contact, and phone:**
(Note: Vendors listed in this section have responded to a solicited vendor query. Numerous potential vendors exist.)
Brown & Root Environmental, Donald Brenneman, (713) 575-4693

4. **Removal or immobilization of metals (radionuclides):** Immobilization by physical encapsulation.

5. **Treated waste characteristics:** Treatability study required for specific treated waste characteristics.

6. **Final waste form:** Sludges will be treated such that there are no free liquids as defined by DOT paint filter test and they can be compacted to 90% Proctor density. A slight volume increase is estimated based on additives for stabilization.

7. **Stage of development:** Full scale, commercially available.

8. **Time required before full-scale installation and operations:** 3 months (time to conduct treatability study and perform pilot-scale demonstration).

9. **Processing rates:** 5,000 gal. of raw waste sludge per day which generated approximately 9 yd^3/hr of treated sludge.

10. **Process equipment readily available:** Yes.

11. **Approximate number of successful full scale projects:** Numerous for metals containing process sludges, but no full scale remediations of high nitrate wastes.

12. **Secondary waste streams produced:** Minimal water removed from B pond sludges (treatment capability exists on-site at Bldg. 374). Possibility of fugitive dust emissions.

13. **Chemicals and additives required:** Variety of flyash, lime, and OU4 soil.

14. **Estimated cost:** $3M for capital costs ($918 per yd^3) and $2.9M for operating and maintenance costs (approximately $887 per yd^3). Estimate is for raw sludge not including transportation and disposal costs.

15. **Unusual potential environmental impact risks:** None.

16. **Unusual potential safety risks:** None.

17. **Other:** Long-term durability may be an issue.

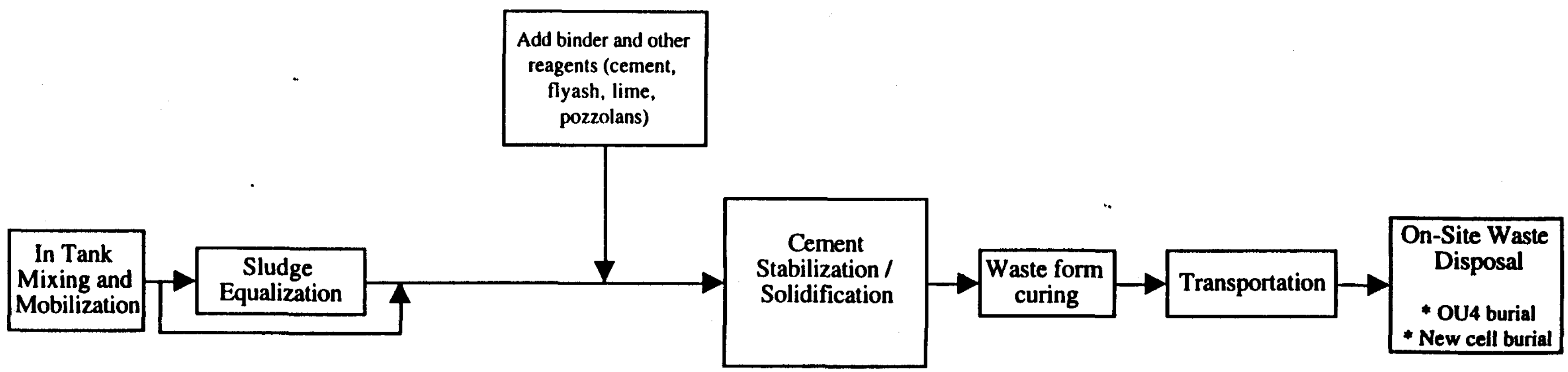
References:

Halliburton NUS Corp. 1994. *Accelerated Sludge Processing Conceptual Design White Paper*. Draft.

Personal Communications.

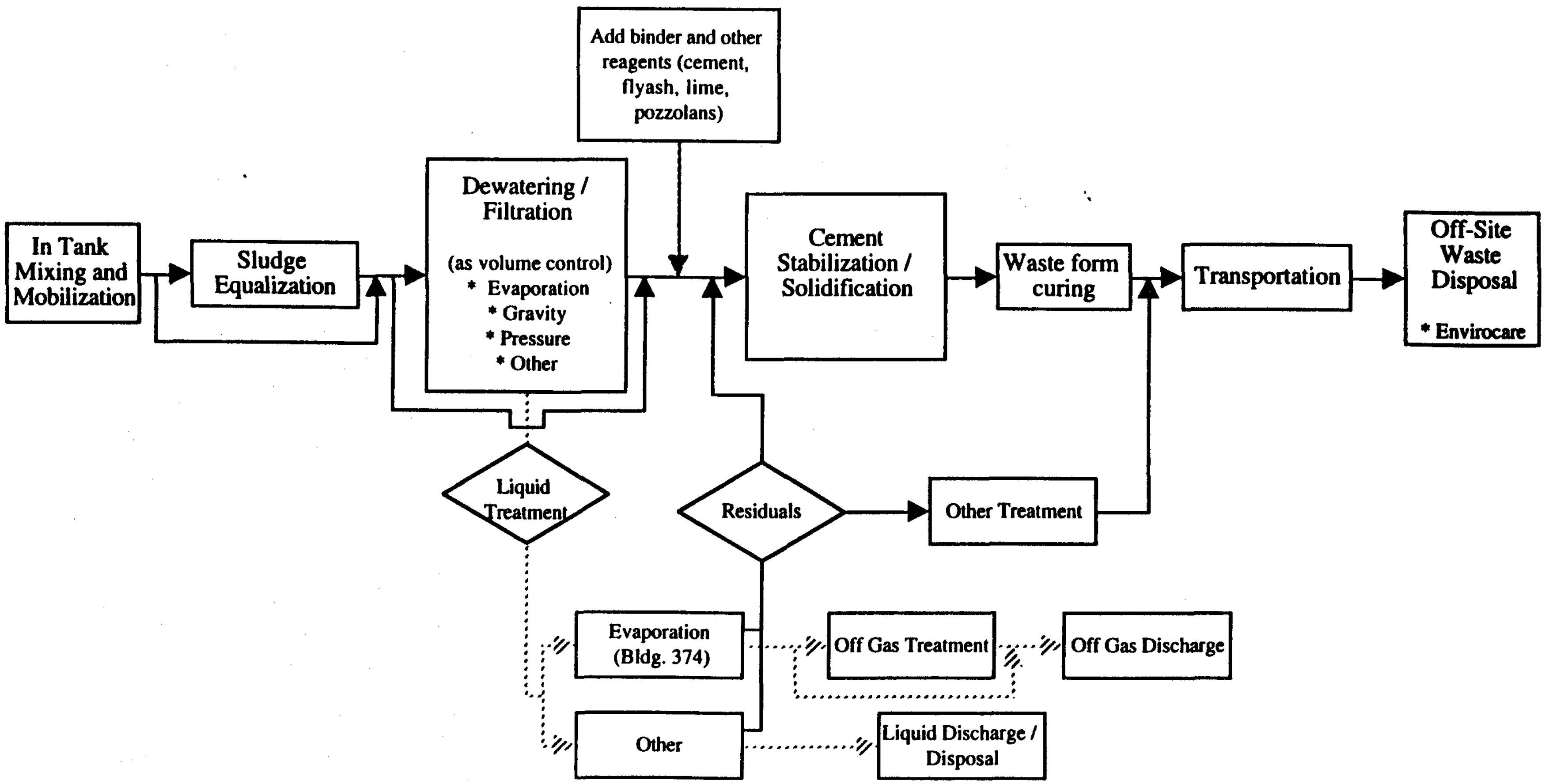
Conceptual Treatment System Flowsheet No. 2A

"Cement Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System
Flowsheet No. 2B

"Cement Stabilization/Solidification and Off-site Land Disposal"



Evaluation and Screening of Treatment and Disposal Options for the Containerized Solar Pond Sludges

Technology Description Fact Sheet

1. **Technology type:** Cement Stabilization/Solidification (Flowsheet No. 2A and B).

2. **Process description:** The sludges are removed from the tanks and transferred into a mixing tank where cement, flyash and/or lime are added. Pretreatment by dewatering may be employed for volume reduction of the final waste form. Based on sludge characteristics, high additive loadings may be required. The metals and radionuclides are immobilized in the matrix and a monolith of various shape is formed.

3. **Potential vendors, contact, and phone:**
(Note: Vendors listed have responded to a solicited vendor query. Numerous potential vendors exist.)
Brown & Root Environmental, Donald Brenneman, (713) 575-4693
IT Corporation, Dr. Stuart Shealy, (615) 690-3211
OHM Remediation Services Corp., Dr. Paul Lear, (800) 537-9540
RFS Clemson Technical Center, Dave McCartney, (803) 646-2413

4. **Removal or immobilization of metals (radionuclides):** Immobilization by chemical binding and physical encapsulation.

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements. Treatability study required for specific treated waste characteristics.

6. **Final waste form:** Can be either monolithic or granular with compressive strength ranging from 20 to 1000 psi. A volume increase of 30 to 50% is estimated.

7. **Stage of development:** Full scale, commercially available.

8. **Time required before full-scale installation and operations:** 8 months (time to conduct treatability study and perform pilot-scale demonstration).

9. **Processing rates:** 2.5 to 200 yd^3/hr of dewatered sludge.

10. **Process equipment readily available:** Yes.

11. **Approximate number of successful full scale projects:** Numerous for metals containing process sludges, but no full scale remediations of high nitrate wastes.

12. **Secondary waste streams produced:** Minimal water removed from sludges for volume reduction if desired (treatment capability exists on-site at Bldg. 374). Possibility of fugitive dust emissions if system is not contained or operated under negative pressure.

13. **Chemicals and additives required:** Variety of cement, flyash, blast furnace slag, lime, soluble silicates may be employed. A viscosity extender to remove sludges from tanks may be required.

14. **Estimated cost:** \$145 to \$600 per yd^3. Estimate is for raw sludge including capital costs.

15. **Unusual potential environmental impact risks:** None.

16. **Unusual potential safety risks:** None.

17. **Other:** Long-term durability may be an issue for on-site disposal but should not be for off-site in an engineered land burial site.

    Sulfides and halides may retard setting.

References:

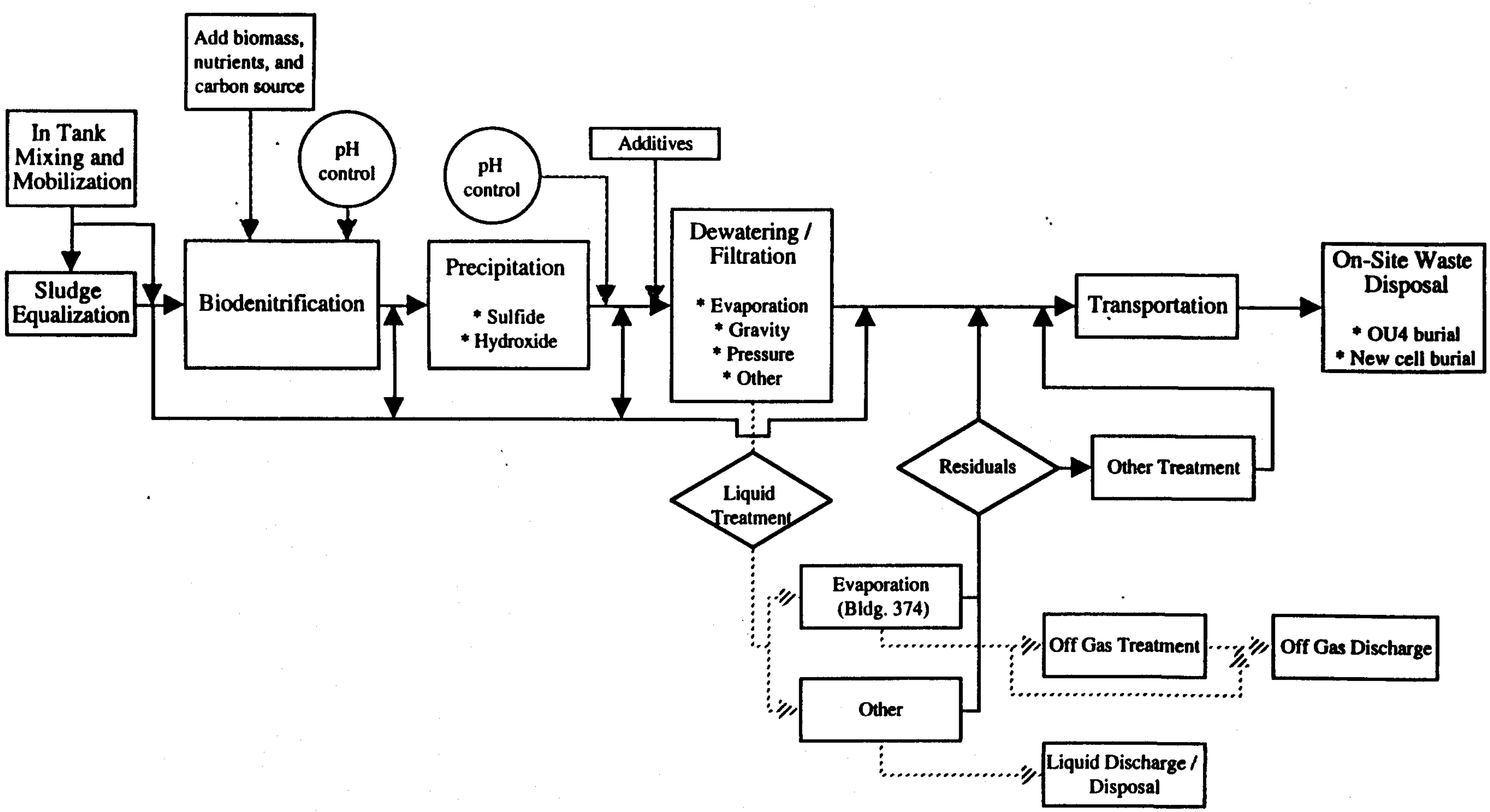
Barth, E. F., et al. 1990. *Stabilization and Solidification of Hazardous Wastes*. Noyes Data Corporation, Park Ridge New Jersey. 390 pages.

Davenport, D. T., T. D. Hylton, and J. J. Perona. 1993. *Feasibility Studies for Treatment System Determination for the X-701B Boxed Sludge*. Draft. ORNL/CF-93/244.

Vendor query responses.

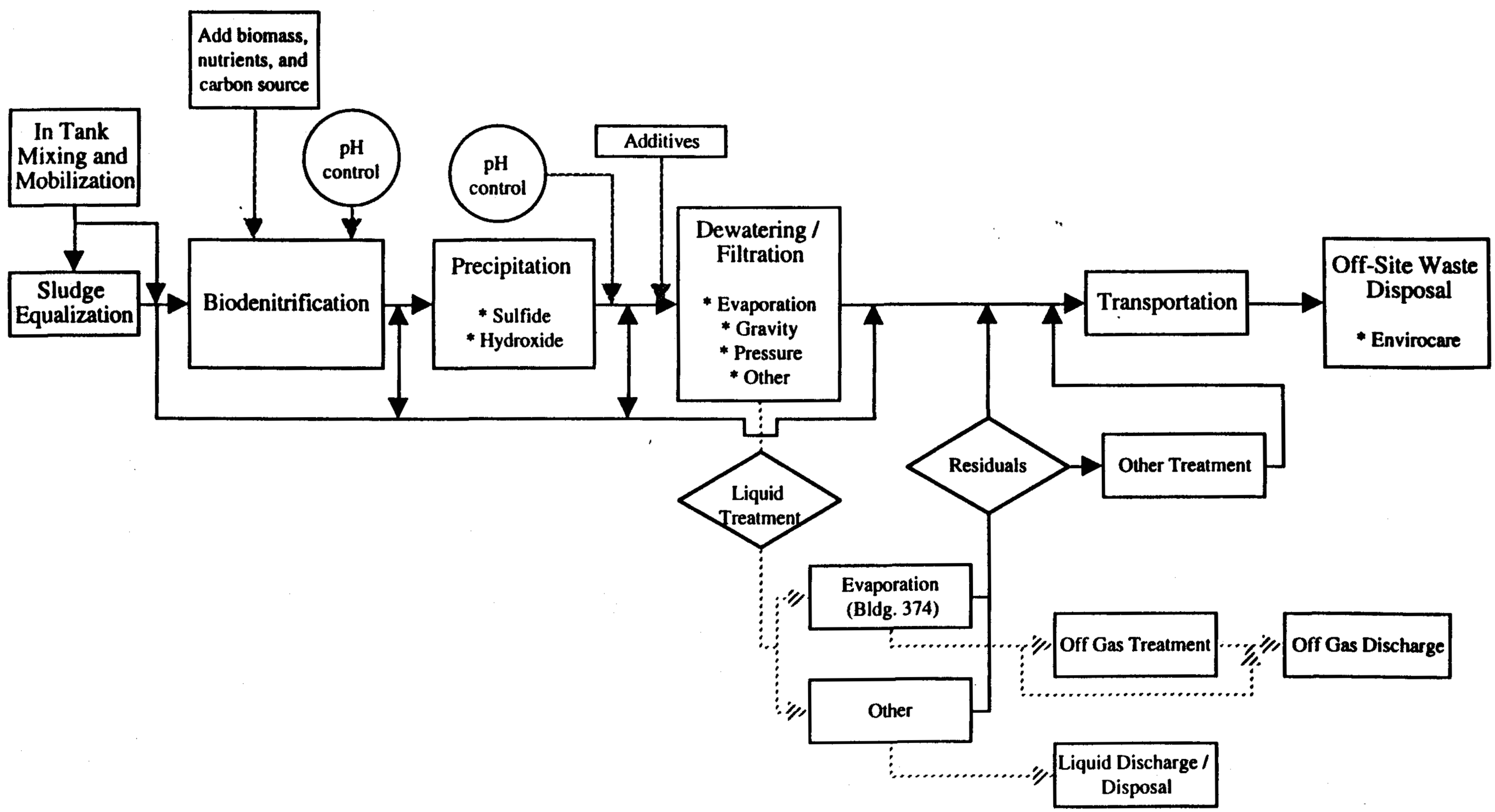
Conceptual Treatment System
Flowsheet No. 3A

"Biochemical Stabilization and On-site Land Disposal"



Conceptual Treatment System Flowsheet No. 3B

"Biochemical Stabilization and Off-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Biochemical Stabilization (Flowsheet No. 3A and B).

2. **Process description:** Biodenitrification may be employed as pretreatment by sludge removal from the tanks and transfer into biodenitrification reactors. Following biodenitrification, a slurry solution of magnesium hydroxide is added to the sludge precipitating the metals as hydroxides. After hydroxide precipitation, a solution of sodium sulfide is added for further precipitation. The flocculated slurry is then filtered to remove the precipitates. The precipitates are then dewatered and the residuals stabilized. Note that cyanide and chromium (VI) would require pretreatment. Pretreatment by dewatering may be employed. The metals and radionuclides are immobilized in the matrix.

3. **Potential vendors, contact, and phone:**
   Numerous potential vendors exist including:
   IT Corporation, Dr. Stuart Shealy, (615) 690-3211
   RFS Clemson Technical Center, Bruce Diel, (803) 646-2413
   Nuclear Fuel Services, David Wise, (615) 743-1795
   OHM Remediation Services Corp., Dr. Paul Lear, (800) 537-9540

4. **Removal or immobilization of metals (radionuclides):** Immobilization by chemical binding and physical encapsulation.

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements. Treatability study required for specific characteristics.

6. **Final waste form:** Filtercake (no free liquids). A volume decrease of up to 50% is estimated.

7. **Stage of development:** Full scale, commercially available depending on raw waste composition.

8. **Time required before full-scale installation and operations:** 12 months (time to conduct treatability study and perform pilot-scale demonstration).

9. **Processing rates:** Approximately 1.5 yd^3/hr based on processing capacity of 6500 gal. of sludge (at 50% solids) per 24 hour period.

10. **Process equipment readily available:** Yes.

11. **Approximate number of successful full-scale projects:** Numerous for industrial sludges, but no full-scale remediations of high nitrate wastes.

12. **Secondary waste streams produced:** Water removed from sludges (treatment capability exists on-site at Bldg. 374). Possibility of fugitive dust emissions.

13. **Chemicals and additives required:** Magnesium hydroxide, flocculation resin, sodium sulfide for precipitation.

14. **Estimated cost:** \$88 to \$146 per yd^3 (75-125/ton) of raw sludge depending on the total volume processed. Costs for the biodenitrification unit process were not available. Estimates do not include transportation and disposal costs.

15. **Unusual potential environmental impact risks:** Treatment requires pH control which if it malfunctions, potential risks may occur (see general comments). Spills of chemicals used for pH adjustment during treatment.

16. **Unusual potential safety risks:** Treatment requires pH control which if it malfunctions, potential risks may occur (see general comments). Use of acidic/caustic chemicals if pH adjustment is required.

17. **Other:** Biodenitrification to reduce the nitrate concentrations in the sludges should reduce the additives required to produce a stable waste form.

    Reduction of nitrate concentrations in the raw sludge may improve waste form setting.

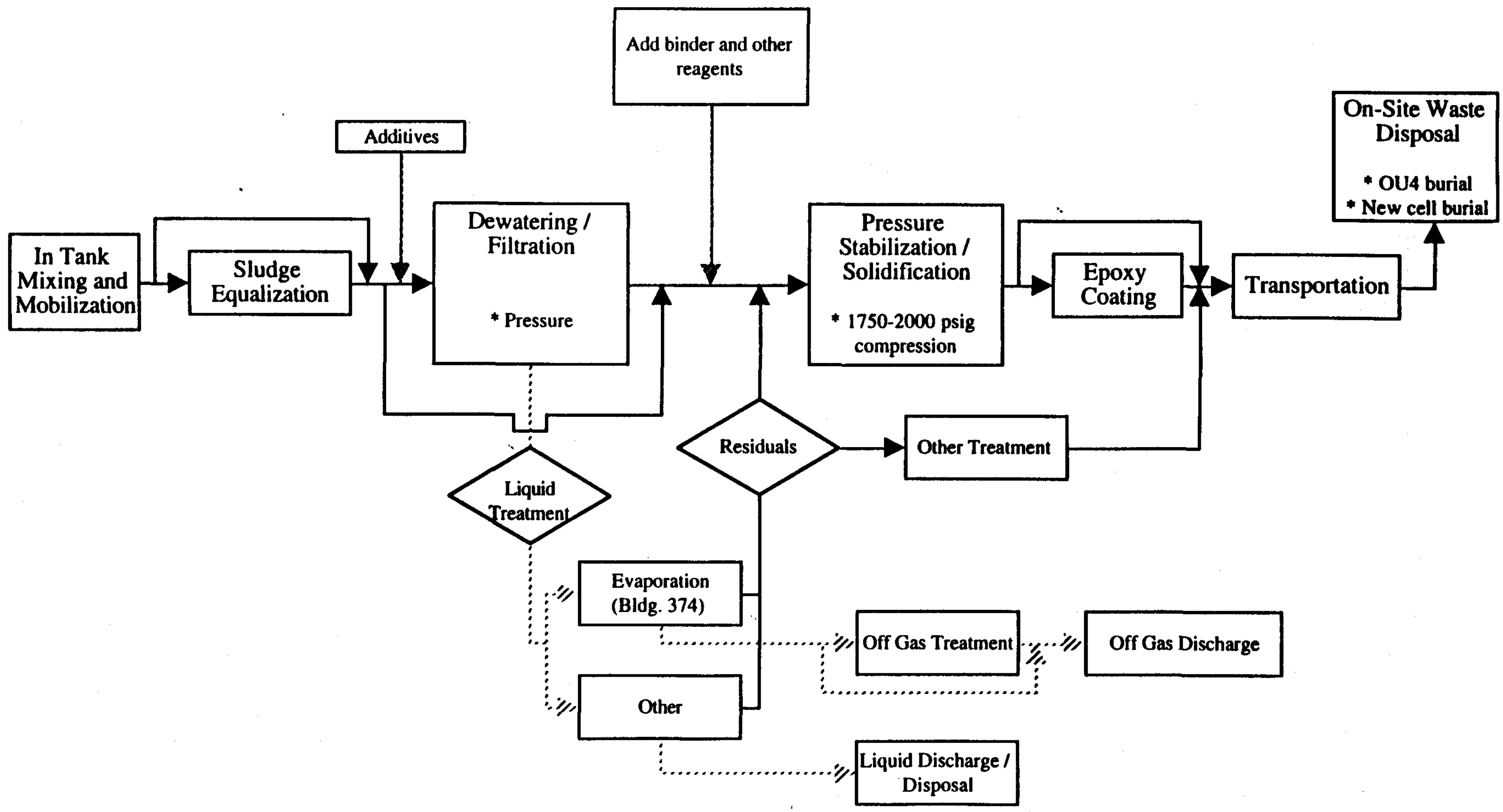
References:

Personal communications.

Vendor query responses.

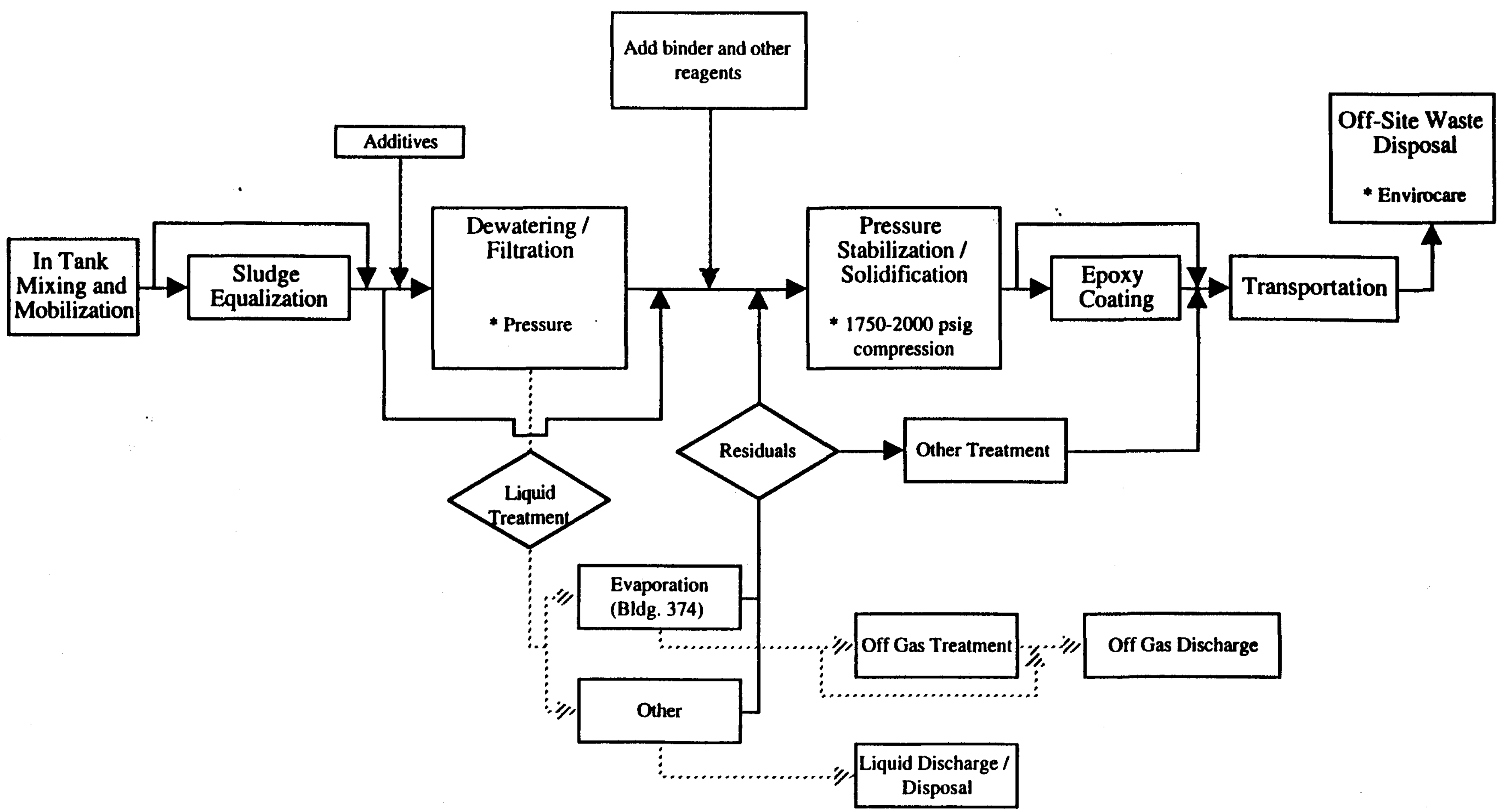
Conceptual Treatment System
Flowsheet No. 4A

"Pressure Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System Flowsheet No. 4B

"Pressure Stabilization/Solidification and Off-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Pressure Stabilization/Solidification (Flowsheet No. 4A and B).

2. **Process description:** The sludges are removed from the tanks and transferred to sludge preprocessing (e.g., biodenitrification) and dewatering. The sludges are then transferred into a mixing tank where proprietary powders and reagents are added for chemical binding. Flyash is then mixed with the sludges and pressed at 1750 to 2000 psi into blocks. The metals and radionuclides are chemically and physically immobilized in the small blocks.

3. **Potential vendors, contact, and phone:**
   (Note: Vendors listed have responded to a solicited vendor query. Other potential vendors may exist.)
   Filter Flow Technology, Inc., Dr. Tod Johnson, (713) 554-5405
   Technical Innovation Development Engineering, M. S. Riddle, (505) 856-0210

4. **Removal or immobilization of metals (radionuclides):** Immobilization by chemical binding and physical compaction.

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements. Treatability study required for specific characteristics.

6. **Final waste form:** Blocks of various size are formed (typically 4" by 8" by 16"). A volume reduction of 30 to 50% is estimated. Smaller blocks may be formed but result in greater surface area which increases potential leachability.

7. **Stage of development:** Bench-scale to commercially available depending on unit process.

8. **Time required before full-scale installation and operations:** 3 months (time to conduct treatability study). Full scale demonstration may be required.

9. **Processing rates:** 0.6 to 9.4 yd^3/hr (6 to >20 tons/hr) of raw sludge depending on throughput for stabilization. Note that reduction of the final waste form block size will reduce the throughput

10. **Process equipment readily available:** Yes (within 90 days).

11. **Approximate number of full-scale projects:** Approximately 20 bench-scale demonstrations.

12. **Secondary waste streams produced:** Water removed from sludges (treatment capability exists on-site at Bldg. 374, but capacity to treat C pond water due to high salt concentrations does not exist.) Evaporation residues may be recycled or treated by other technologies.

13. **Chemicals and additives required:** Flyash is required for stabilization. Proprietary products [total estimated cost of chemicals = $0.80/1000 gal.]). May require bioreactor chemicals (methanol, activated carbon, caustic and acid).

14. **Estimated cost:** Estimated costs per yd^3 not available without bench scale testing. Equipment costs expected to be approximately $257,000 for full scale block press ($78/$yd^3$ of raw sludge).

15. **Unusual potential environmental impact risks:** None.

16. **Unusual potential safety risks:** None.

17. **Other:** Process materials can be immediately handled.

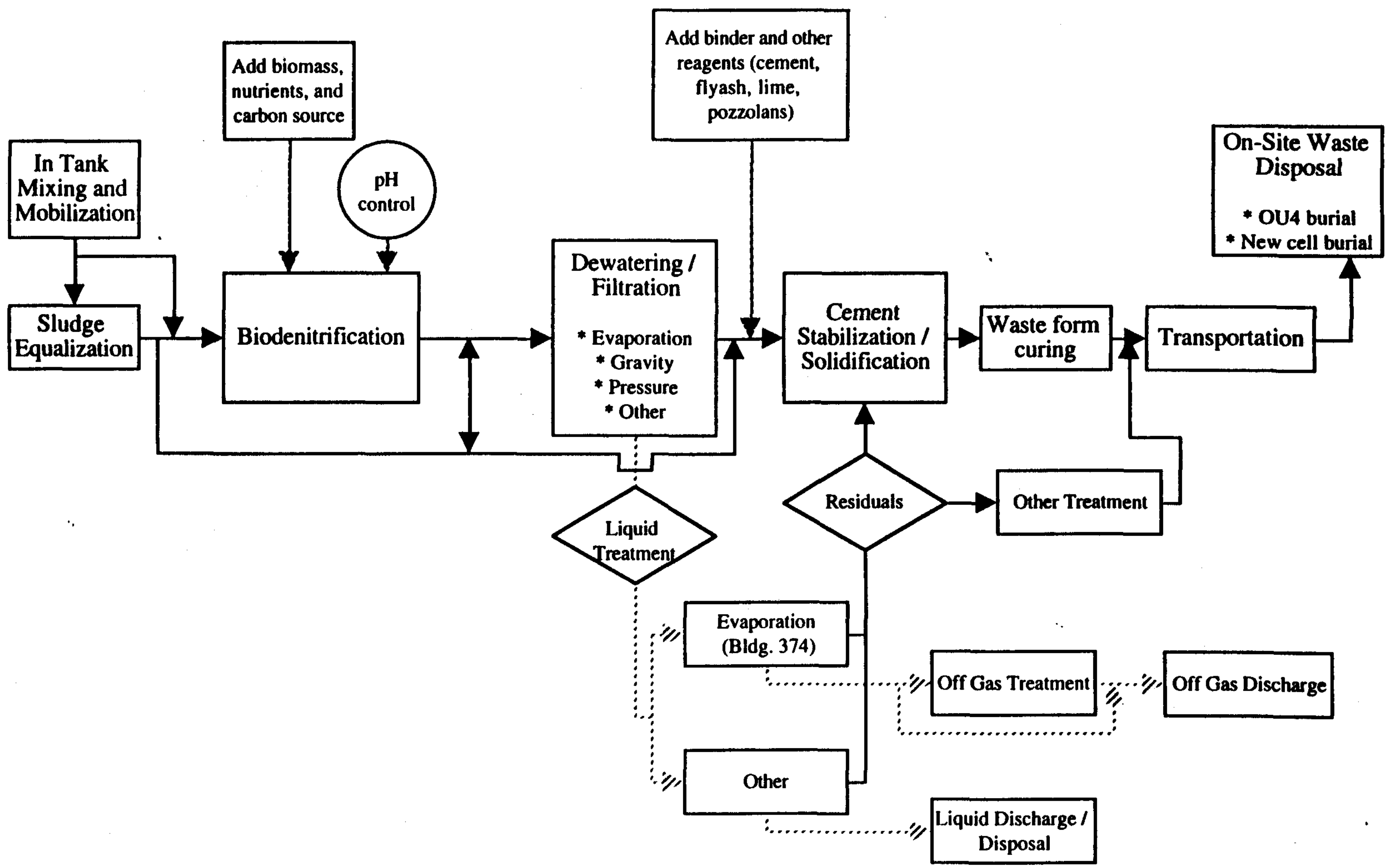
    This is a proprietary process with complex implentability. Proprietary technologies would require a sole source justification for procurement.

References:

Vendor query responses.

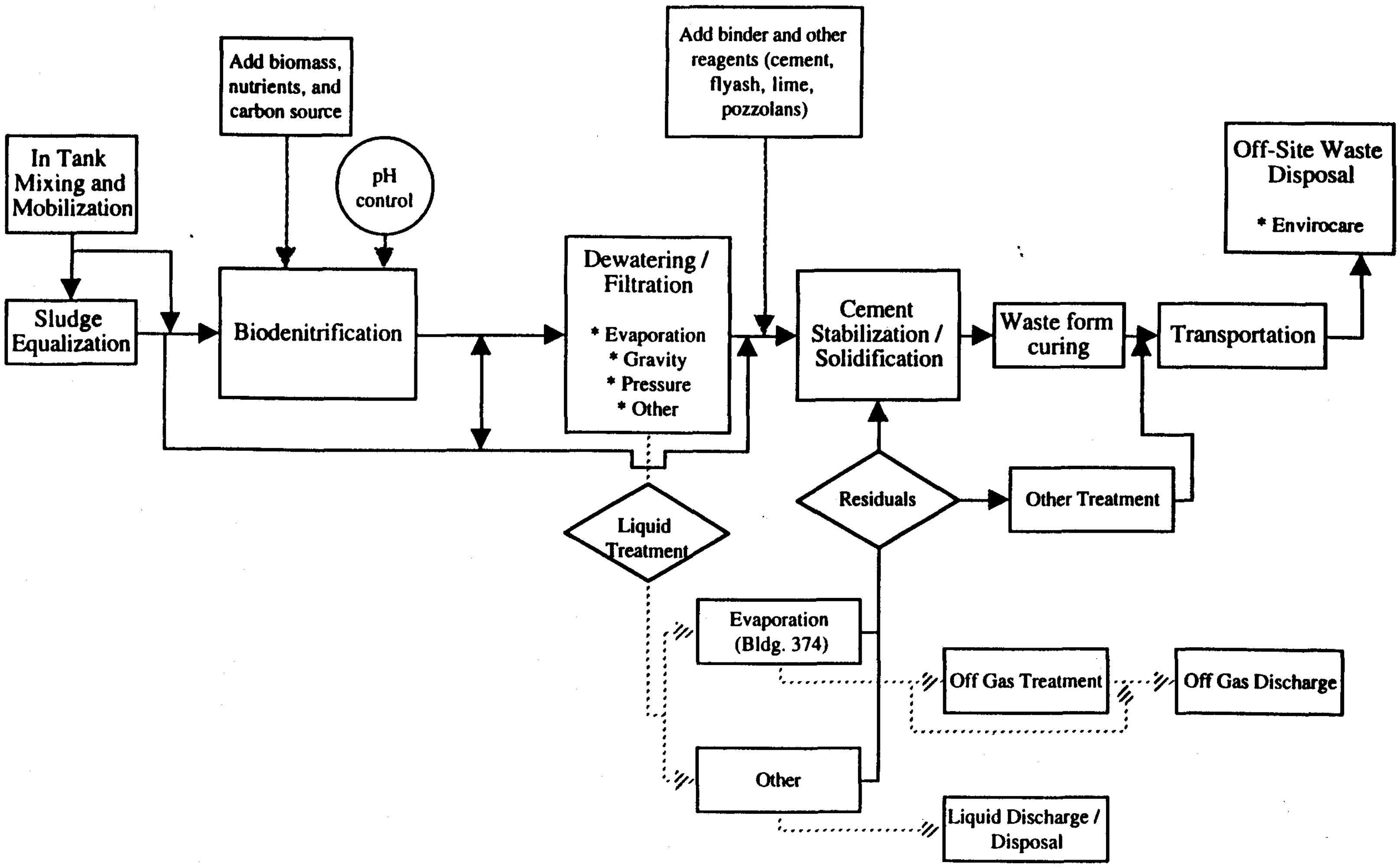
Conceptual Treatment System Flowsheet No. 5A

"Biodenitrification followed by Cement Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System Flowsheet No. 5B

"Biodenitrification followed by Cement Stabilization/Solidification and Off-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Biodenitrification followed by cement stabilization/solidification (Flowsheet No. 5A and 5B).

2. **Process description:** The sludges are removed from the tanks and transferred into biodenitrification reactors. Sludges exiting biodenitrification are transferred into a mixing tank where cement, flyash and/or lime are added. Pretreatment by dewatering may be employed. The metals and radionuclides are immobilized in the matrix and a monolith of a variety of shapes is formed.

3. **Potential vendors, contact, and phone:**
   Numerous potential vendors exist including:
   IT Corporation, Dr. Stuart Shealy, (615) 690-3211
   RFS Clemson Technical Center, Dave McCartney, (803) 646-2413
   OHM Remediation Services Corp., Dr. Paul Lear, (800) 537-9540

4. **Removal or immobilization of metals (radionuclides):** Immobilization by chemical binding and physical encapsulation.

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements. Treatability study required for specific characteristics.

6. **Final waste form:** Can be either monolithic or granular with compressive strength ranging from 20 to 1000 psi. A volume increase of 30 to 50% is estimated based on cement stabilization/solidification.

7. **Stage of development:** Full scale, commercially available depending on raw waste composition.

8. **Time required before full-scale installation and operations:** 8 months (time to conduct treatability study and perform pilot-scale demonstration).

9. **Processing rates:** 30 to 200 yd^3/hr of dewatered sludge.

10. **Process equipment readily available:** Yes.

11. **Approximate number of successful full-scale projects:** Numerous for industrial sludges, but no full-scale remediations of high nitrate wastes.

12. **Secondary waste streams produced:** Water removed from sludges (treatment capability exists on-site at Bldg. 374). Possibility of fugitive dust emissions if system is not contained or operated under negative pressure.

13. **Chemicals and additives required:** Variety of cement, flyash, blast furnace slag, lime, soluble silicates may be employed. Additional chemicals that might be required include viscosity extender (to remove sludges from tanks) and hypochloric acid (if pH adjustment is required).

14. **Estimated cost:** \$145 to \$600 per yd^3 based on cement stabilization/solidification. Costs for the biodenitrification unit process were not available.

15. **Unusual potential environmental impact risks:** Treatment requires pH control which if it malfunctions, potential risks may occur (see general comments).

16. **Unusual potential safety risks:** Treatment requires pH control which if it malfunctions, potential risks may occur (see general comments).

17. **Other:** Biodenitrification to reduce the nitrate concentrations in the sludges should reduce the additives required to produce a stable waste form.

    Reduction of nitrate concentrations in the raw sludge may improve waste form setting.

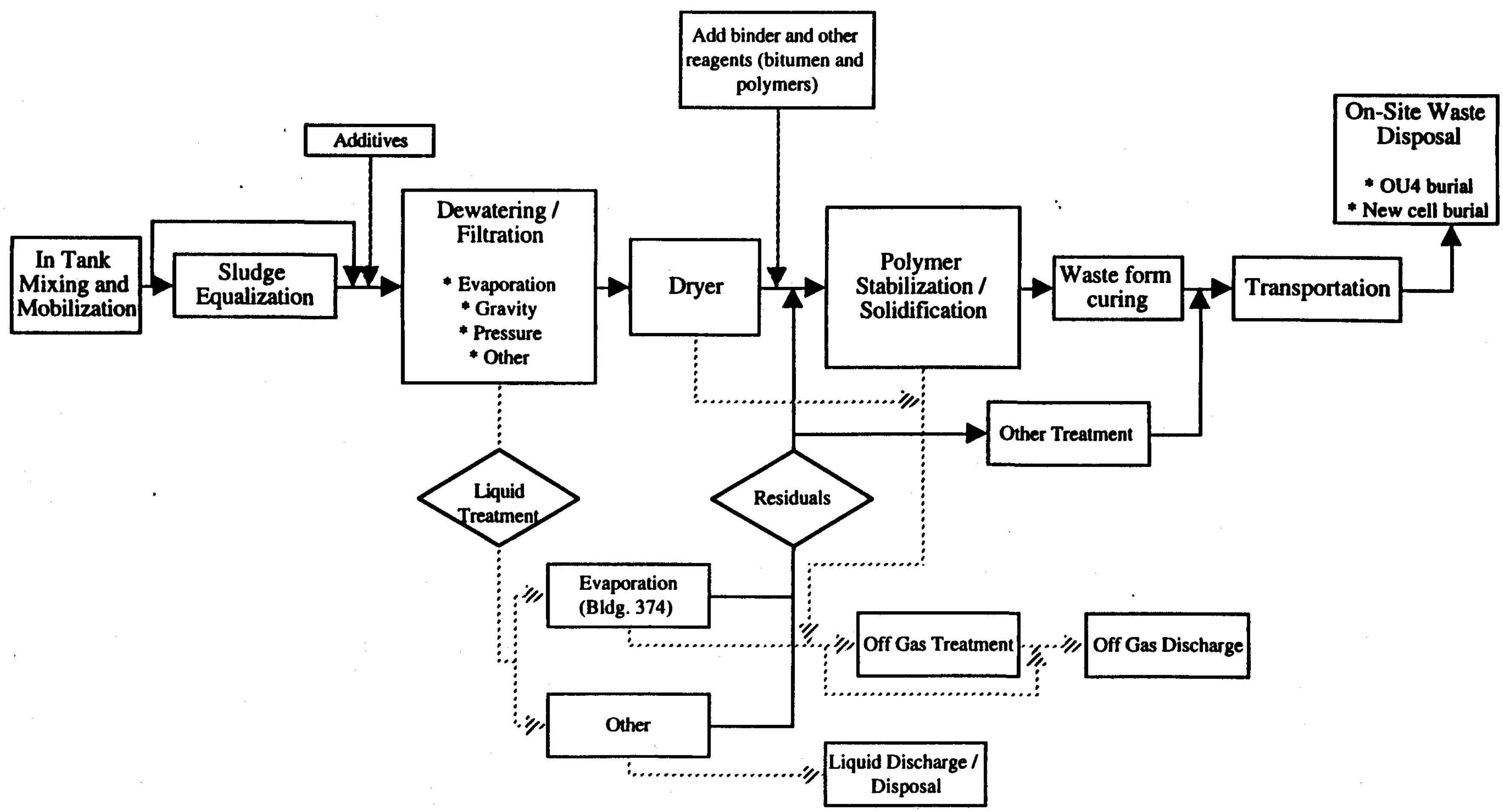
References:

Personal communications.

Vendor query responses.

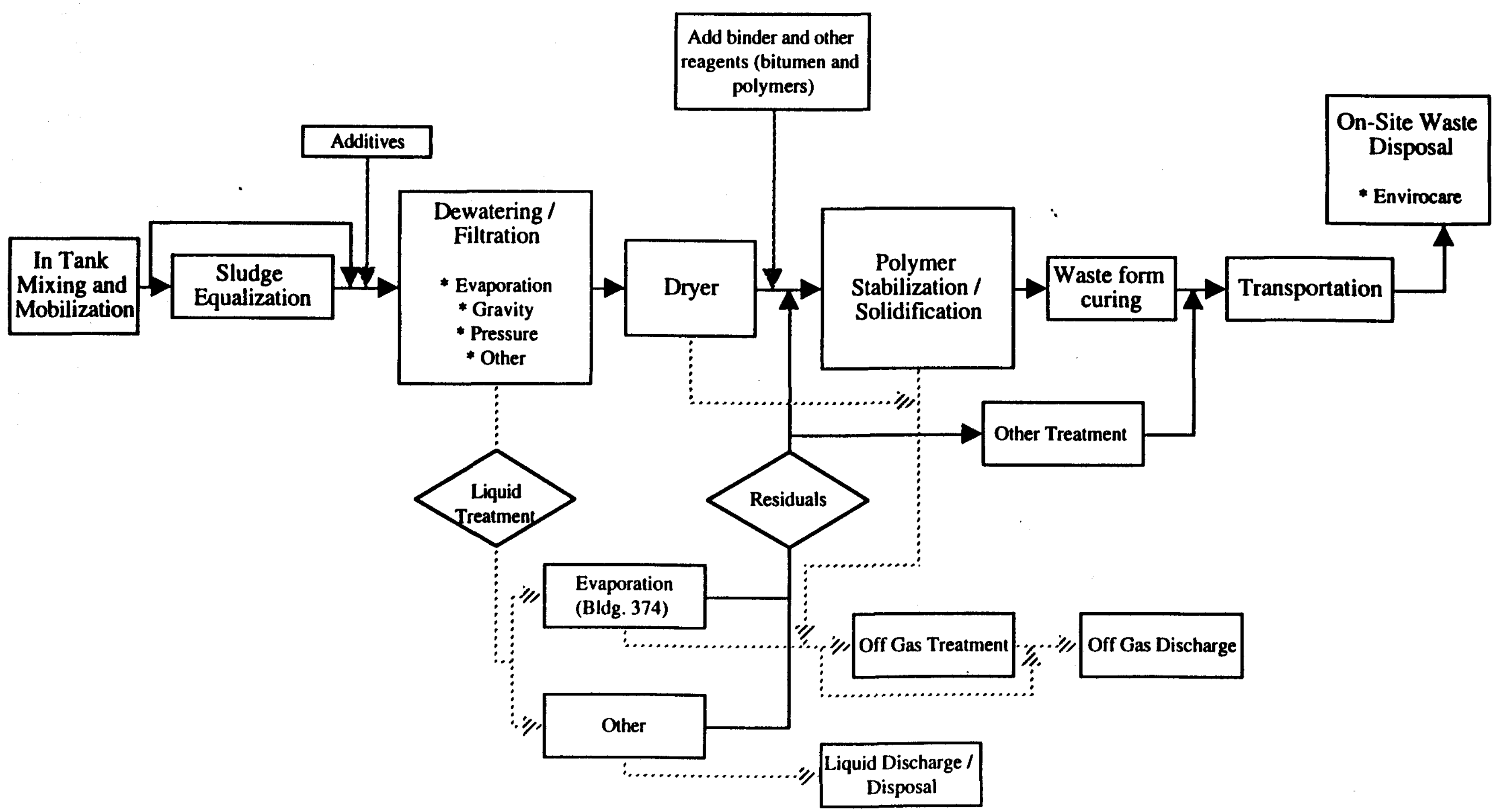
Conceptual Treatment System Flowsheet No. 6A

"Polymer Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System
Flowsheet No. 6B

"Polymer Stabilization/Solidification and Off-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Polymer Stabilization/Solidification (Flowsheet No. 6A and B).

2. **Process description:** The sludges are removed from the tanks and transferred to dewatering equipment. Following dewatering, the sludges are thermally dried. The dry material is then mixed with molten polyethylene. The thermal dryer (hot oil heated) has off-gas treatment (catalytic converter or condensation for volatile organic compounds) prior to discharge to the atmosphere. The metals and radionuclides are immobilized in the matrix and a monolith is formed. Coarse materials must undergo size reduction or be screened prior to treatment.

3. **Potential vendors, contact, and phone:**
(Note: Vendors listed responded to a solicited vendor query. Other potential vendors may exist.)
Diversified Technologies Services, Inc., Dennis Brunsell, (615) 539-9000 ext. 24
ETAS, Dr. Richard Lo, (214) 630-6610
IT Corporation, Dr. Stuart Shealy, (615) 690-3211
RF Weston, Michael Cosmos, (610) 701-3000

4. **Removal or immobilization of metals (radionuclides):** Immobilization by physical encapsulation.

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements. Treatability study required for specific characteristics.

6. **Final waste form:** Variable waste forms can be produced. Compressive strength and volume reduction depend on the final recipe. Minimal volume increase is estimated (less than cement stabilization).

7. **Stage of development:** Bench- and pilot-scale. Full-scale demonstration (25 yd^3/hr) has been installed and operated at Brookhaven National Laboratory.

8. **Time required before full-scale installation and operations:** 12 months (time to conduct treatability study and conduct pilot-scale demonstration). Full-scale demonstration may be required prior to operation.

9. **Processing rates:** 25 to 60 yd^3/hr of dewatered sludge.

10. **Process equipment readily available:** Full-scale commercial system does not exist. Fabrication and installation of a full-scale system would require 6 to 9 months.

11. **Approximate number of successful full-scale projects:** None.

12. **Secondary waste streams produced:** Water removed from sludges (treatment capacity exists on-site at Bldg. 374). There will also be a condensate stream from the dryer that will contain some entrained solids and any volatile organics from the original waste that must be disposed (Minimal volatile organics are expected in the condensate based on low sporadic concentrations in the raw waste.)

13. **Chemicals and additives required:** Polyethylene (0.5 to 1.5 lbs per lb of waste). A viscosity extender to remove sludges from tanks may be required.

14. **Estimated cost:** \$79 to \$900 per yd^3 of encapsulated waste. Cost estimates were taken from vendor input and may be high. Large variance may be due to inclusion/exclusion of capital equipment costs. An additional cost increase of \$175 to \$290 per yd^3 for thermal dryer.

15. **Unusual potential environmental impact risks:** None.

16. **Unusual potential safety risks:** Final waste form is extruded at approximately 130°C. Use of caustic chemicals if pH adjustment is required.

17. **Other:** Operating and maintenance requirements are expected to be higher than for cement stabilization. One advantage of encapsulation is that it does not depend on chemical reactions of waste and binder. This might also be considered a disadvantage because the waste is not chemically bonded within the matrix.

Polyethylene might increase volume but have little impact on weight. Thus it might have cost advantages over cement if transportation costs are based on weight.

May require specialized mixing equipment.

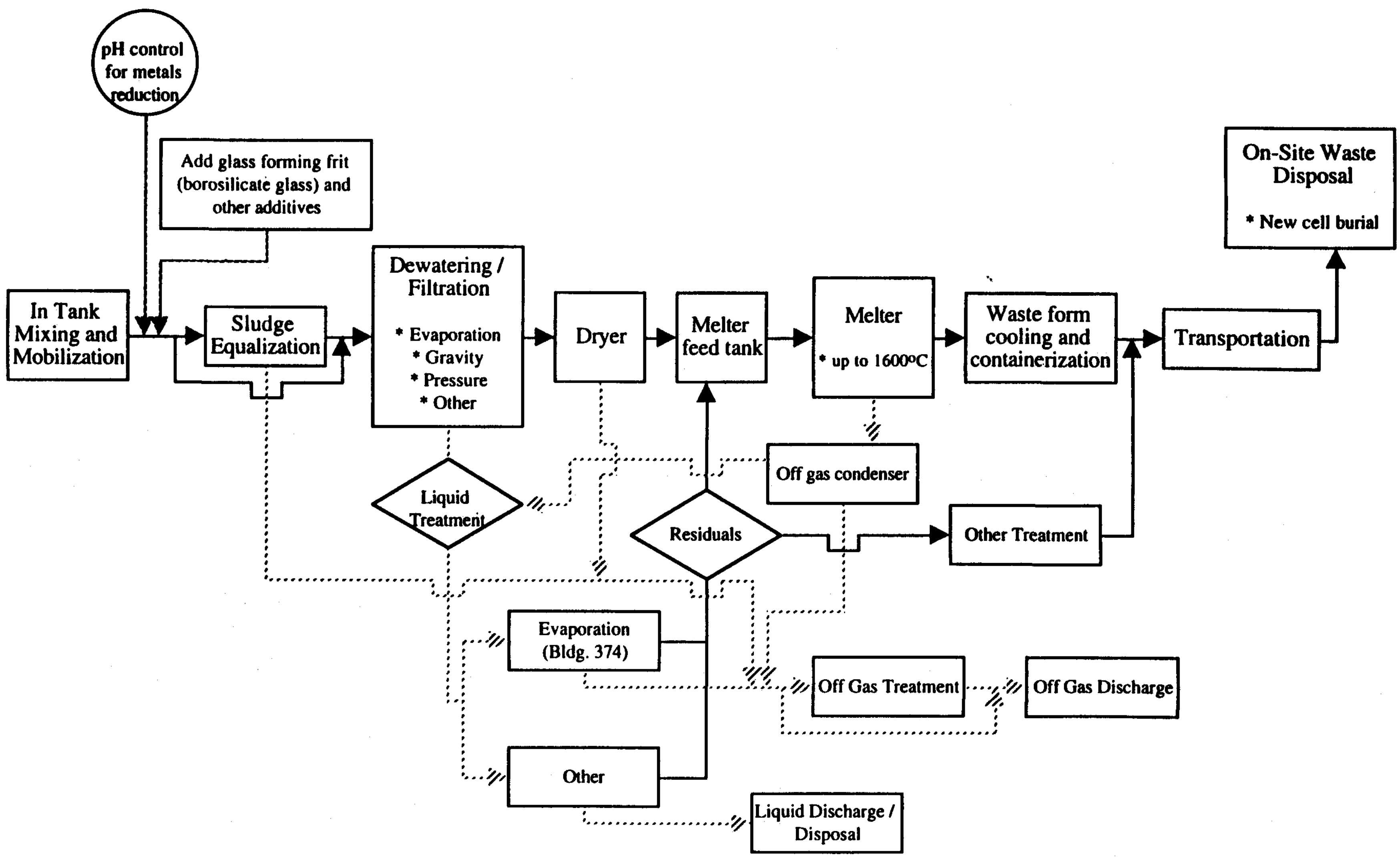
References:

Barth, E. F., et al. 1990. *Stabilization and Solidification of Hazardous Wastes.* Noyes Data Corporation, Park Ridge New Jersey. 390 pages.

Vendor query responses.

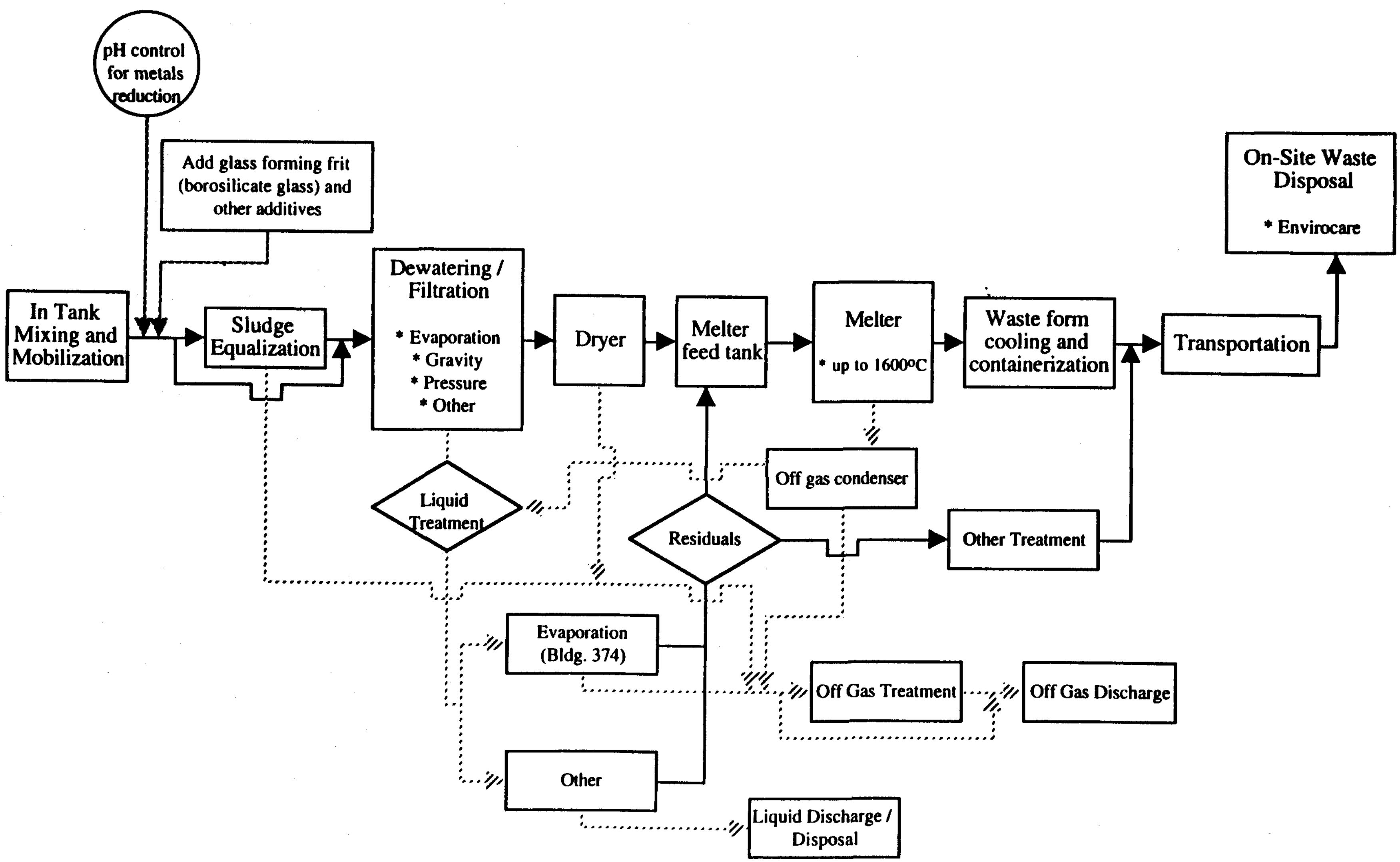
Conceptual Treatment System Flowsheet No. 7A

"Vitrification Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System
Flowsheet No. 7B

"Vitrification Stabilization/Solidification and Off-site Land Disposal"



Evaluation and Screening of Treatment and Disposal Options for the Containerized Solar Pond Sludges

Technology Description Fact Sheet

1. **Technology type:** Vitrification Stabilization/Solidification (Flowsheet No. 7A and B).

2. **Process description:** Process involves four main systems: feed, melter, off-gas treatment, and glass discharge and handling system. First the sludge must be pumped from the tanks to the vitrification system feed. The feed is dried then pumped into the melter where it is dropped onto the surface of a molten glass pool. The liquid evaporated and is treated in the off-gas system while the solids are oxidized and melted into glass. Various melters can be used including a joule melter (glass is heated by electrodes) or a cyclone furnace (glass is heated by natural gas with the molten slag layer retained on the melter wall by centrifugal action). Off-gas treatment should include a catalytic converter or scrubbers prior to release to the atmosphere.

3. **Potential vendors, contact, and phone:**
   (Note: Vendors listed have responded to a solicited vendor query. Other potential vendors may exist.)
   Babcock & Wilcox, Michael Holmes, (216) 829-7662
   Battelle, Richard Peters, (509) 376-4579
   Diversified Technologies Services, Inc., Dennis Brunsell, (615) 539-9000 etn. 24
   GTS Duratek, William Greenman or Sarah Bennett, (410) 312-5100
   RFS Clemson Technical Center, Lew Goodroad, (803) 646-2413

4. **Removal or immobilization of metals (radionuclides):** Immobilization by vitrification (melting).

5. **Treated waste characteristics:** Technology is capable of immobilizing constituents to LDR requirements as the glass product is leach resistant. Treatability study required for specific characteristics.

6. **Final waste form:** Glass can be either discharged in bulk (e.g. drums) or as marble-like glass pieces. "Marbles" vary in size from 1/4 to 3/4 inch diameter and may have whisker-like pieces and other small pieces of glass associated with them.

Compressive strength of glass estimated to be >10,000 psi. Volume reduction (slurry volume to glass volume) is estimated to range from 30 to 70%.

7. **Stage of development:** Bench-, pilot-, and full-scale commercially available systems. A system is being designed for sludge at Savannah River, with roughly the same level of nitrates, capable of processing about 10,000 lbs of sludge per day. Demonstration have been conducted at Catholic University of America, Fernald, PNL, Hanford, and in Japan and Germany.

8. **Time required before full-scale installation and operations:** 14 to 18 months (time to conduct crucible melts and analysis and treatability study [2 to 6 months} and fabricate melter [12 months]).

9. **Processing rates:** 0.04 to 110 yd^3/day (0.1 to 100 ton/day) (wide variation in processing rates is based on different melter sizes). Residence times for the glass in the melter can be as high as 20 hrs.

10. **Process equipment readily available:** No commercial melter exists. Fabrication and installation of a full-scale system would require at least 12 months.

11. **Approximate number of successful full-scale projects:** Several full-scale demonstrations have been completed.

12. **Secondary waste streams produced:** Water removed from sludges (treatment capability exists on-site at Bldg. 374). There will also be off-gas from the melter that must be treated (e.g., catalytic oxidation and HEPA filters).

13. **Chemicals and additives required:** Depending on chemical analysis of sludge the following chemicals may be required: glass formers (silica or diatomaceous earth), carbonates (sodium, potassium, lithium, and/or calcium), alumina, magnesia, iron hydroxide, and/or boric acid. Off-gas treatment may require sodium hydroxide, hydrogen peroxide, urea, and sulfuric acid.

14. **Estimated cost:** $400 to $7000 per cubic yard (most estimates range from $2100 to $5400 per cubic yard). Capital equipment costs are estimated to range from $0.5 to $7 million.

15. **Unusual potential environmental impact risks:** Potential fugitive emmissions during handling and treatment (see general comments).

16. **Unusual potential safety risks:** Potential fugitive emmissions during handling and treatment (see general comments).

17. **Other:**

References:

Barth, E. F., et al. 1990. *Stabilization and Solidification of Hazardous Wastes.* Noyes Data Corporation, Park Ridge New Jersey. 390 pages.

Personal Communications.

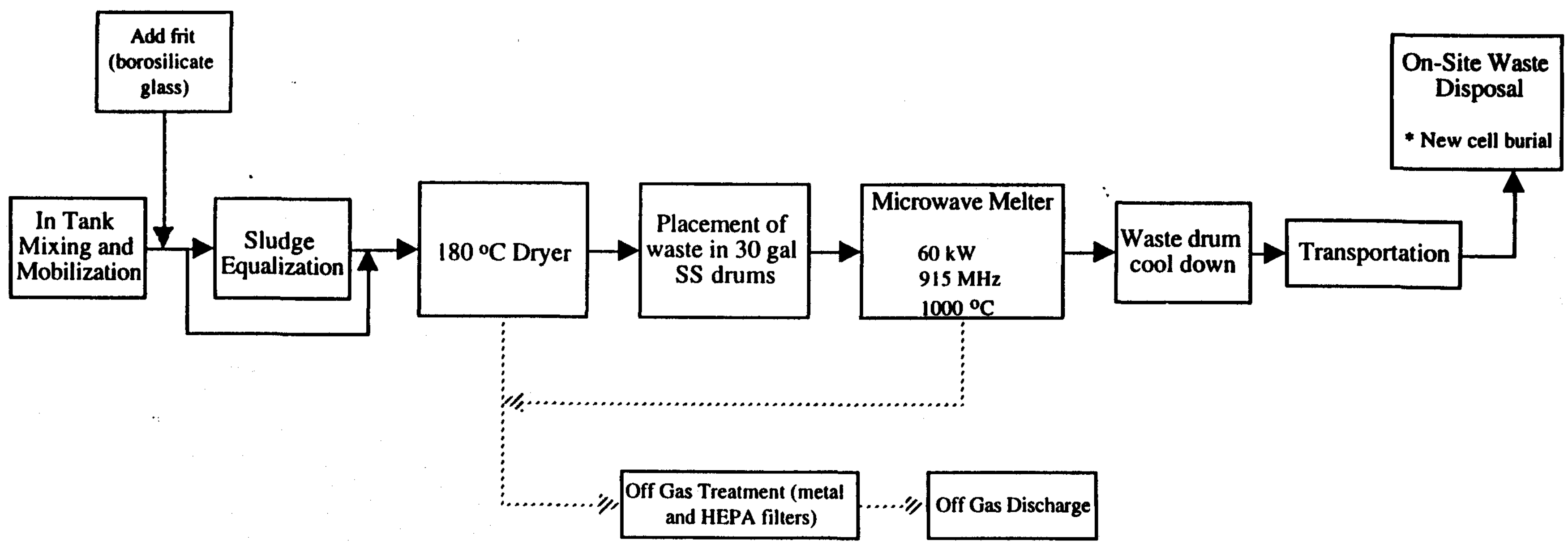
Ritter, J. A., et al. 1992. High-level radioactive waste vitrification technology and its applicability to industrial waste sludges. *Water Science Technology*, **25**(3), 269-271.

Vendor query responses.

VISITT Database.

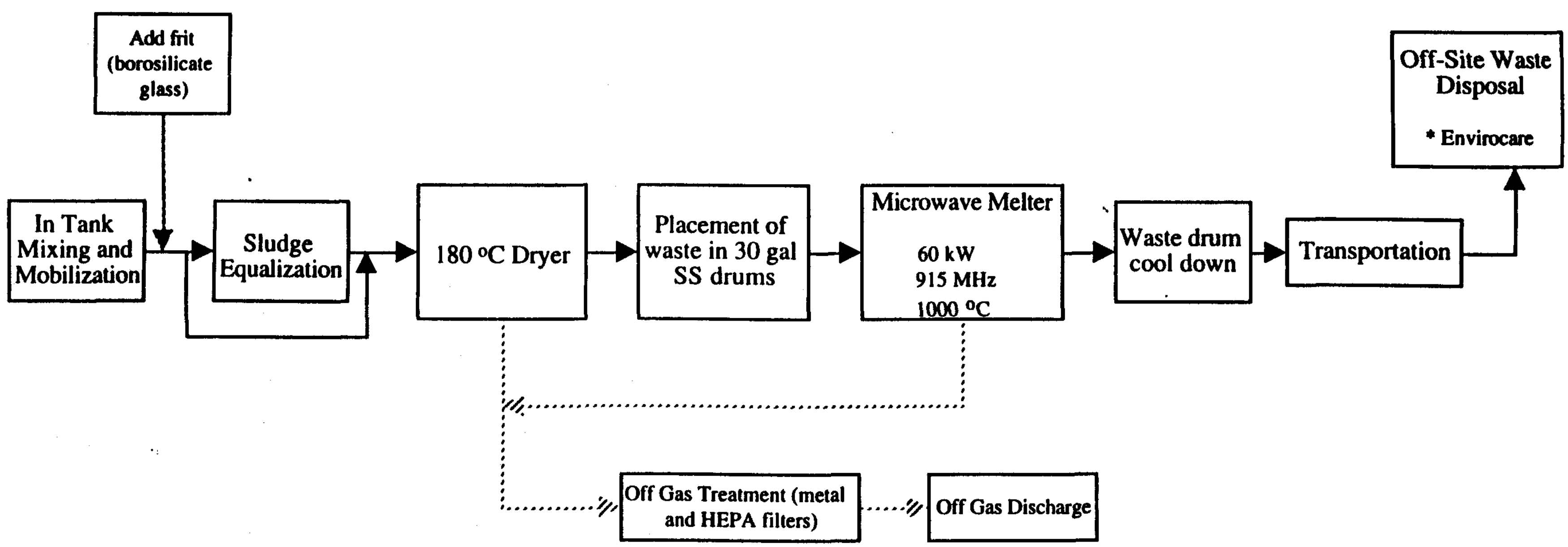
Conceptual Treatment System Flowsheet No. 8A

"Microwave Stabilization/Solidification and On-site Land Disposal"



Conceptual Treatment System Flowsheet No. 8B

"Microwave Stabilization/Solidification and Off-site Land Disposal"



Evaluation and Screening of Treatment and Disposal Options
for the Containerized Solar Pond Sludges

Technology Description Fact Sheet

1. **Technology type:** Microwave Melter (Flowsheet No. 8A and B).

2. **Process description:** The sludge is dried and then transferred into 30-gal. stainless steel drums which are connected to the unit. After frit material is added to the drum, microwave energy is transmitted to the drum (internal material temperatures reach up to 1000°C). Off-gas treatment consists of a filter system prior to release to the atmosphere. The process continues until 300 kilograms of waste material has accumulated in the 30-gallon drum.

3. **Potential vendors, contact, and phone:**
EG&G, Greg Sprenger or Veryl Eschen, (303)966-3159 or (303) 966-5377

4. **Removal or immobilization of metals (radionuclides):** Immobilization by microwave melting.

5. **Treated waste characteristics:** Treatability study required for specific characteristics. Technology is capable of immobilizing constituents to LDR requirements as the glass product is leach resistant.

6. **Final waste form:** 30-Gallon stainless steel drums. Estimated volume reduction (slurry volume to glass volume) up to 80%.

7. **Stage of development:** Advanced bench-scale.

8. **Time required before full-scale installation and operations:** Unknown.

9. **Processing rates:** 0.05 yd^3/hr (40 kg/hr).

10. **Process equipment readily available:** No commercial system exists, but all components are commercially available. Three demonstration scale systems are located on site.

11. **Approximate number of successful full-scale projects:** Several on-site demonstrations have been completed including on pond sludges.

12. **Secondary waste streams produced:** Off-gas from the system is filtered.

13. **Chemicals and additives required:** Frit (borosilicate glass formers).

14. **Estimated cost:** Capital equipment, construction, and engineering costs are estimated at $6.2 million (approximately $2000 per yd^3 of raw sludge).

15. **Unusual potential environmental impact risks:** Potential fugitive emmissions during handling and treatment (see general comments).

16. **Unusual potential safety risks:** Potential fugitive emmissions during handling and treatment (see general comments).

17. **Other:** System may be best applied to small unique waste streams due to processing in 30-gal. batches.

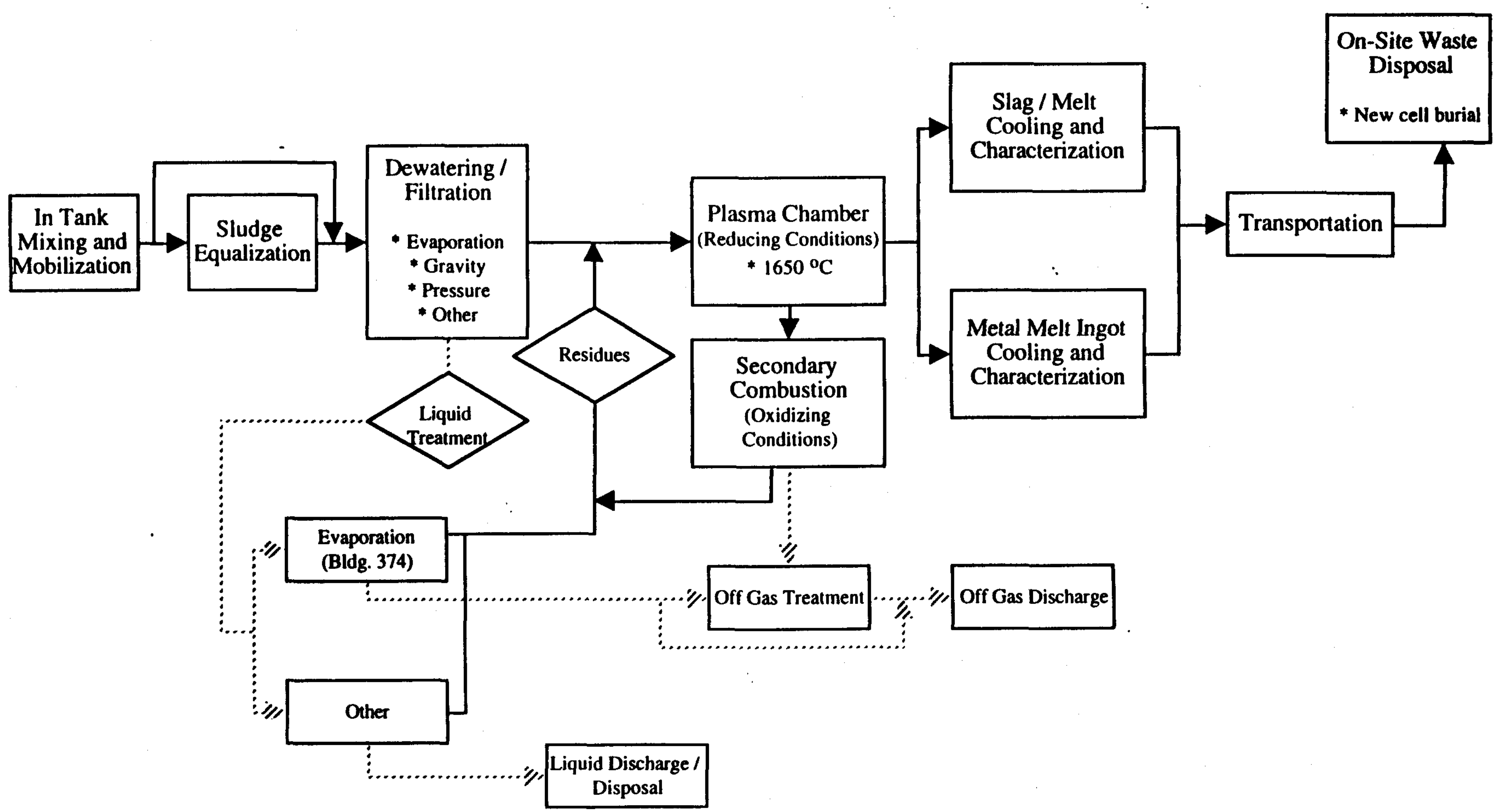
References:

EG&G Rocky Flats, Inc. 1994. *Description of Systems and Capabilities at the Rocky Flats Plant for Demonstrating and Testing Microwave Solidification Technology.*

Personal Communications.

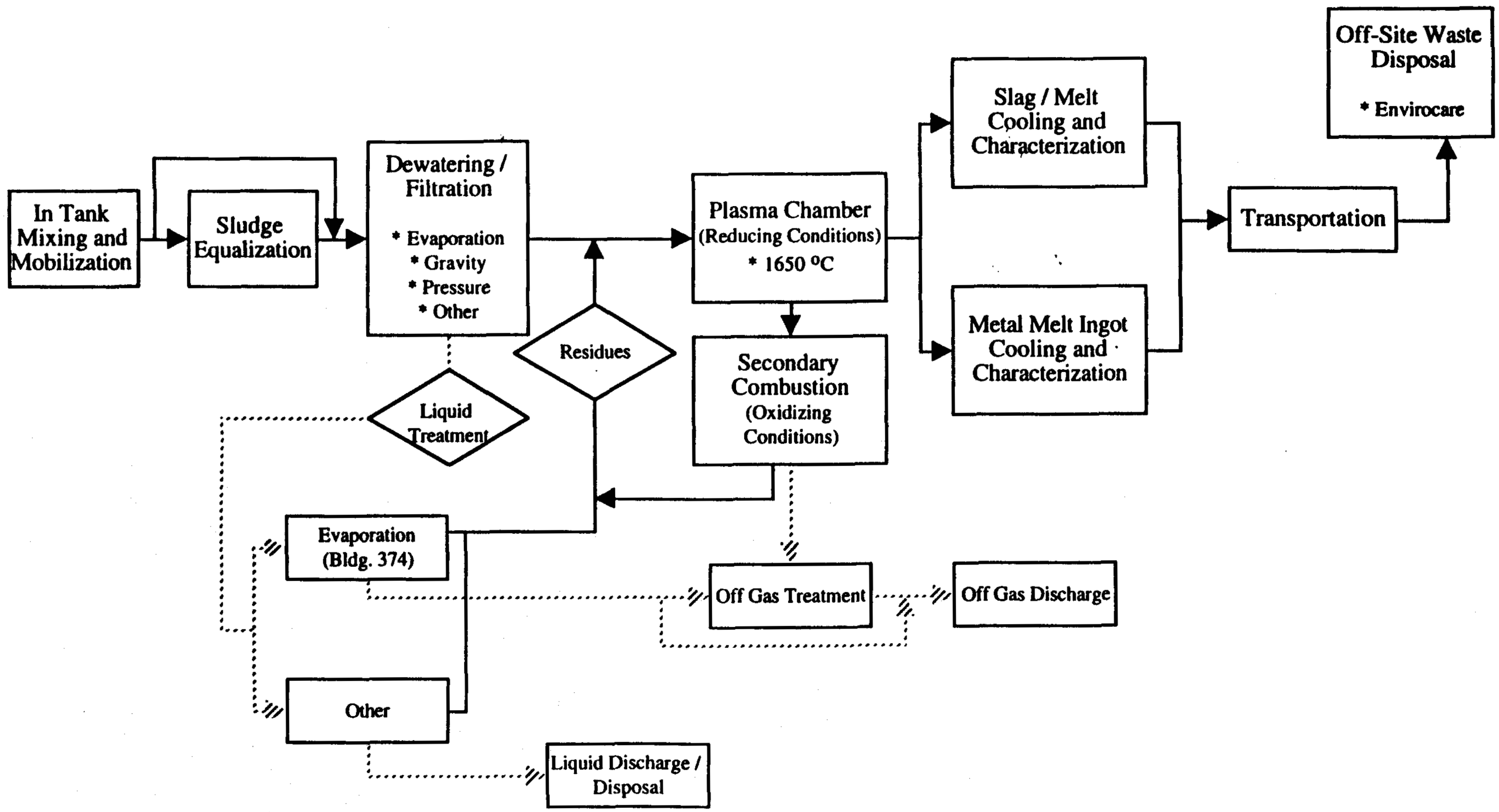
Conceptual Treatment System Flowsheet No. 9A

"Plasma Hearth Stabilization and On-site Land Disposal"



Conceptual Treatment System Flowsheet No. 9B

"Plasma Hearth Stabilization and Off-site Land Disposal"



Technology Description Fact Sheet

1. **Technology type:** Plasma Hearth Solidification/Stabilization (Flowsheet No. 9A and B).

2. **Process description:** The sludges are removed from the tanks and transferred to the feed system. The wastes are then fed into the plasma chamber where volatile metals and compounds are vaporized and then fed into a secondary combustion chamber to form innocuous products. The solids from the plasma chamber are incorporated into a molten bath which is then cooled and solidified into a vitrified slag.

3. **Potential vendors, contact, and phone:**
(Note: Vendors listed have responded to a solicited vendor query. Other potential vendors may exist.)
SAIC, Ray Geimer, (208) 528-2144

4. **Removal or immobilization of metals (radionuclides):** Immobilization by melting.

5. **Treated waste characteristics:** Technology is capable of immobilizing metals to LDR requirements as the glass slag is leach resistant. Treatability study required for specific characteristics.

6. **Final waste form:** Glass is discharged in bulk but can be size reduced if necessary.

7. **Stage of development:** Bench- and pilot-scale.

8. **Time required before full-scale installation and operations:** Unknown.

9. **Processing rates:** Up to 2.3 yd^3/hr (up to 2 tons/hr) of raw sludge.

10. **Process equipment readily available:** No commercial system exists.

11. **Approximate number of successful full-scale projects:** Pilot-scale demonstration has been completed.

12. **Secondary waste streams produced:** Off-gas from the plasma and secondary chamber must be treated.

13. **Chemicals and additives required:** Unknown.

14. **Estimated cost:** Complete procurement, development, construction, testing, and evaluation for a full-scale system is expected to cost about $2 million (approximately $612/yd^3 of raw sludge).

15. **Unusual potential environmental impact risks:** Potential fugitive emmissions during handling and treatment (see general comments).

16. **Unusual potential safety risks:** Potential fugitive emmissions during handling and treatment (see general comments).

17. **Other:**

References:

Mixed Waste Integrated Program Annual Report. 1993.

Personal Communications.

ORNL. 1993. *Oak Ridge National Laboratory Technology Logic Diagram.* Prepared for the Office of Technology Development, U.S. Department of Energy.

Appendix G - Detailed Results of Candidate Technology Screening

Appendix G: Detailed Results of Candidate Technology Screening

Results from the candidate technology screening are provided in this appendix including individual technology evaluation team member review forms and summary information. Results are discussed in Section 5 and statistical evaluation of the results are presented in Appendix H.

Table G.1 Containerized Solar Pond Sludge Treatment Wants Weighting Summary

	Weighting by technology want									
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	8	7	8	10	9	3	10	7	8	9
2	10	9	5	5	6	1	10	9	10	10
3	10	7	7	9	5	9	9	7	7	7
4	10	10	3	7	8	3	9	7	3	5
5	10	7	3	8	9	3	10	7	5	6
6	10	7	9	6	10	8	8	4	7	3
7	10	9	8	4	8	10	8	5	7	7
8	10	5	5	8	10	3	10	8	6	6
9	8	5	10	8	8	3	10	5	5	5
10	10	10	4	6	6	6	6	6	3	3
11	10	7	7	9	4	9	10	7	7	7
Total	106	83	69	80	88	58	100	72	68	68
Average Weight	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2
Rank	1	4	7	5	3	10	2	6	8	9
Ave. with high and low omitted	9.8	7.6	6.2	7.3	8.1	5.2	9.3	6.6	6.1	6.1

Table G.2 Summary of Solar Ponds Kepner-Tregoe Analysis

System	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total Score (rank)	Total score without cost
System 1 - Simple Stabilization												
Score	6.8	8.8	7.0	6.2	5.4	9.0	9.6	7.6	6.5	4.8		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	65.4	66.1	44.1	45.1	43.6	47.7	87.7	49.6	40.6	29.9	519.9	470.3
System 2A - Cement S/S, OU4 burial												
Score	8.4	9.3	8	8.4	7.4	8.4	8.4	6.5	8.2	6.9		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	81.2	69.5	50.4	61.0	58.9	44.8	76.9	42.5	50.7	42.8	578.9	536.4
System 2B - Cement S/S, New cell												
Score	9	8.8	8.4	8.5	7.4	8.1	8.3	6.4	8.1	7.2		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	86.4	66.1	53.3	62.4	58.9	42.9	75.3	41.4	50.2	44.5	581.3	539.9
System 2C - Cement S/S, Envirocare												
Score	8.3	8.6	8	8.1	7.3	8.3	8.4	5.3	8.4	8.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	79.4	64.8	50.4	59.1	58.2	43.8	76.1	34.3	52.4	50.2	568.6	534.4
System 3A - Biochemical Stabilization, OU4 burial												
Score	7	8.4	7.5	7.4	7.1	8.1	7	5.9	6.5	5.3		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	67.2	62.7	47.5	53.8	56.7	42.9	63.7	38.4	40.6	32.7	506.2	467.8
System 3B - Biochemical Stabilization, New cell												
Score	7.5	7	7	7.4	7.3	7.5	7.1	5.8	6.0	5.5		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	72.4	52.5	44.1	54.4	58.2	40.0	64.5	37.8	37.2	34.4	495.6	457.7
System 3C - Biochemical Stabilization, Envirocare												
Score	7	7	6.8	7.4	7.0	7.7	7	4.7	6.2	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	67.2	52.5	43.0	53.8	56.0	41.0	63.7	30.7	38.3	40.0	486.1	455.4
System 4A - Pressure S/S, OU4 burial												
Score	7.1	8.1	6.5	7.1	6.8	7.4	5.9	5.3	6.4	6.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	68.1	60.7	41.2	51.8	54.5	39.0	53.8	34.3	39.4	37.8	480.6	446.3

Table G.2 Summary of Solar Ponds Kepner-Tregoe Analysis (*continued*)

System	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total Score	Total score without cost
System 4B - Pressure S/S, New cell												
Score	7.3	8.3	7.4	7.4	7	7.3	6	5.5	5.9	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	74.2	62.0	47.0	53.8	56.0	38.5	54.6	36.0	36.6	39.4	498.2	462.2
System 4C - Pressure S/S, Envirocare												
Score	7.3	8.1	6.6	6.5	6.5	6.8	5.8	5	6.4	7		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	69.8	60.7	41.8	47.8	52.4	36.1	52.9	32.5	39.4	43.4	476.9	444.4
System 5A - Biochemical S/S, OU4 burial												
Score	7.8	8.5	7.2	7.6	7.3	7.7	6.4	5.7	7.1	5.6		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	75.0	64.1	45.2	55.7	58.2	41.0	57.9	37.2	44.0	34.9	513.3	476.1
System 5B - Biochemical S/S, New cell												
Score	8.3	8.3	7.6	7.9	7.3	7.4	6.5	5.4	7.2	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	79.4	62.0	48.1	57.7	58.2	39.0	59.6	35.4	44.5	39.4	523.5	488.1
System 5C - Biochemical S/S, Envirocare												
Score	7.8	8.3	7.4	7.7	7.3	7.5	6.3	4.6	7.4	7.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	75.1	62.0	46.4	56.4	58.2	40.0	61.2	30.1	46.2	44.0	519.6	489.5
System 6A - Polymer S/S, OU4 burial												
Score	7.4	8.4	8.4	8.3	7.3	6.6	5.4	3.9	6.4	6.2		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	70.7	63.4	52.7	60.4	58.2	35.2	49.6	25.4	40.0	38.3	493.9	468.5
System 6B - Polymer S/S, New cell												
Score	7.8	8.4	8.4	8.3	7.3	6.3	5.5	4	6.4	6.7		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	75.1	63.4	53.3	60.4	58.2	33.2	50.5	26.0	40.0	41.7	501.7	475.7
System 6C - Polymer S/S, Envirocare												
Score	7.6	8.4	8.7	8.2	7.3	6.5	5.5	3.4	6.5	7.3		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	73.3	63.4	55.0	59.7	58.2	34.7	50.5	22.4	40.6	45.1	502.9	480.4

Table G.2 Summary of Solar Ponds Kepner-Tregoe Analysis (*continued*)

System	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total Score	Total score without cost
System 7A - Vitrification, New cell												
Score	7.6	7.6	6.3	7.9	8.4	4.6	2.4	2	4.4	4.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	73.3	57.3	39.5	57.7	66.9	24.6	22.3	13.0	27.6	27.6	409.9	396.9
System 7B - Vitrification, Envirocare												
Score	7.4	7.6	6.1	7.7	8.2	4.7	2.5	1.2	4.5	4.6		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	70.7	57.3	38.4	56.4	65.4	25.1	23.2	11.8	28.7	28.7	405.2	393.3
System 8A - Microwave, New cell												
Score	8.1	8.2	6.9	8.4	8.5	4.6	3.6	2	5.7	6.2		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	77.6	61.4	43.5	61.1	68.4	24.6	33.1	13.0	35.5	37.8	455.9	442.9
System 8B - Microwave, Envirocare												
Score	7.8	8.2	6.4	8.2	8.4	4.7	3.7	1.8	5.8	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	75.1	61.4	40.1	59.7	66.9	25.1	33.9	11.8	36.1	39.4	449.5	437.6
System 9A - Plasma Hearth, New cell												
Score	6.5	7.5	5.4	7.6	8	3.2	1.7	2	3.7	3.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	62.8	56.6	33.8	55.7	64.0	16.9	15.7	13.0	23.1	20.8	362.5	349.5
System 9B - Plasma Hearth, Envirocare												
Score	6.3	7.5	5.4	7.5	7.9	3.1	1.8	1.8	3.8	3.5		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score (rank)	60.2	56.6	33.8	55.1	63.3	16.4	16.5	11.8	23.7	22.0	359.3	347.5

Table G.3 Summary of Solar Ponds Kepner-Tregoe Results for Simple Stabilization

	Wants Criteria										Total Score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	10	4	8	9	7	10	8	8	7		
2	10	10	10	8	7	9	9	8	8	5		
3	10	10	10	10	10	8	9	5	10	9		
4	3	7	3	2	2	8	10	8	5	1		
5	8	10	5	8	7	10	10	8	5	2		
6	2	10	10	2	2	10	10	8	2	4		
7	4	7	8	5	7	10	10	8	8	7		
8	6	8	8	2	1	10	10	8	6	2		
9	5	5	5	5	5	9	9	8	5	2		
10	8	10	4	8	5	10	10	10	5	5		
11	10	10	10	10	5	8	9	5	10	9		
Ave score	6.8	8.8	7	6.2	5.4	9	9.6	7.6	6.5	4.8		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	65.4	66.1	44.1	45.1	43.6	47.7	87.7	49.6	40.6	29.9	519.9	470.3

Table G.4 Summary of Solar Ponds Kepner-Tregoe Results for Cement S/S, OU4 Burial

Evaluator	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total score	Total score w/o cost
1	10	10	8	8	10	5	8	8	8	9		
2	10	10	10	10	7	8	8	2	10	10		
3	10	10	10	10	10	8	9	5	10	9		
4	7	10	10	7	6	9	10	8	10	4		
5	8	10	9	9	8	10	10	8	5	5		
6	9	10	4	8	9	8	8	8	10	10		
7	5	9	8	7	5	9	10	8	9	8		
8	8	8	8	8	8	10	6	5	8	4		
9	7	5	6	6	7	8	7	7	5	3		
10	9	10	5	9	6	10	8	8	5	5		
11	10	10	10	10	5	8	9	5	10	9		
Ave score	8.4	9.3	8	8.4	7.4	8.4	8.4	6.5	8.2	6.9		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	81.2	69.5	50.4	61.1	58.9	44.8	76.9	42.5	50.7	42.8	578.9	536.4

Table G.5 Summary of Solar Ponds Kepner-Tregoe Results for Cement S/S, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	10	8	8	8	10	5	6	8	6	5		
2	10	10	10	10	7	8	8	5	10	10		
3	10	10	10	10	10	8	9	5	10	9		
4	7	7	10	7	6	9	10	8	10	8		
5	9	10	9	9	8	8	9	8	5	5		
6	9	10	9	8	9	9	10	8	10	10		
7	7	9	8	7	5	8	9	8	9	8		
8	10	8	8	8	8	10	6	5	8	5		
9	8	5	6	8	7	6	7	5	6	5		
10	9	10	5	9	6	10	8	5	5	5		
11	10	10	10	10	5	8	9	5	10	9		
Ave score	9	8.8	8.4	8.5	7.4	8.1	8.3	6.4	8.1	7.2		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	86.4	66.1	53.3	62.4	58.9	42.9	75.3	41.4	50.2	44.5	581.3	539.9

Table G.6 Summary of Solar Ponds Kepner-Tregoe Results for Cement S/S, Envirocare

Evaluator	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total score	Total score w/o cost
1	7	8	7	6	10	5	6	5	6	7		
2	10	10	10	10	7	8	8	5	10	10		
3	9	9	9	9	9	8	9	2	9	8		
4	7	7	10	7	6	9	10	8	10	8		
5	8	10	9	9	8	9	9	8	5	5		
6	9	10	9	8	9	9	10	8	10	10		
7	6	9	6	7	5	7	9	8	9	9		
8	10	8	8	8	8	10	7	5	9	8		
9	7	5	6	7	7	8	7	2	7	7		
10	9	10	5	9	6	10	8	5	8	8		
11	9	9	9	9	5	8	9	2	10	9		
Ave score	8.3	8.6	8.0	8.1	7.3	8.3	8.4	5.3	8.4	8.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	79.4	64.8	50.4	59.1	58.2	43.8	76.1	34.3	52.4	50.2	568.6	534.4

Table G.7 Summary of Solar Ponds Kepner-Tregoe Results for Biochemical Stabilization, OU4 Burial

	Wants Criteria											Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total score**	
1	10	9	8	8	10	6	7	5	7	5		
2	9	9	9	10	8	6	2	2	8	7		
3	8	8	8	8	8	7	7	5	8	7		
4	3	7	3	4	3	8	8	8	5	1		
5	8	10	8	9	9	10	10	8	5	5		
6	4	10	10	4	4	9	6	5	4	4		
7	4	8	8	6	6	9	8	5	6	6		
8	8	8	8	8	9	10	7	8	9	4		
9	7	5	8	7	8	8	7	7	6	5		
10	8	10	5	9	5	8	7	7	6	6		
11	8	8	8	8	8	8	8	5	8	8		
Ave score	7.0	8.4	7.5	7.4	7.1	8.1	7.0	5.9	6.5	5.3		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	67.2	62.7	47.5	53.8	56.7	42.9	63.7	38.4	40.6	32.7	506.2	467.8

Table G.8 Summary of Solar Ponds Kepner-Tregoe Results for Biochemical Stabilization, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	10	9	8	8	10	4	8	5	8	6		
2	9	9	9	10	8	6	3	2	7	7		
3	8	8	8	8	8	7	7	5	8	7		
4	3	0	3	4	3	8	8	8	1	1		
5	9	10	8	9	10	8	9	8	5	5		
6	4	4	4	4	4	10	7	8	2	4		
7	6	8	8	6	6	8	7	5	6	6		
8	10	8	8	8	10	10	7	8	9	5		
9	8	5	8	8	8	6	7	5	6	6		
10	8	8	5	9	5	8	7	5	6	6		
11	8	8	8	8	8	8	8	5	8	8		
Ave score	7.5	7	7	7.4	7.3	7.5	7.1	5.8	6	5.5		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	72.4	52.5	44.1	54.4	58.2	40.0	64.5	37.8	37.2	34.4	495.6	457.7

Table G.9 Summary of Solar Ponds Kepner-Tregoe Results for Biochemical Stabilization, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	7	9	5	8	7	4	7	5	7	8		
2	9	9	9	10	8	6	3	2	7	7		
3	8	8	8	8	8	7	7	2	8	7		
4	3	0	3	4	3	8	8	8	1	1		
5	8	10	8	9	10	9	9	8	5	5		
6	4	4	4	4	4	10	7	8	2	4		
7	5	8	8	6	6	7	7	5	6	7		
8	10	8	9	8	10	10	7	5	9	9		
9	7	5	8	7	8	8	7	2	7	7		
10	8	8	5	9	5	8	7	5	8	8		
11	8	8	8	8	8	8	8	2	8	8		
Ave score	7.0	7.0	6.8	7.4	7.0	7.7	7.0	4.7	6.2	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	67.2	52.5	43.0	53.8	56.0	41.0	63.7	30.7	38.3	40.0	486.1	455.4

Table G.10 Summary of Solar Ponds Kepner-Tregoe Results for Pressure S/S, OU4 Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	7	8	8	8	8	5	6	5	6	5		
2	8	8	8	8	5	7	2	2	5	8		
3	9	9	9	9	9	8	8	5	8	8		
4	7	6	6	6	6	8	7	8	10	4		
5	6	10	5	5	8	4	3	5	2	2		
6	7	10	4	8	7	7	7	2	5	10		
7	5	8	8	7	8	9	9	5	7	8		
8	6	8	1	4	4	10	3	5	8	4		
9	7	5	8	7	7	8	5	8	7	6		
10	9	10	8	9	6	8	8	8	5	5		
11	7	7	7	7	7	7	7	5	7	7		
Ave score	7.1	8.1	6.5	7.1	6.8	7.4	5.9	5.3	6.4	6.1		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	68.1	60.7	41.2	51.8	54.5	39.0	53.8	34.3	39.4	37.8	480.6	446.3

Table G.11 Summary of Solar Ponds Kepner-Tregoe Results for Pressure S/S, New Cell Burial

Evaluator	Wants Criteria 1	2	3	4	5	6	7	8	9	10	Total score	Total score w/o cost
1	7	8	8	7	8	5	5	5	6	6		
2	8	8	8	8	5	8	3	5	5	7		
3	9	9	9	9	9	8	8	5	8	8		
4	7	8	6	6	6	8	7	8	6	6		
5	7	10	5	6	8	4	3	5	2	2		
6	7	10	7	7	7	8	8	5	5	10		
7	7	8	8	7	8	8	8	8	7	8		
8	9	8	8	7	6	10	4	5	8	5		
9	8	5	8	8	7	6	5	5	6	6		
10	9	10	8	9	6	8	8	5	5	5		
11	7	7	7	7	7	7	7	5	7	7		
Ave score	7.7	8.3	7.4	7.4	7.0	7.3	6.0	5.5	5.9	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	74.2	62.0	47.0	53.8	56.0	38.5	54.6	36.0	36.6	39.4	498.2	462.2

Table G.12 Summary of Solar Ponds Kepner-Tregoe Results for Pressure S/S, Envirocare

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	6	8	8	6	8	4	4	5	7	7		
2	8	8	8	8	5	8	4	5	5	7		
3	9	9	9	9	9	8	8	2	8	8		
4	7	6	6	6	6	8	7	8	6	6		
5	6	10	5	6	8	4	3	5	2	2		
6	7	10	7	7	7	8	8	5	5	10		
7	6	8	6	6	7	7	8	8	7	9		
8	8	8	1	1	2	5	2	5	8	6		
9	7	5	8	7	7	8	5	5	7	7		
10	9	10	8	9	6	8	8	5	8	8		
11	7	7	7	7	7	7	7	2	7	7		
Ave score	7.3	8.1	6.6	6.5	6.5	6.8	5.8	5.0	6.4	7.0		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	69.8	60.7	41.8	47.8	52.4	36.1	52.9	32.5	39.4	43.4	476.9	444.4

Table G.13 Summary of Solar Ponds Kepner-Tregoe Results for Biochemical S/S, OU4 Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	9	9	6	6	7	5	4	2	6	5		
2	9	9	7	7	5	7	4	4	5	4		
3	8	8	8	8	8	7	8	5	8	8		
4	7	10	10	7	6	9	7	8	10	4		
5	8	10	9	9	8	10	10	8	5	5		
6	10	10	4	9	10	7	5	5	10	10		
7	5	9	8	8	5	8	7	5	8	6		
8	8	8	9	8	10	10	5	5	9	5		
9	7	5	6	7	8	8	7	8	5	3		
10	9	10	6	9	7	8	7	8	6	6		
11	6	6	6	6	6	6	6	5	6	6		
Ave score	7.8	8.5	7.2	7.6	7.3	7.7	6.4	5.7	7.1	5.6		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	75.1	64.1	45.2	55.7	58.2	41.0	57.0	37.2	44.0	34.9	513.3	476.1

Table G.14 Summary of Solar Ponds Kepner-Tregoe Results for Biochemcial S/S, New Cell Burial

	Wants Criteria										Total score	Total score w/o cost
Evaluator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	8	8	6	6	7	5	4	2	6	5		
2	9	9	7	7	5	7	5	4	5	4		
3	8	8	8	8	8	7	8	5	8	8		
4	7	8	10	7	6	9	7	8	10	8		
5	9	10	9	9	8	8	9	8	5	5		
6	10	10	9	9	10	8	7	8	10	10		
7	7	9	8	8	5	7	6	5	8	6		
8	10	8	9	10	10	10	6	5	9	6		
9	8	5	6	8	8	6	7	5	6	6		
10	9	10	6	9	7	8	7	5	6	6		
11	6	6	6	6	6	6	6	5	6	6		
Ave score	8.3	8.3	7.6	7.9	7.3	7.4	6.5	5.4	7.2	6.4		
Weighting factor	9.6	7.5	6.3	7.3	8.0	5.3	9.1	6.5	6.2	6.2		
Weighted score	79.4	62.0	48.1	57.7	58.2	39.0	59.6	35.4	44.5	39.4	523.5	488.1