Case Study of Anomalies Encountered During Remediation of Mixed Low-Level Waste Burial Grounds in the 100 and 300 Areas of the Hanford Site

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ABSTRACT

Under the U.S. Department of Energy's River Corridor Closure Project, Washington Closure Hanford has completed remediation of more than 10 mixed low-level waste burial grounds in the 100 and 300 Areas of the Hanford Site. The records of decision for the burial grounds required excavation, characterization, and transport of contaminated material to a *Resource Conservation and Recovery Act of 1976*-compliant hazardous waste landfill. This paper discusses a sample of the anomalous waste found during remediation and provides an overview of the waste excavation activities. The 100 Area burial grounds received plutonium production reactor waste and waste associated with various test programs. Examples of 100 Area anomalies include spent nuclear fuel, elemental mercury, reactor hardware, and the remains of animals used in testing the effects of radionuclides on living organisms. The 300 Area burial grounds received waste from research and development laboratories and fuel manufacturing operations. Of the seven 300 Area burial grounds remediated to date, the most challenging has been the 618-2 Burial Ground. It presented significant challenges because of the potential for airborne alpha contamination and the discovery of plutonium in an isotopically pure form. Anomalies encountered in the 618-2 Burial Ground included a combination safe that contained gram quantities of plutonium, miscellaneous containers of unknown liquids, and numerous types of shielded shipping casks. Information presented in this paper will be an aid to those involved in remediation activities throughout the U.S. Department of Energy complex and at other nuclear waste disposal sites.

INTRODUCTION

Washington Closure Hanford (WCH) is a limited liability corporation owned by Washington Group International, Bechtel National, and CH2M HILL selected to manage the $1.9 billion Hanford River Corridor Closure Contract (RCCC) for the U.S. Department of Energy. The RCCC work scope includes the deactivation and cocooning of plutonium production reactors, remediation of burial grounds and waste sites along the Columbia River, and the operation of the Environmental Restoration Disposal Facility (ERDF). In August 2006, WCH completed the first year of its 7-year contract.

This paper focuses on burial grounds located in the Hanford Site 100 and 300 Areas, which received low-level, mixed low-level, and transuranic (TRU) waste. These burial grounds range in size from 10 m by 30 m (11 ft by 33 ft) to greater than 100 m by 300 m (109 ft by 328 ft). This paper summarizes the quantities of waste recovered during remediation and provides a discussion of some of the anomalies encountered through December 2006. The 200 Area burial grounds located on the central plateau are not within the scope of the RCCC.

SITE BACKGROUND

Some operational background is provided for a better understanding of the nature and types of burial ground waste. The Hanford Site located in Washington State encompasses 1517 km^2 (586 mi^2) and is divided into three major areas. The 100 Areas, located at the north end of the site, contain nine surplus plutonium production reactors. The 200 Areas, are located in the center of the site, contains the chemical processing facilities and the high-level waste storage tanks. The 300 Area, located at the south end of the site, contains the former fuel fabrication facilities and research laboratories.

The first 100 Area production reactor (B Reactor) was brought online in 1944. B Reactor was of a graphite modulated design and used single-pass cooling water. It was fueled with natural uranium in a solid, cylindrical form. During the period 1945 to 1955, seven more production reactors of similar design were constructed in the 100 Areas. For safety reasons the reactors were located in five areas spaced approximately 4 km (2.5 mi) apart along the banks of the Columbia River. Each of the reactor areas operated independently, and each had its own set of waste burial grounds.

Using the knowledge gained from years of operation and process refinement, the last and most modern reactor (N Reactor) was brought online in 1964. N Reactor differed from the single-pass reactors in that it had a closed primary loop cooling system. It was fueled using slightly enriched uranium in an innovative fuel element design. Shortly after N Reactor came online, the older single-pass reactors began to be phased out of operation. By 1971, N Reactor was the only operating reactor at the Hanford Site. It continued to produce plutonium until its permanent shutdown in January 1987. [1]

Construction of the 300 Area began in 1943. Initially it housed the research facilities and fuel fabrication facilities required to support B Reactor construction and operation. The 300 Area evolved to contain numerous research facilities for plutonium refining, irradiated fuel examination, and radioisotope research. Between 1944 and 1957 more than 1,000 research tests were performed in the 300 Area. [1] Many of these tests produced unique waste that was sent to the 300 Area burial grounds.

The 300 Area fuel fabrication facilities produced fuel elements for the eight single-pass reactors and N Reactor. Single-pass fuel was produced between 1944 and 1971. Its production consisted of the heating and extrusion of uranium billets into rods, outgassing and straightening of the rods, cutting and machining of the rods into elements, cleaning and degreasing the elements, and cladding. The cladding process involved a triple-dip process in which the elements were bathed in molten baths of bronze, tin, and then an aluminum-silicone mixture. In 1954, the triple-dip process was replaced with a simpler lead dip process. On average 30,000 fuel elements were produced weekly using the lead dip process. [1]

N Reactor fuel was produced from 1961 to December 1986. It differed from single-pass fuel in that it had a hollow core to allow the passage of cooling water and it had an extruded cladding.

The extrusion process was performed by placing a Zircoloy-2 inner and outer shell around a prepared uranium tube. The shell assembly was heated and then pressed through an extrusion die. The high pressure exerted during the extrusion process resulted in a strong bond between the cladding and the uranium tubing. The extruded tubing was then cut to length and caps were welded over the ends to complete the fuel element. N Reactor fuel production reached a peak of 250 elements per week in the mid-1980s. [2]

The exact knowledge of the burial ground contents is not available due to the lack of historical record keeping. Review of historical documents provides some indication of the types of waste to be encountered. Prior to 1954, the 300 Area burial grounds received small quantities of unsegregated radioactive solid waste (mixed high and low activity). In 1954, high contamination levels from a fire in the 618-4 Burial Ground resulted in the opening of the 618-10 burial ground to receive high level waste. The 618-10 burial ground is located 6.5 km (4 mi) to the north of the 300 Area. Remediation of this burial ground is currently in the design phase and is not within the scope of this paper. [3]

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WASTE DISPOSAL AND TRANSPORTATION

Most waste from burial ground remediation is sent to the Environmental Restoration Disposal Facility (ERDF) located in the central plateau of the Hanford site. The ERDF is a *Resource Conservation and Recovery Act* (RCRA)-compliant, *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA)-authorized hazardous waste landfill. Its current operational capacity is 7.25 million metric tons (8 million tons) with room for additional expansion. By August 2006, ERDF had received 6.6 million metric tons (6 million tons) of waste.

Waste is shipped to ERDF in reuseable 18-metric-ton (20-ton) roll-off containers. The containers are of carbon steel construction and have a soft top. To minimize contamination issues, the containers are lined with a 0.5 mm low-density polyethylene liner before loading. A fleet of haul trucks that deliver and pick up containers from the field remediation sites is maintained at ERDF. A typical burial ground remediation project will load 25 to 50 containers per day depending on its distance from ERDF.

300 AREA BURIAL GROUNDS

The 300 Area contains nine major burial grounds that were in operation from 1945 through 1976. These burial grounds were of an unlined trench construction approximately 4.9 m (16 ft) deep by 30 m (100 ft) wide by 90 m (300 ft) long. The trenches were filled with bulk waste consisting of construction debris, process equipment, industrial equipment, laboratory waste, protective equipment, and drummed wastes, and then covered with several feet of soil. Uranium is the primary radionuclide found in these burial grounds, although small quantities of laboratory waste containing fission products and plutonium may be present. An aerial view of the 300 Area burial grounds is shown in Figure 1.

As of December 2006, two 300 Area burial grounds remain to be remediated: the 618-7 Burial Ground and the 618-1 Burial Ground (white background). Remediation work at the 618-7 Burial

Ground will begin in January 2007, followed by 618-1 in approximately 2 years. A summary of the major 300 Area burial grounds, listed in their order of remediation, is provided in Table I.

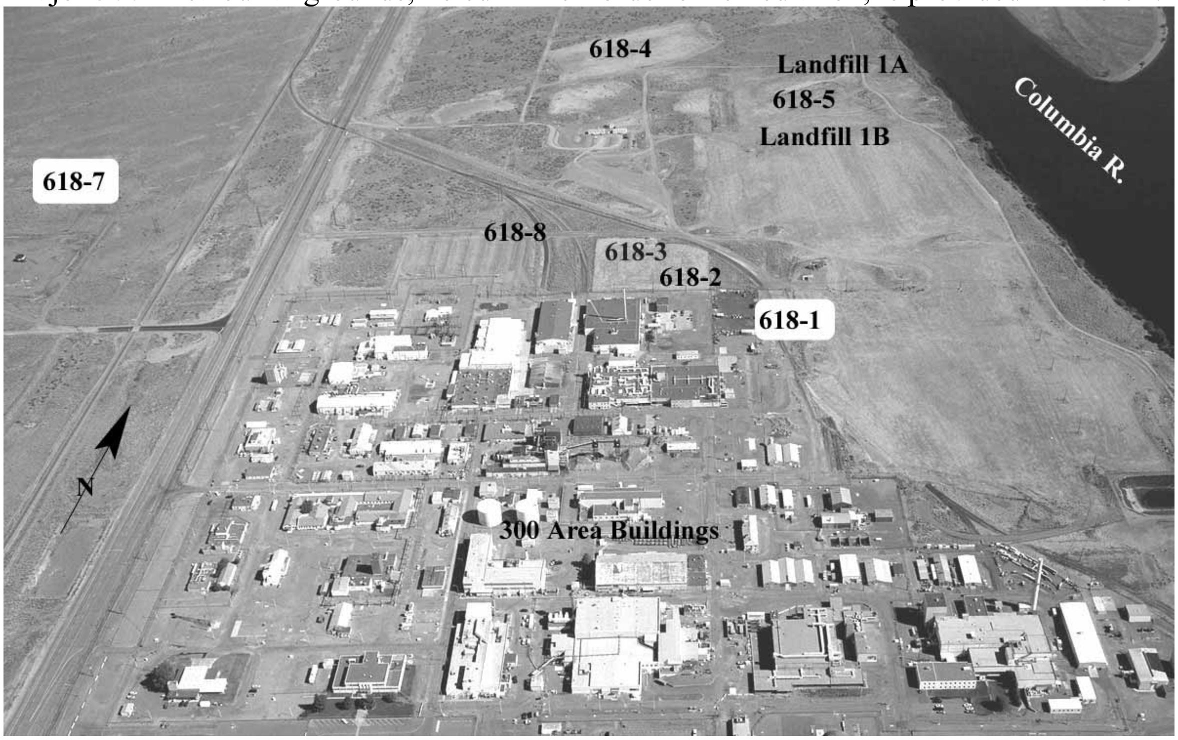

Fig. 1. Aerial view of 300 Area burial grounds.

Table I. Remediation Status of 300 Area Burial Grounds

Name	Type of Waste	Date Operated	Contaminated Material (US Ton)	Completion/ (Start) Date
Landfill 1A [4]	300 Area laboratory wastes with mixed construction debris	Undocumented	19,500	6/2000
Landfill 1B [5]	300 Area construction debris	Pre-1953 based on historical records	35,600	6/2000
618-4 Burial Ground [6]	300 Area fuel fabrication waste and process equipment	1955 to 1961	51,300	5/2003
618-5 Burial Ground [7]	300 Area fuel fabrication waste and process equipment	1945 to 1962	46,200	9/2003
618-3 Burial Ground [8]	300 Area construction debris and process equipment	1954 to 1955	21,000	10/2004
618-8 Burial Ground [9]	300 Area construction debris	1954	10,000	11/2004
618-2 Burial Ground	300 Area laboratory and fuel fabrication waste	1951 to 1954	38,000	9/2006
618-7 Burial Ground	300 Area construction	Pre-1953 based on	35,600	(1/2007)

Name	Type of Waste	Date Operated	Contaminated Material (US Ton)	Completion/ (Start) Date
	debris	historical records		
618-1 Burial Ground	300 Area laboratory wastes with mixed construction debris	1945 to 1950	19,500	(10/2008)

300 AREA ANOMALOUS WASTE

During remediation of the 618-4 Burial Ground, 520 drums containing depleted uranium lathe turnings were recovered. The turnings were potentially pyrophoric and were originally packaged in oil contaminated with polychlorinated biphenyls (PCBs). Each recovered drum was inspected to ensure the uranium turnings were covered with oil. If needed, mineral oil was added to the drum overpack. Because of the PCBs, the uranium turnings were sent offsite for treatment. The solidified turnings were returned for disposal at ERDF and the oil was sent to the mixed waste *Toxic Substances Control Act* (TSCA) incinerator located at Oakridge, Tennessee.

A total of 266 drums containing uranium oxide were recovered from the 618-4 Burial Ground. Some of the oxide drums contained hazardous levels of cadmium, lead, and barium that presented significant health risk if the material became airborne. To minimize the potential for a spill the drums were hoisted from the excavation site in disposable lifting bags. The lifting bag containing the drum was then placed in an overpack. The oxide drums were disposed at ERDF after being macro-encapsulated.

During remediation of the 618-5 Burial Ground, a 15 cm (6 in) section of pipe was recovered that contained a precipitate-like material. During sorting operations, pressure exerted on the pipe by a front-end loader caused the precipitate material to ignite in a bright flash. Analysis of the precipitate showed high concentrations of iron and aluminum but did not indicate why the mixture was reactive. The flash did not cause damage or injury but did present a risk to nearby workers sorting material. Material sorting procedures and training were changed to eliminate hand sorting of suspect material.

In December 2004, a combination safe approximately 0.5 m^3 (18 ft^3) in size was uncovered in the 618-2 Burial Ground. The safe was damaged during excavation allowing some of its contents to be removed as shown in Figure 2. The safe contents included a 4 L (1 gal) bottle marked lanthanum fluoride, a flask, several metal beakers, and some unknown canisters. The bottle contained approximately 1 L (1 qt) of white cloudy liquid, and the flask contained 125 mL (4.23 oz) of a clear liquid. A radiological inventory of the safe and its contents were made using the Canberra In Situ Object Counting System (ISOCS), and the results are summarized in Table II.

Fig. 2. Combination safe recovered from the 618-2 Burial Ground.

Interestingly, investigation of the ISOCS results showed that gram quantities of plutonium were present. This was unexpected in that the initial field gamma dose measurements were very low (<0.5 mR). This can be explained due to the lack of the strong gamma emitter Am-241 being present with the plutonium. Plutonium produced at the Hanford Site is reported to contain approximately 0.5% Pu-241, which produces an Am-241 daughter product that is easy to detect. The plutonium samples from the safe contained 1,000 times less Pu-241 then expected. As a result, the samples contained a proportionately lower concentration of Am-241 making it harder to detect. Due to the purity of the plutonium sample recovered from the safe, it was believed to have historical significance and a sample was provided to Pacific Northwest National Laboratory (PNNL) nuclear chemistry group for additional analysis. Result from the PNNL analysis will be available at a later date.

Working with the safe and its contents required special handing requirements typically not used in field remediation. Sampling efforts were conducted in a glovebag located in a high-efficiency particulate air (HEPA) filtration ventilated structure. Workers wore Level B personal protective equipment for radiological and industrial hygiene concerns. The flighty nature of the separated Pu-239 was indicated by airborne particulate levels rising to 43 DAC (derived air concentrations) inside the ventilated structure. The pre-planned engineering controls prevented internal exposure to the workers or a release of radioactive material to the environment. Following characterization, the safe and contents were designated as being TRU material and were packaged for disposal at the Waste Isolation Pilot Plant.

Table II. Radiological Inventory of the 618-2 Safe

Item	Estimated Total Activity
Safe containing broken glass, broken concrete chunks, and other unknown material	≈164,000 µCi Pu-239 ≈ 146 µCi Am-241
4 L glass bottle labeled “$LaFl_3$” containing 1 L of cloudy white liquid	≈ 30,200 µCi Pu-239
250 mL Erlenmeyer flask containing 125 mL of clear liquid	≈ 2,930 µCi Pu-239 <1 µCi Am-241
Other items removed from safe (i.e., canisters and metal beakers)	≈ 11,500 µCi Pu-239

Another inherent risk associated with the plutonium from the 618-2 Burial Ground was the potential for it to become airborne during excavation and sorting operations. To address this risk, a monitoring program was implemented that provided next-day results on lapel and perimeter air monitoring. Daily work control practices were modified based on the air monitoring results. In addition, a soil fixative consisting of magnesium or calcium chloride was thoroughly mixed with the soil during excavation. After the addition of the fixative, the soil retained its moisture content under the hot summer conditions, thus lessening the potential for dusting.

100 AREA BURIAL GROUNDS

A summary of the remediation status of the 100 Area burial grounds is presented in Table III. As of December 2006, one 100 Area burial ground has been remediated and seven are in progress. An aerial view of the 118-B-1 Burial Ground under remediation is shown in Figure 3. This burial ground is typical of those found in the 100 Areas and is similar in construction to those in the 300 Area.

Waste encountered in the 100-B/C Area burial grounds consists of process equipment, spline cases, vertical control rods, lead sheeting/bricks, soft waste, tar, wax, casks, small glass/plastic containers, piping, construction debris, and fuel spacers. In addition some specialty waste forms have been encountered such as tritium targets, which contain lithium tubes, barium tubes, and elemental mercury.

Table III. Remediation Status of the 100 Area Major Burial Grounds

Name	Type of Waste	Date Operated	Contaminated Material (US Ton)[a]	Completion/ (Start) Date[b]
118-B-1	100 Area reactor waste and construction debris	1944 to 1973	84,400	(3/2004)
118-B-3	100 Area reactor waste and construction debris	1956 to 1960	17,100	4/2005
118-C-1	100 Area reactor waste	1953 to 1969	33,000	(6/2004)
118-D-1	100 Area reactor waste	1944 to 1967	96,300	(2010)
118-D-4	100 Area reactor waste	1953 to 1967	189,000	(Before 12/2011)
126-D-2	100 Area reactor waste and construction debris	1943 to 1986	143,000	(Before 12/2011)
118-D-2	100 Area reactor waste	1949 to 1979	70,000	(2008)
118-D-3	100 Area reactor waste	1956 to 1973	381,000	(2007)
126-DR-1	100 Area construction debris	1975 to NA	46,300	(12/2006)
118-F-1	100 Area reactor waste	1954 to 1965	399,000	(12/05)
118-F-2	100 Area reactor waste	1945 to 1965	186,000	(1/06)
118-F-5	Laboratory animal waste	1954 to 1975	62,600	(11/05)
118-F-6	Laboratory animal waste	1965 to 1973	182,000	(12/05)
118-H-1	100 Area reactor waste	1949 to 1965	144,000	(Before 12/2010)
118-H-3	100 Area reactor waste	1953 to 1957	25,200	(Before 12/2010)
118-K-1	100 Area reactor waste	1953 to 1975	30,100[c]	(5/2006)

[a] Contaminated soil volumes are taken from the remedial design report. [10]
[b] Remediation start dates are based on Tri-Party Agreement milestones unless otherwise noted.
[C] From 118-K-1 Burial Ground Remedial Action Request for Proposal. [11]

100 AREA ANOMALOUS WASTE

Highly radioactive fuel elements and other irradiated reactor waste present unique remediation and waste disposal challenges. Fuel element fragments have been encountered in the 118-B-1, 118-C-1, and 118-F-1 Burial Grounds and are reported to have contact dose rate readings of up to 150 R/hr. Before waste material can be shipped to ERDF, it must be sorted to remove fuel elements or fragments. The sorting process is performed by spreading the material in a 15 cm to 30 cm (6 in to 12 in) lift and then surveying with a specially designed gamma detector that is shown in Figure 4. The detector contains multiple gamma sensors in an array that is connected to a laptop computer that continuously monitors readings. High readings are flagged during the survey and then investigated at a later time. This method has successfully led to the recovery of more than 20 pieces of irradiated fuel from the 118-F-1, 118-B-1, and 118-C-1 Burial Grounds.

Fig. 3. 118-B-1 Burial Ground (100-B/C Area) under remediation, looking south.

Fig. 4. Multiple array gamma detector for locating irradiated fuel fragment.

The 118-B-1 Burial Ground experienced a spontaneous ignition of some material during sorting operations that resulted in a poof of white smoke. The cause of the smoke was never identified, but was believed to be similar to the flash event that occurred in a 300 Area burial ground. Other waste material recovered from the 100 Area burial grounds has been similar in nature to that in the 300 Area and has not presented a significant waste handling or disposal problem.

SUMMARY

To date, two major burial grounds (618-1 and 618-7) remain to be remediated in the 300 Area. The 618-7 Burial Ground is expected to contain a large number of drums containing Zircaloy-2 chips. Research and characterization sampling indicate that the Zircaloy-2 chips may be pyrophoric and require treatment before disposal. The safe excavation, storage, and treatment of the Zircaloy-2 drums is a primary concern.

Remediation of the 100 Area burial grounds began in March 2004. To date, one burial ground has been remediated, eight are under remediation, and seven more will undergo remediation between now and 2011. Waste forms encountered thus far have not presented significant treatment or disposal problems with the exception of highly radioactive fuel elements. A new sorting method has been successfully used to rapidly locate irradiated spent fuel with minimal exposure to workers.

Important lessons learned from burial ground remediation include the following:

- Review historical records including radiological surveys to determine the types of waste forms that may be present. Design a monitoring plan to address the identified contaminant risks.
- Anticipate that some recovered waste may be pyrophoric and will require specialized handling procedures.
- For sites that may have Pu-239 present, anticipate the possibility that it may be present in an isotopically pure form, making it difficult to detect with field instrumentation.
- Control of wind-blown dust and debris is essential to preventing airborne contamination releases.

In conclusion, much knowledge has been gained remediating more than 20 low-level waste burial grounds at the Hanford Site. Burial ground remediation work can be performed safely if work planning and implementing documents are prepared to correspond with the uncertainty of the waste to be encountered. In short, if little is known about the burial ground, plan for the worst.

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