Definition and Compositions of Standard Wastestreams for Evaluation of Buried Waste Integrated Demonstration Treatment Technologies

Steven O. Bates

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**Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415**

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Definition and Compositions of Standard Wastestreams for Evaluation of Buried Waste Integrated Demonstration Treatment Technologies

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Prepared by

S. O. Bates, Scientific Specialist
Buried Waste Integrated Demonstration

22 June 93
Date

Reviewed by

R. K. Farnsworth, Project Manager
Buried Waste Integrated Demonstration

24 June 1993
Date

B. M. Gardner, Project Manager
Buried Waste Integrated Demonstration

6/28/93
Date

Approved by

K. M. Kostelnik, Coordinator
Buried Waste Integrated Demonstration

6/29/93
Date

ABSTRACT

The Buried Waste Integrated Demonstration (BWID) Project was organized at the Idaho National Engineering Laboratory to support research, development, demonstration, testing, and evaluation of emerging technologies that offer promising solutions to remediation of buried waste. BWID will identify emerging technologies, screen them for applicability to the identified needs, select technologies for demonstration, and then evaluate the technologies based on prescribed performance objectives. The technical objective of the project is to establish solutions to Environmental Restoration and Waste Management's technological deficiencies and improve baseline remediation systems.

This report establishes a set of standard wastestream compositions that will be used by BWID to evaluate the emerging technologies. Five wastestreams are proposed that use four types of waste and a nominal case that is a homogenized combination of the four wastes. The five wastestreams will provide data on the compositional extremes and indicate the technologies' effectiveness over the complete range of expected wastestream compositions.

SUMMARY

The mission of the Buried Waste Integrated Demonstration (BWID) at the Idaho National Engineering Laboratory (INEL) is to support the development and demonstration of a suite of technologies that are integrated with commercially-available baseline technologies to form a comprehensive remediation system for effectively and efficiently remediating buried waste that is disposed of throughout the U.S. Department of Energy complex. BWID will evaluate and validate demonstrated technologies and transfer the information and equipment to the INEL's Environmental Restoration and Waste Management Program.

Because of the diverse technologies being evaluated to treat buried waste, it is difficult to make direct comparisons of the technologies' effectiveness. It is critical that standard wastestream compositions are established so that the performance of the technologies can be compared, and input can be provided to the Remedial Investigation/Feasibility Study process. Standardizing wastestream compositions will provide a common basis to evaluate and compare the different technologies. These standard compositions will also be used to evaluate pretreatment technologies.

Wastes are placed into four types; contaminated soil, metals, combustibles, and various sludge wastes. The following five wastestreams are the standards proposed for technology evaluation:

- Soil only—typical INEL Subsurface Disposal Area (SDA) soil made up of silty clays and sand
- High-metal content waste—INEL SDA soil with ≥ 15 wt% of various steels, aluminum, lead, and zirconium alloys
- High-combustible content waste—INEL SDA soil with ≥ 10 wt% of various paper, plastic, wood, and other miscellaneous combustibles
- Sludge wastes—Rocky Flats Plant 74 series sludges including hydrated oxides, organics on calcium silicate, and nitrates salts
- Nominal content waste—a combination of the above streams.

The five standard wastestreams cover four types of wastes and a nominal case that is a combination of the four wastes, as if the waste site had been homogenized. The five standard wastestreams provide data at the extremes of the compositional envelope and centroid composition (i.e., nominal composition). These data indicate the effectiveness of the technology over the complete range of expected wastestream compositions.

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ACRONYMS

BWID	Buried Waste Integrated Demonstration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U. S. Department of Energy
EDTA	Ethylenediaminetetraacetic acid
ER&WM	Environmental Restoration and Waste Management Program
GTCC	Greater-than-Class C
INEL	Idaho National Engineering Laboratory
LLW	Low-level radioactive waste
MWIP	Mixed Waste Integrated Program
RCRA	Resource Conservation and Recovery Act
RDDT&E	Research and development demonstration, testing, and evaluation
RFP	Rocky Flats Plant
RI/FS	Remedial Investigation/Feasibility Study
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
SDA	Subsurface Disposal Area
TRU	Transuranic
TSA	Transuranic Storage Area

Definition and Compositions of Standard Wastestreams for Evaluation of Buried Waste Integrated Demonstration Treatment Technologies

1. INTRODUCTION

The Buried Waste Integrated Demonstration (BWID) Project was organized at the Idaho National Engineering Laboratory (INEL) to support research and development demonstration, testing, and evaluation (RDDT&E) of emerging technologies that offer promising solutions to problems associated with the environmental restoration of buried waste. The BWID Project addresses difficult remediation problems associated with U. S. Department of Energy (DOE) complex-wide buried waste with particular focus on transuranic (TRU)-contaminated buried waste.

BWID's mission is to support the development and demonstration of a suite of technologies that are integrated with commercially-available baseline technologies to form a comprehensive remediation system for effectively and efficiently remediating buried waste sites throughout the DOE complex. BWID will evaluate and validate demonstrated technologies and transfer the information and equipment to the Environmental Restoration and Waste Management (ER&WM) Program to support remediation planning and implementation.

The goal of BWID is to determine the threshold of capability for emerging technologies. Technologies will be identified, screened for applicability to the identified needs and requirements of ER&WM, selected for demonstration, and evaluated based on prescribed performance objectives. This effort will determine implementability, effectiveness, potential schedule reduction, and potential cost savings of emerging technologies that will shape remediation plans and implementation of the environmental restoration of buried waste.

BWID's technical objective for the program is to solve identified ER&WM technological deficiencies and improve baseline remediation systems. Technologies that can potentially apply to buried waste remediation will be investigated to support the Remedial Investigation/Feasibility Study (RI/FS) process in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) evaluation criteria.

Because of the variety of buried waste treatment technologies being evaluated, it is difficult to make direct comparisons of the technologies' effectiveness. It is critical that standard wastestream compositions be established so that the performance of the technologies can be compared, and the input can be provided to the RI/FS process. This will provide a common basis to evaluate and compare the different technologies. These standard compositions will also be used to evaluate pretreatment technologies.

1.1 Purpose

This document establishes a set of standard wastestream compositions that will be used by BWID to evaluate emerging technologies so that

- Performance of different treatment technologies has a common basis for equitable comparison (apples with apples, not apples and oranges)
- Wastestreams are chosen that will closely match the needs of the greatest number of ER&WM activities at DOE sites
- Output from pretreatment technologies is used by primary treatment technologies to allow for system evaluations
- Workload on treatment technology investigators is reduced by having standard wastestream compositions already in place.

1.2 Scope

This document stresses nonradioactive, simulated standard wastestream compositions. However, nonradioactive surrogates will be used to provide some indication of the radionuclide's performance. Nonradioactive, simulated wastestreams must be used for demonstration and evaluation because of waste minimization requirements and the high cost and difficulty of testing radioactive materials. The total amounts of radioactive contaminants in the actual wastes are generally too small to have significant impact on the bulk processing of the waste. In addition, the makeup of radioactive wastestreams in radioactive testing will depend on the scale of the demonstration and the site where the evaluation will take place. Ultimately, waste form evaluation will still require confirmation using radioactive components, but this could be confirmed using laboratory scale testing.

The hazardous components in the waste should be included if possible. However, it is understood that many sites may not have this capability because of permitting and containment equipment. Surrogates can be used in lieu of actual hazardous waste components if suitable surrogates exist. The surrogates suggested for the radioactive and hazardous components will be addressed in a later section of this report.

The standard wastestreams should be used in all pretreatment, primary treatment, and secondary waste treatment technology demonstrations. Not only will this provide a common basis for evaluation, but the output streams from one step in the treatment process could be used in the next step (i.e., the output stream from a pretreatment step could be used in a primary treatment demonstration). Use of the standard wastestreams will allow for broader system demonstrations that provide more prototypical data. The cost would also be reduced because the input standard wastestream would already be available.

The standard wastestreams should not be viewed as restrictive or inflexible. There must be enough flexibility in the standard wastestreams to push the technologies' processing and waste form envelopes. For example, the high-metal content wastestream has a ratio of 15 wt% metal/85 wt% soil. A demonstration may determine the limits of the technology and extend the metal content to a higher ratio, such as 50 wt% metal/50 wt% soil or higher. Flexibility will also allow for test equipment and/or permitting limitations (i.e., equipment size, run of nonhazardous materials only, or feed system limitations). Because the composition of the buried wastestreams is similar to stored wastestreams (minus the soil), in some cases, the standard wastestream could be modified to include stored waste compositions and provide for a data base with broader applicability.

1.3 Assumption

The composition of buried waste will vary from one disposal site to another depending on the source waste and method of disposal. However, the major types of wastestreams throughout the DOE complex are similar. It is assumed that Pit 9 of the SDA at the INEL's Radioactive Waste Management Complex (RWMC) is typical of these wastestreams, so it will be used as the basis for the standard wastestreams. Pit 9 is a typical wastestream because of the types of wastes and associated packaging (e.g., boxes and drums) contained within the pit.^a Pit 9 was chosen because of its relatively high degree of characterization and proximity to other major BWID demonstrations. Details of Pit 9 are found in Section 2.

Because the wastes buried in Pit 9 are from the Rocky Flats Plant (RFP), and the general process has changed little from the time the waste was buried, the Pit 9 wastestreams are similar to those to be evaluated in the Mixed Waste Integrated Program (MWIP). The exception is the soil associated with the buried waste. However, most sites would also have some contaminated soils.

a. D. A. Arrenholz and J. L. Knight, *Historical Report of Transuranic Waste Pits and Trenches at the Subsurface Disposal Area on the Radioactive Waste Management Complex at the INEL*, EG&G Idaho, Inc., WTD-91-027, August 1991.

2. BACKGROUND

As of 1990, the amount of buried waste located throughout the DOE complex is estimated at approximately 2.1 million m³.¹ The DOE facilities where most of these wastes are located are the Hanford Site, Savannah River Site, INEL, Los Alamos National Laboratory, Oak Ridge National Laboratory (X-10), and RFP. The wastes at these various sites have been buried or stored in several types of structures, such as trenches, pits, buildings, and storage pads. Waste disposal activities at DOE sites were conducted according to the applicable regulations and laws and the accepted engineering practices at the time.

Approximately half of all DOE buried waste was disposed of before 1970. Disposal regulations at that time permitted the commingling of various types of waste [i.e., TRU, low-level radioactive waste (LLW), and hazardous]. As a result, much of the buried waste throughout the DOE complex is presently believed to be contaminated with both hazardous and radioactive materials. DOE buried wastes typically include TRU-contaminated radioactive waste, LLW, hazardous waste (per 40 CFR 261), greater-than-Class-C (GTCC) waste (per 10 CFR 61.55), mixed TRU waste, and mixed LLW. Interstitial soils (and possibly underburden soils) are also believed to be contaminated as a result of leakage of the buried waste packages. This associated soil significantly increases the volume of materials requiring remediation.

Typical buried waste includes construction and demolition materials (lumber, concrete blocks, and steel plates), laboratory equipment (hoods, desks, tubing, and glassware), process equipment (heat exchanger, valves, ion exchange resins, and high-efficiency particulate air filters), maintenance equipment (hand tools, cranes, oils, and greases), decontamination materials (paper, rags, and plastic bags), and process wastes (salts and sludges).

A variety of containers were used for the disposal of buried waste. At the INEL, containers used for waste shipment include steel drums (30, 40, and 55-gal), cardboard cartons, and wooden boxes (up to 105 × 105 × 214 in.). Larger individual items were disposed of separately as loose trash. Degradation of the waste containers is believed to have contaminated the immediately surrounding soil. Estimates of contaminated soils are in the order of 2.27×10^5 m³ (8×10^6 ft³). The waste and site characteristics of the RWMC are generally representative of other DOE buried waste sites. Therefore, remediation technology demonstrations performed at the INEL should be transferable for potential applications at other DOE buried waste sites.

From 1952 until 1970, TRU and LLW generated at the RFP, INEL, and elsewhere were sent to the INEL for burial in a series of pits and trenches located in the RWMC SDA. Since the baseline of the BWID investigations is the treatment of buried TRU waste, this report concentrates on the TRU wastes generated at the RFP and buried in the SDA from 1954 until 1970 in trenches 1 to 10 and pits 1 to 6 and 9 and 10.

An estimated 2.67 million ft³ of TRU and LLW are buried in the RWMC SDA trenches and pits, of which about 2.02 million ft³ are TRU waste from the RFP. The remaining waste is low-level beta/gamma waste, with the majority generated by various INEL facilities operating when the pits and trenches were used as disposal areas. The breakdown for the estimated waste volumes is presented in Table 1.²

Table 1. Estimated waste volumes in TRU-containing SDA areas.

Waste type ^a	Location	Volume	
		(m ³)	(ft ³)
TRU	Pits 1-6, 9, and 10	49,089	1,733,334
TRU	Trenches 1-10	4,011	141,628
TRU	Break in computer data, 1958-1959	4,142	146,254
LLW	Pit 1 ^b	1,314	46,397
LLW	Pits 2-6, 9, and 10	13,094	462,349
LLW	Trenches 1-10	3,964	139,969
Total		75,614	2,669,931

a. Excludes retrieved wastes.

b. No computer or burial records available. An efficiency factor of 27% of the excavated volume was used to calculate these figures.

Waste containers (primarily steel drums and wooden and cardboard boxes) were stacked to optimize disposal space from 1952 to 1963. From 1963 to 1969, waste containers were randomly dumped into the pits to minimize personnel radiation exposure. The stacking procedure was reinstituted in 1969 to optimize disposal space. When full, the pits and trenches were backfilled and covered with a minimum of 3 ft of silty clay soil (i.e., overburden).³ TRU waste from the RFP was generally commingled with LLW (primarily from the INEL) in trenches 1 to 10 through late 1957. At that time, waste burial was shifted to pits, and the INEL LLW and RFP TRU waste was generally segregated, although both types were often located in the same pit.⁴ Currently, pit and soil vault disposal at the SDA is limited to LLW only; trenches are no longer used for waste disposal.

Beginning in November 1970, the policy of burying TRU waste belowground was discontinued, and the RWMC Transuranic Storage Area (TSA) was established for the aboveground storage of TRU waste. Approximately 60,000 m³ (2.1 million ft³) of TRU waste are stored at the RWMC TSA. The majority of the waste stored at the TSA was generated by the RFP. Other contributors were Mound Laboratory, Miamisburg, Ohio; Battelle Columbus Laboratories, Columbus, Ohio; Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania; Argonne National Laboratory-East, Argonne, Illinois; and INEL operations.

2.1 Pit 9 Waste Characterization Data

Pit 9 is located in the northwest corner of the SDA and is the best characterized of the pits and trenches in the SDA. Pit 9 has also been selected as the location for the DOE Environmental Restoration comprehensive demonstration that will use currently available technologies to retrieve and treat the buried waste⁵ and will establish a baseline for comparing treatment technologies. For these reasons, Pit 9 will be used as the basis for establishing the compositions of the BWID standard wastestreams. While the Pit 9 waste composition may not be identical to all other buried waste sites nationwide, the compositions should be similar enough to evaluate most issues associated with buried waste processing.

Based upon the available shipping records and information contained within the Radioactive Waste Management Information System (RWMIS), the waste buried in Pit 9 is primarily RFP-generated TRU waste with some LLW from generators located at the INEL. Radioactive waste was buried in Pit 9 from November 1967 to June 1969, and containers of TRU waste from the RFP were buried from February 1968 to September 1968. A total of approximately 4250 m³ (150,000 ft³) of waste is buried within the pit, of which approximately 3115 m³ (110,000 ft³) are TRU waste from the RFP. It is estimated that the total metal content of the TRU and LLW buried in Pit 9 was approximately 664,300 kg with the following breakdown: 427,000 kg carbon steel; 217,000 kg stainless steel; 2,300 kg aluminum; 3,000 kg lead; and 15,000 kg zirconium and zirconium alloy. It was also estimated that approximately 315,000 kg of combustibles (e.g., wooden boxes, paper, wood scraps, rags, rubber, plastic, graphite, asphalt, and oil) were contained in the buried wastes from the RFP and the INEL.⁶ Table 2 provides a detailed listing of the waste types contained in Pit 9 and waste generators.

As shown in Table 2, the TRU waste from RFP consists primarily of 74 series sludges (i.e., 2,106 drums of content code 002, =460,000 kg), assorted solid waste (i.e., 1,512 drums of content code 003 consisting of paper, metal, wood, plastic, glass, rubber, and miscellaneous material), and cardboard boxes containing empty drums (i.e., 1,471 drums/boxes of content code 093). The large quantities of metals and combustibles present in content codes 003 and 093, as well as in other INEL-generated LLW, provides the basis for selecting a mixed metals content waste and combustible solids content waste as two of the standard wastestreams. The single largest TRU waste form present in Pit 9 consists of the 74 series sludges, which are described in a Section 3.4, Sludge Waste.

Table 2. Pit 9 waste breakdown.

Code description	Generator ^a							
	RFP	TAN	TRA	NRF	CPP	CFA	PER	ANL
002 74 Series sludge	2,106 BLM ^b	—	—	—	—	—	—	—
003 Paper, metal, wood	1,512 BLM	—	13 BXC ^c	17 BXC	11 BXC	—	8 BXC	68 BXC
004 Graphite, paper	303 BLM	—	—	—	—	—	—	—
006 Concrete, masonry	—	—	—	137 ft ³	25 BXC	—	—	—
007 Rad waste, not otherwise specified	—	—	405 ft ³	33 BXC	—	—	—	—
008 Combustibles	—	—	36 BXC	85 BXC	17 BXC	3 BXC	—	—
010 Metal scrap	—	—	120 ft ³	25 BXC 1,278 ft ³	11 BXC 450 ft ³	—	—	—
024 Pipe	—	—	1,328 ft ³	—	—	—	—	—
026 Wood scrap	96 BXW ^d	—	—	550 ft ³	—	—	—	—
027 Metal components	—	11,881 ft ³	43 BXC 128 ft ³	1,338 ft ³	—	90 ft ³	—	—
028 Unirradiated fuel	—	—	—	—	—	—	5 BXC	—
030 Stainless steel, aluminum	—	—	—	840 ft ³	—	—	—	—
031 Dirt	—	—	—	164 ft ³	576 ft ³	—	—	—
032 Lead	—	—	20 ft ³	—	—	30 ft ³	—	—
035 Chemical Warfare Service filters	66 BXC	—	—	—	—	—	—	—
040 Zirconium	—	—	—	—	415 ft ³	—	—	—
043 Filters	1 BXW	—	—	—	—	—	—	—
053 Oil	—	—	—	9 BLM	—	—	—	—
064 Asphalt, gravel	—	—	102 ft ³	—	—	—	—	—
066 Paper, equipment	423 BXW	—	—	—	—	—	—	—
088 Equipment, scrap metal	3 BXW	133 ft ³	500 ft ³	—	—	—	—	—
089 Sand	—	480 ft ³	—	—	—	—	—	—
093 Empty drums	1,471 BLM/BXC ^e	—	—	—	—	—	—	—

a. TAN—Test Area North (INEL); TRA—Test Reactor Area (INEL); NRF—Nuclear Reactor Facility (INEL); CPP—Chemical Processing Plant (INEL); CFA—Central Facilities Area (INEL); PER—Power Excursion Reactor (INEL); ANL—Argonne National Laboratory-West (INEL).

b. BLM—barrel, metal. Fifty-four drums of code 002 have been subtracted from the RWMIS data and added to code 093 based on comparisons with shipping records.

c. BXC—box, cardboard.

d. BXW—box, wooden.

e. Codes 092, 019, and 54 containers of code 002 have been added to the code 093 total based on corrections to be made to the RWMIS from comparisons with shipping records.

3. STANDARD WASTESTREAM COMPOSITIONS

The composition of buried waste throughout the DOE complex will vary significantly because of the waste types buried, configuration in which the waste was disposed (stacked versus random dump drums), physical form of the waste (large objects or pieces versus liquids on sorbents), and disposal depth. There are four waste types: contaminated soil, metals, combustibles, and various sludge wastes. To evaluate a treatment technology, examples of each of these wastestreams should be considered. The following five wastestreams are the standards proposed for technology evaluation.

- Soil only—typical INEL SDA soil made up of silty clays and sand
- High-metal content waste—INEL SDA soil with ≥ 15 wt% of various steels, aluminum, lead, and zirconium alloys
- High-combustible content waste—INEL SDA soil with ≥ 10 wt% of various paper, plastic, wood, and other miscellaneous combustibles
- Sludge wastes—RFP 74 series sludges including hydrated oxides, organics on calcium silicate, and nitrates salts
- Nominal content waste—a combination of the above streams to evaluate interactions.

The five standard wastestreams cover four types of wastes and a nominal case that is a homogenized combination of the four wastes (in this proposed case, Pit 9). These five standard wastestreams provide data at the extremes of the compositional envelope and a centroid composition (the nominal composition). These data provide an indication of the technology effectiveness over the complete range of expected wastestream compositions.

The physical form of each of these wastestreams depends on the methods used to retrieve the waste and soil from the pits or trenches. Pretreatment such as sorting, sizing, or incineration will also effect the physical (and possibly the chemical) form of the wastes. Because these standard wastestreams will be used for pretreatment and primary treatment demonstrations, the physical form may need modifications to be representative. The physical disposal form of each standard wastestream will be the starting point in evaluating the form to be used in the demonstrations.

3.1 Soil

Retrieval of limited parts of the SDA found a large number of breached containers.⁷ Because of the length of time the containers have been buried, it is anticipated that most of the waste containers will have deteriorated and/or been breached. It is assumed the soil interstitial to the waste and below the waste will be contaminated because of the decomposition and leaching of waste into the surrounding soil. The overburden (i.e., soil placed on top of the waste) may also be contaminated. In some areas of the SDA, such as the acid pit, waste was disposed of directly into the soil.

For example, the Pit 9 contaminated soil is the largest of all the wastestreams that may be treated. In Pit 9 there are approximately 7080 m³ (250,000 ft³) of overburden soil, 4250 m³ (150,000 ft³) of packaged waste, and 9910 m³ (350,000 ft³) of interstitial soil and underburden.⁸ Assuming a 1.86 bulk density for the soil,⁹ the mass of interstitial and underburden soil is approximately 1.84×10^7 kg compared to approximately 9.79×10^5 kg of actual disposed packaged waste (approximately a 19:1 soil to waste ratio).¹⁰ Assuming that the overburden soil is clean, the soil still could be over 50% by volume and over 90% by mass of the contaminated material that may need to be treated. This shows the importance of this standard wastestream in the evaluation of treatment technologies.

During demonstration, INEL SDA soil should be used. The INEL SDA soil is made up of silty clays and sand. Typical physical properties for soil and sediment at the SDA are provided in Table 3.¹¹ For some laboratory scale testing or modeling, the nominal composition of the soil, as oxides, is provided in Table 4.

The physical form of the soil is expected to be loose dirt that is placed in large boxes during retrieval. These boxes are used only for transport to the treatment facility.

3.2 High-Metal Content Standard Wastestream

The second standard wastestream is a high-metal content waste. Fifteen waste types (i.e., 15 content codes) are present in Pit 9 with varying amounts and types of metals. The metal is present in the form of drums (both empty and containing waste), scrap metal, tools, pipe, discarded equipment and components, and atypical wastes such as steel vaults, pickup beds, reactors, and shipping casks. It is assumed that large, atypical metal structures will be sized before treatment. Table 5 shows an estimate of the quantities of metals contained in the TRU and LLW buried in Pit 9.

Clements and Kudera reported the results of actual visual examinations of drums of RFP TRU metal waste stored at the RWMC.¹² The Clements and Kudera data are likely more representative of containerized metal waste buried/stored later at the RWMC than specifically for Pit 9. Clements and Kudera examined 29 drums of metal waste (content codes 320, 480, and 481) that had been in storage for periods from 6 months to 12 years. The major differences between the Pit 9 estimate and the later stored waste evaluation are higher percentages of both aluminum and copper. To allow for a more general standard wastestream, the Pit 9 metals composition was modified to increase the percentage of these two metals. This metals composition for the high-metal standard wastestream is presented in Table 6.

Table 3. Typical INEL soil properties.

Specific gravity	2.66
Bulk density	1.86 g/cm ³
Porosity	35.3%
Moisture content	14.2%
Vertical hydraulic conductivity	2.9×10^{-3} m/day

Table 4. Summary of oxide composition of SDA soil.

Oxide	Wt% oxide
Al_2O_3	13.20
Fe_2O_3	4.70
CaO	4.11
K_2O	3.34
MgO	1.92
Na_2O	1.50
TiO_2	0.76
MnO_2	0.11
BaO	0.10
ZrO_2	0.10
B_2O_3	0.06
NiO	0.04
Cr_2O_3	0.02
SrO	0.02
Total	99.92

Table 5. Estimated metals in Pit 9.

Metal	Mass (kg)	Weight (%)
Carbon steel	427,000	64.3
Stainless steel	217,000	32.7
Aluminum	2,300	0.3
Lead	3,000	0.4
Zirconium and zirconium alloys	15,000	2.3
Total	664,300	100.0

Table 6. Metal composition for BWID standard wastestream.

Metal	Weight (%)	
	Hazardous	Nonhazardous
Carbon steel	60.0	60.5
Stainless steel	30.5	30.5
Aluminum	5.0	5.0
Zirconium and zirconium alloys	2.5	2.5
Copper	1.5	1.5
Lead	0.5	0.0
Total	100.0	100.0

As indicated before, some soil will be associated with the wastestreams. The average weight percent metal for Pit 9 is estimated at 4.0 wt%. For other pit and trenches in the SDA, the average mass of metal ranged from 1.7 to 11.6 wt%.^b To allow for some error, the standard wastestream for high-metal content will contain 15 wt% metal and 85 wt% soil. However, if this amount of metal would not push the technologies being evaluated, higher concentrations of metal, such as 50 wt% metal, 50% soil, maybe used.

3.3 High-Combustible Solid Waste

The third type of wastestream to be identified as a standard wastestream is a high-combustible solid waste. An estimated 315,000 kg (694,000 lb) of combustible wastes were buried in Pit 9. These solid combustible wastes are from 12 different waste forms/content codes, principally comprised of cardboard, wood boxes, wood scrap, paper, rags, rubber, plastic, asphalt, and oil.¹³ Of the 315,000 kg of combustibles, 115,000 kg are wooden boxes. The remaining 200,000 kg are buried in containers with other materials, and the exact composition of combustibles is unknown.

Data presented in the Clements and Kudera report will again be used to estimate the combustible waste compositions because the combustible wastes in storage should still be fairly representative of similar wastes buried in the SDA. Forty drums of combustible TRU waste generated at the RFP (content codes 328, 330, 336, 337, 900, and 970) and stored at the RWMC for periods from 6 months to 12 years were examined and characterized.¹⁴ The resulting simulated waste compositions (except for the wooden boxes) were derived from averaging all data gathered during the examination of the 40 individual waste drums and revising the calculated weight percents by omitting minor and hazardous components (i.e., glass, steel, lead, leaded rubber, cemented resins,

b. E. C. Garcia, S. M. Thurmond, and J. Knight. "Estimate of Metal Content of SDA," BWP-ISV-006, Rev. 0, EG&G Idaho, Inc., January 1989.

salts, and concrete).¹⁵ The results were added to the wooden boxes to produce the standard wastestream for high combustibles shown in Table 7.

The high-combustible wastestream will need to have soil added to be representative and to produce a viable final waste form. The combustibles comprise about 2 wt% of the mass of the interstitial and underburden soil. To allow for some error, the standard wastestream for high-combustible content will contain 10 wt% combustibles (see Table 7) and 90 wt% soil. However, if this amount of solid combustibles does not push the technologies being evaluated, higher concentrations of combustibles maybe used (such at 50 wt% combustible and 50% soil). If the combustible stream is to be treated separately (for example using incineration), a 100 wt% combustibles level would be used.

3.4 Sludge Waste

The 74 series sludge waste is the largest single type of waste disposed of in Pit 9. The 74 series of sludges is comprised of five types of sludge: 741, 742, 743, 744, and 745. Each of these will be addressed below. Shipping records indicate that 2,106 55-gal drums of 74 series sludge were buried in Pit 9, but the records do not identify the types of 74 series sludge in each drum. An estimate of the number of each type was made using the relative percentages of 74 series sludges generated and shipped from the RFP.¹⁶ This estimate is presented in Table 8. The 741 and 742 sludges are similar¹⁷ and will be treated as a single standard wastestream. The 744 sludge is a relatively small component compared to the other sludges and will not be used as a standard wastestream. However, the details of the 744 sludge will be presented so that potential problems with the sludge can be identified and testing conducted if needed. Because of the difference in the makeup of remaining sludges, each of these will be presented as a separate standard wastestream.

Table 7. Composition of solid combustible fraction (10 wt% with 90 wt% soil) of BWID standard wastestream for combustible solids.

Material	Mass (kg)			Weight (%)
	Waste	Wooden boxes	Total	
Plastic (polyethylene)	70,000	—	70,000	22
Paper	40,000	—	40,000	13
Wood	30,000	115,000	145,000	46
Rubber	30,000	—	30,000	10
Sorbent	20,000	—	20,000	6
Cloth	10,000	—	10,000	3
Total	200,000	115,000	315,000	100

Table 8. Summary of 74 series sludges estimated to be in Pit 9.

Code 74	Series sludge	Number of drums	Percent
Prefix description			
741	First stage	232	11
742	Second stage	337	16
743	Organic setups	969	46
744	Special setups	84	4
745	Evaporator salts	484	23
Total		2,106	100

3.4.1 Series 741 and 742 Sludges—Hydrated Oxides

Series 741 and 742 sludges, first stage and second stage water treatment sludges respectively, will be treated as a single standard wastestream because the 741 and 742 sludges are similar chemically. Together these sludges represent the second largest quantity of sludge buried/stored drums (i.e., 27%). Both 741 and 742 sludges are described as being generated from treating aqueous process wastes. The 741 sludge is a wet sludge produced from treating aqueous process wastes such as ion-exchange column effluent, distillates, and caustic scrub solutions; whereas, the wet 742 sludge was produced from treatment of all other radioactively and/or chemically contaminated aqueous plant wastes and further treatment of the first-stage effluent. During both treatment processes, the aqueous wastes are (a) made basic, if necessary, with sodium hydroxide; (b) treated with chemicals including ferric sulfate, calcium chloride, magnesium sulfate, and flocculating agents to precipitate radioactive elements; and (c) filtered out of the precipitated hydrated oxides of iron, magnesium, aluminum, silicon, plutonium, and americium. The filtered, hydrated metal oxides constitute the 741 and 742 sludges and contain 50 to 70 wt% water. The sludges were packaged into 55-gal drums in two layers of plastic bags with 40 to 50 lbs of dry Portland cement added around the bags to ensure absorption of any free liquids.¹⁸

The standard wastestream simulation of the 741/742 sludge can be seen in Table 9. The Clements and Kudera data on the examinations of the 20 drums of 741/742 sludge yield an average net weight of 386 lbs per drum.¹⁹ An average of 45 lbs per drum of Portland cement is assumed to produce an estimated 11.6% of Portland cement, 44.2% of metal hydroxides, and 44.2% of water.

3.4.2 Series 743 Sludge—Organics on Calcium Silicate

The 743 sludge results from organic wastes processed in grease plant operations. It typically consists of a mixture of oils, solvents, and miscellaneous organics. The 743 sludge is described as an organic setup produced from blending approximately 30 gal of organic wastes with 100 lbs of calcium

Table 9. Composition of standard wastestream 741 and 742 sludge.

Material	Weight (%)
Metal hydroxides—subtotal	44.2
Al(OH) ₃	11.5
Ca(OH) ₂	6.6
Fe(OH) ₃	10.8
KOH	7.4
Mg(OH) ₂	7.9
Portland cement	11.6
Water	44.2
Total	100

silicate (actually a Manville product called MICROCEL E). About 10 to 20 lbs of Oil-Dry absorbent was added to the top and bottom of the drum. The organic waste liquid was described as consisting of 47% (by volume) lathe coolant (60% Texaco Regal Oil and 40% carbon tetrachloride), 10% trichloroethane degreaser, and 43% miscellaneous organics (trichloroethylene, tetrachloroethylene, hydraulic oil, gearbox oil, spindle oil, Freon, Varsol, etc.).²⁰ The nonhazardous and hazardous standard wastestream compositions for the 743 sludge are provided in Table 10.

3.4.3 Series 744 Sludge—Special Setups

The 744 series sludge represents a relatively small percentage of the 74 series RFP sludges. The 744 sludge is from special setups and is difficult (if not impossible) to characterize from available records. Because of its relatively small percentage of the total waste and the uncertain composition, no standard wastestream will be prepared, and no testing is required. For background, the following is a general description of the 744 waste.

Series 744 sludge resulted from treating liquid wastes that were not compatible with the 741 and 742 aqueous waste treatment processes because of the plutonium complexing nature of these 744 liquid wastes. The complexing chemicals included some alcohols, organic acids, and Versenes [trade name for chelating agents containing ethylenediaminetetraacetic acid (EDTA)]. These complexing liquid wastes were absorbed in a cement mixture composed of approximately 190 lbs of Portland cement and 50 lbs of pipe insulation cement, such as magnesia cement. The cements were placed in a prepared 55-gal drum; the drum was then placed on a drum roller and rolled to ensure mixing of the cements. All liquid wastes were made basic before added to the cement mixture. Approximately 26.4 gal of the liquid waste were then poured on the cement mixture and allowed to solidify before adding 10 to 15 lbs of Portland cement as a cap on top of the cemented liquid

Table 10. Hazardous and nonhazardous composition of standard wastestream for 743 sludge.

Waste component	Volume (%)	
	Nonhazardous	Hazardous
Texaco regal oil	50	30
Hydraulic oil	40	35
Wheel bearing grease	10	5
CCL ₄		20
C ₂ H ₃ Cl ₃		10
Calcium silicate	100 lbs /30 gal of waste oils	100 lbs /30 gal of waste oils
Oil-Dry	10 to 20 lbs per drum	10 to 20 lbs per drum

waste.²¹ Clements and Kudera visually examined 10 drums of 744 sludge that had been stored for periods from 6 months to 12 years and found that each 55-gal drum contained an average of 490 lbs. of cemented sludge waste.²²

3.4.4 Series 745 Sludge—Nitrate Salts

Series 745 sludge consists of a salt residue generated by concentrating and drying liquid waste from the solar evaporation ponds at the RFP. Liquid effluent from the second-stage aqueous waste treatment process and all other plant-generated liquid wastes not requiring treatment were concentrated by evaporation in these solar ponds. The concentrated liquid waste was then pumped from the ponds to an evaporator, where it was further concentrated and dried. This formed a salt residue estimated to consist of 60% sodium nitrate, 30% potassium nitrate, and 10% miscellaneous material. The remaining 10% is estimated to be comprised of chlorides, sulfates, and hydroxides with the same ratio (60/30) of sodium and potassium found in the nitrates salts.²³ Because of the similar chemistry of sodium and potassium and to simplify the makeup of the standard wastestream, the 10% miscellaneous material is simulated as sodium salts only. During packaging, Portland cement was added to damp or wet salt, when necessary.²⁴ The composition for this standard wastestream is shown in Table 11.

3.5 Nominal Composition

The purpose of the nominal composition is to provide a standard wastestream that contains all the waste components found in the buried waste so that interactions occurring between the components during the treatment process can be evaluated. The nominal standard wastestream also provides a centroid composition compared to the extreme points of only processing one waste type

Table 11. Composition of standard wastestream for 745 series sludge.

Material	Weight (%)
NaNO ₃	60
KNO ₃	30
NaCl	3.4
NaSO ₄	3.3
NaOH	3.3

at a time. Based upon estimates of total waste volume to contaminated soil volume in the TRU-containing pits and trenches within the SDA, it is likely that the weight percent of soil to be processed will greatly exceed that of the waste from breached containers. However, since a soil only standard wastestream is already listed, the nominal content standard wastestream will have heavier weight fractions of the other standard wastestreams to allow for a heavy off-set from the nominal and provide a broader range of data. The metal standard wastestream was arbitrarily set at 60 wt% soil, 15 wt% each of the mixed metals waste and 741/742 sludge, and 10 wt% combustible solids waste. The composition of the nominal content waste is shown in Table 12.

Table 12. Composition of nominal standard wastestream.

BWID standard wastestream	Weight (%)
Soil	60
Metal	15
Solid combustibles	10
74 series sludge—subtotal	15
741 and 742	4
743	9
745	2
Total	100

4. RADIONUCLIDE, HAZARDOUS VERSUS SURROGATES

Because of the difficulty, secondary waste, and cost associated with conducting demonstrations with radioactive materials, it is anticipated that most demonstrations will be conducted using nonradioactive materials with surrogates to estimate radionuclide behavior. This will also help to minimize waste generated during demonstration. The radionuclide content of Pit 9 is presented in Table 13.²⁵ The radionuclides with the greatest mass and curie content are uranium, plutonium, and americium. While there are no perfect surrogates for these radionuclides, cerium is generally the most conservative.^c Other less conservative surrogates of plutonium, in the degree of similarity to plutonium are neodymium > lanthanum > praseodymium > gadolinium > ytterbium > dysprosium > erbium > europium > terbium > lutetium > samarium.²⁶ It is recommended that all testing be conducted with a surrogate that will have detectible levels in the waste form. For general testing, cerium is the recommended surrogate. Approximately 0.5 wt% as Ce_2O_3 should provide an adequate level of surrogate.

As with the radionuclides, there is also significant difficulty and cost associated with using hazardous materials in demonstrations. If possible, the actual hazardous components should be used. If not used, surrogate use is preferred if a viable substitute exists. However, before using hazardous waste components, secondary waste generation and disposal issues should be taken into account and balanced against the technical need to use hazardous components. Summaries of the hazardous waste components estimated to be in Pit 9 are presented in Tables 14 and 15. Because of the wide variation of hazardous components, no specific surrogates will be recommended. However, the surrogates should be identified and justified in test planning.

c. Conservative or less conservative refers to the degree that the replacement chemical simulates the behavior of the original compound. A conservative surrogate best simulates the properties of the original compound.

Table 15. Typical summary of hazardous organics in TRU pits and trenches.

Component	Volume (gal)	Volume (m ³)
Texaco Regal Oil	5,875	22.24
CCL	3,677	13.92
Used oil (50%)	2,378	9.00
Alcohols	1,287	4.87
Organic acids	1,287	4.87
Versene (EDTA)	1,287	4.87
Ether	838	3.17
1,1,1-trichloromethane	753	2.85
Trichloroethylene	565	2.14
Perchloroethylene	565	2.14
Gasoline	163	0.62
Ethylene glycol	49	0.19
Polychlorinated biphenyls	0.10	0
Total	18,724	70.87

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