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MIXED WASTE REMOVAL FROM A HAZARDOUS WASTE STORAGE TANK

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ABSTRACT

The spent fuel transfer canal at the Oak Ridge Graphite Reactor was found to be leaking 400 gallons of water per day into the surrounding soil. Sampling of the sediment layer on the floor of the canal to determine the environmental impact of the leak identified significant radiological contamination and elevated levels of cadmium and lead which are hazardous under the Resource Conservation and Recovery Act (RCRA). Under RCRA regulations and Rules of Tennessee Department of Environment and Conservation, the canal was considered a hazardous waste storage tank. This paper describes elements of the radiological control program established in support of a fast-track RCRA closure plan that involved underwater mapping of the radiation fields, vacuuming, and ultra-filtration techniques that were successfully used to remove the mixed waste sediments and close the canal in a method compliant with state and federal regulations.

BACKGROUND

The Oak Ridge Graphite Reactor was decommissioned in 1963 after 20 years of continuous operation and designated a historic landmark by the U.S. Department of the Interior in 1966 and by the American Nuclear Society in 1992. Its primary mission was to demonstrate the production of plutonium from uranium in a reactor and the feasibility of extracting it from irradiated uranium slugs. During operation, spent fuel slugs were pushed from the reactor and slid down a chute into an underground, water-filled concrete reservoir connecting the reactor to the reprocessing facility. A monorail and chain hoist were used to manually transfer slugs underwater to the reprocessing facility where plutonium was chemically extracted. Of the thousands of fuel slugs processed, it is estimated that roughly 200 ruptured in the reactor or in the canal, leading to its contamination.

In March 1990, it was discovered that the canal was losing water at the rate of approximately 400 gallons per day. Sampling of the canal's contents to evaluate possible environmental consequences due to its radioactive contamination identified concentrations of lead and cadmium exceeding the limits set forth by the Resource Conservation and Recovery Act (RCRA). The potential risk to the public due to radiological contamination from the leak was determined to be negligible.[1] However, under RCRA regulations and Rules of Tennessee Department of Environment and Conservation, the canal was considered a hazardous waste storage tank, storing the characteristic hazardous wastes lead and cadmium. RCRA requirements for the closure of the tank are addressed in the Closure Plan.[2]

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The canal is an "L"-shaped structure located under portions of Building 3001 (the Graphite Reactor) and Building 3019 (the Radiochemical Processing Pilot Plant) at the Oak Ridge National Laboratory. Its dimensions are 101-ft long, 10.5-ft deep, and 7-ft wide at one end and 11.5-ft deep and 5-ft wide at the other end with a volume of approximately 62,000 gallons. Located at the north end is a 7-ft × 7-ft × 20-ft-deep pit into which spent fuel slugs were ejected from the reactor. The atmosphere of the canal room is isolated from that of Building 3019 by a concrete wall that drops below the surface of the water, creating an airlock through which sources and assemblies may pass underwater. The canal room is maintained at a negative pressure (≈ 0.25-in. w.g.) relative to adjacent areas and exhaust air is HEPA filtered before passing to the building stack.

The canal was used as a receiving and discharge area for spent fuel slugs from the Graphite Reactor, enriched fuel from the Low Intensity Test Reactor, Oak Ridge Research Reactor, Tower Shielding Facility, and for miscellaneous sealed radioactive materials such as ^{60}Co.[3] Before the sediment removal phase of the closure could proceed, the recovery and disposal of a significant number of ^{60}Co and ^{90}Sr sources had to be effected. The canal held 834 ^{60}Co sources and 16 ^{90}Sr sources, estimated at more than 150,000 Ci total activity. A specially modified spent fuel transport cask was used to transport sources from the canal to a hot cell for repackaging and transfer to the Retrievable Waste Storage Area at Solid Waste Storage Area (SWSA) 5. The cask had been modified with a retractable shield drawer on the bottom to allow bottom-end loading and unloading. Based upon pocket dosimeter data[4] from personnel exposed, the collective dose equivalent for the source removal task was less than 0.6 person-rem, half the ALARA estimate. The maximum individual dose equivalent was 76 mrem. No worker exceeded daily or weekly administrative dose limits. Air monitoring demonstrated that no airborne contamination was generated.

Following source removal operations, plans were implemented to remove and immobilize the sediments. The scope of work required a subcontractor to remove and stabilize the sediments in accordance with contract Technical Specifications,[5] ORNL Environmental, Safety and Health procedures, and Title 29 of the Code of Federal Regulations, Part 1910.120, "Hazardous Waste Operations and Emergency Response." The sediment removal technique including difficulties and solutions is summarized in the Closure Certification Report.[6]

RADIOLOGICAL CONTROLS

Site Survey

Prior to equipment setup, the subcontractor's Radiological Control Technicians performed baseline surveys to document existing radiological conditions. Removable contamination levels as high as 79,000 dpm/100 cm^2 β-γ (4,000 av) and 480 dpm/100 cm^2 α (100 av) were found. Air sampling generally showed levels of airborne contamination to be below 10% of the derived air concentration (DAC) for ^{239}Pu. The general area background was about 3 mR h^{-1} with the canal water maintained at its usual level. Over time, radionuclides from the water had been absorbed into the concrete walls, requiring the water to be maintained at a specific level to provide shielding from the walls. Background radiation levels rose significantly if the water level was lowered even 1 ft. Mapping of the radiation fields on the canal floor identified numerous locations of previously unidentified high-activity debris, with several individual readings greater than 1,000 R h^{-1}. Prior to vacuuming the sediments, Operations Technicians used long-handled reach rods to remove the large pieces of debris and isolate them in special containers placed into the canal for this purpose.

Site Control

In compliance with DOE 5480.11, "Radiation Protection for Occupational Workers," radiological zoning and posting had been established prior to source or sediment removal operations. Compliance with 29 CFR 1910.120, however, required establishment of an Exclusion Zone, a Contamination Reduction Zone (CRZ), and a Support Zone. The canal room, beginning at the top of the canal access stairs, was posted as a Contamination Area. In addition, the Exclusion Zone was designated as the canal work area up to the step-off pad at the base of the stairs. The region from the step-off pad at the base of the stairs to the top of the stairs was designated the CRZ. A tent-like enclosure and a step-off pad were set up outside the door at the top of the stairs, and they and an additional 100 ft^2 area were designated the Support Zone. The Support Zone was also posted as a clean Regulated Area (an administrative control for any controlled space with a potential for surface contamination between one and ten times the guides specified in Attachment 2 to DOE 5480.11).

All tasks performed in either the Exclusion Zone or the CRZ were controlled by daily Radiation Work Permits (RWP). Prework surveys were performed before operations began each day to document radiological conditions in the Exclusion Zone. Administrative limits and survey results which included radiation and contamination levels documented on site maps formed the basis for RWP requirements. Daily dose limits and minimum levels of personnel protection equipment (PPE) were documented on the RWP. Generally, the minimum PPE consisted of coveralls taped at wrists and ankles, skull cap, water-repellant suit, two pairs of rubber gloves, two pairs of plastic shoe covers, one pair of rubber shoe covers, and safety glasses. Radiation safety briefings covering current radiological conditions and RWP requirements were conducted before the start of work each day. As conditions changed, workers were apprised of the conditions affecting them. These briefings included planning of the work, staging the job, limiting time in specific areas of the canal, and the use of shielding, when needed.

Contamination Control

Zoning and posting were important elements of the contamination control program. The area of highest contamination was designated the Exclusion Zone. The Support Zone was maintained as a clean area. The CRZ established between these two zones prevented the spread of high contamination from the Exclusion Zone to the Support Zone. In addition to this role, the CRZ was designed to facilitate decontamination of personnel, equipment and samples; emergency response; and equipment resupply. Clean protective clothing, respirators, monitoring equipment, sampling supplies, and other equipment were all maintained outside of the CRZ. Personnel donned their PPE in the Regulated Area and entered the Exclusion Zone through the CRZ. Tacky step-off pads were used to reduce the transfer of contamination from areas of high contamination to areas of low contamination. Personnel exiting the Exclusion Zone removed and segregated their outer layer of PPE before stepping onto the step-off pad and entering the CRZ. Before leaving the CRZ and stepping onto the step-off pad leading to the Support Zone, personnel removed their remaining PPE. Whole-body frisking was required for all personnel exiting Contamination Areas (i.e., Exclusion Zone and CRZ). The extent of frisking required of personnel exiting Regulated Areas was determined based on "track-out" possibility. The Support Zone/Regulated Area was maintained free of transferrable contamination (verified by daily surveys); therefore, only minimal frisking requirements (tops and bottoms of hands and shoes) were implemented. All equipment leaving the Contamination Area was surveyed prior to release to the Support Zone and unrestricted area; the administrative limits for removable contamination for equipment for unrestricted use being 20 dpm/100 cm^2 for α and 200 dpm/100 cm^2 for β-γ.

Exposure Control

Prior to initiation of any work at the canal site, all workers submitted urine samples for *in vitro* bioassay and underwent whole-body and lung counting to measure and document individual levels of existing internally deposited contamination. Thermoluminescent dosimeters (TLDs) were issued to workers to monitor whole-body shallow and penetrating doses. TLDs were exchanged quarterly at first and then monthly as personnel exposures began to increase significantly. To track the short-term accumulation of worker doses, direct reading dosimeters (DRD) were used. DRD results were tracked on a computer system and updated weekly. Administrative dose limits of 20 mrem d^{-1} and 100 mrem wk^{-1} were imposed on all workers for the first four months of the project. When the sand filters and the underwater filtration system were employed, run times were longer and limits of 60 mrem d^{-1} were approved.

Immediately following equipment setup, a strippable coating was applied to the exposed portions of the canal walkways to reduce the airborne contamination levels and to protect the underlying surface from increased contamination in the event of an uncontained spill. Plastic sheeting was laid down and dikes were built under and around equipment with the highest potential for leaks. Whenever leaks were detected, operations were halted until the leak was repaired and the spill cleaned up. Even small leaks halted operations because air drying might have increased the potential for airborne contamination, possibly leading to a respiratory protection requirement. During operations, a multi-phased air monitoring program was conducted to determine respiratory protection and protective clothing requirements. Since ^{239}Pu was a known contaminant in the sediments, ^{239}Pu airborne contamination could not be discounted without isotopic analyses. Results of air sample counting data were conservatively related to the DAC_{Pu-239}. Real-time air monitors were used continuously. As long as the airborne concentrations stayed below 1 DAC, the determination for respiratory protection was left up to the judgement of the subcontractor's Radiological Control Group. Respiratory protection was seldom utilized during the project. The administrative limits for internal exposure were less than 200 DAC-hours annually and less than 4 DAC-hours weekly.

Work area surveys consisting of radiation and contamination measurements were performed at least twice daily and more frequently if warranted. Survey results were documented in the form of maps that were posted in each area and updated daily. Early in the project, surveys were relatively uncomplicated. As removal operations progressed, dozens of new source terms developed (e.g., sediment and spent filters accumulating in drums stored out of the water, internally contaminated transfer lines, and pumps) and contributed to increases in the general area background. Drums of spent sand filter media, reading from 200 mR h^{-1} to 700 mR h^{-1}, were stored on the back side of the canal wall to reduce the general area background. Sand filters were backflushed to a high integrity container (HIC) located on a platform above the canal. The exposure rate from the HIC gradually increased, eventually reading about 200 mR h^{-1} on contact, until its contents were sampled and transferred to the ORNL Liquid Low-Level Waste (LLLW) system.

Exposure Evaluation

The radiological cost for this portion of the project (sediment removal and packaging) was approximately 6 person-rem. The highest individual dose equivalent was estimated at 1,280 mrem. Extremity dosimetry was used for a 2-wk period during which the contents of drums were being consolidated. No individual exceeded the administrative extremity limit of 1,000 mrem wk^{-1}. The highest reading for extremities on one individual was 719 mrem and 625 mrem for the left and right hands, respectively.

The sediment removal operation entailed several tasks that contributed to personnel exposure, including:

1. On one occasion before the "catch" drum was installed, hot debris lodged in the primary pump, necessitating repair when cycling the pump failed to dislodge the debris. Partial disassembly of the pump, reading 450 mR h^{-1} at contact, was required to return it to service.
2. Approximately 50 filter changeouts were required with the underwater filtration system. Each changeout involved 4 filter elements. Before draining the water, each filter element measured about 60 mrad h^{-1} β-γ. Drained, each element measured about 100 mrad h^{-1} β and about 30 mR h^{-1} γ. Approximately 200 of these filter elements were handled over the course of the project.
3. The contents of the "catch" drum and the sand filters were another source of high exposures. Personnel received significant exposures in short periods during the waste sampling and packaging phase of operations. The contents of the "catch" drums were manually consolidated into two drums. Because of the size and viscosity of the debris in the drums, suction transfer was not feasible; thus, personnel used a scoop to transfer the contents from one drum to the other. When it was not possible to scoop the contents further, the drums were manually inverted and rinsed, one into the other. Plastic face shields were used in case of splashing. Extremity dosimetry was utilized in later stages of the consolidation task. The consolidated drums were stored partially submerged in the canal to be dewatered.
4. While the drums were being dewatered, other waste consolidation and removal tasks were being completed in the vicinity of the radiation field created by these drums. The general area background was 450 mR h^{-1} at the edge of the canal but decreased rapidly with distance. The consolidated drums read 8 R h^{-1} and 18 R h^{-1} near contact with the tops and 800 mR h^{-1} and 2 R h^{-1} at 18 in. above the tops, respectively. These drums could not be completely submerged while they were being dewatered. The highest readings on the three sand filter drums were 700, 400, and 225 mR h^{-1} at contact.
5. Before these five drums were moved to SWSA 5, they had to be resampled because insufficient RCRA and isotopic analyses had been performed initially.
6. Removal of the two highest reading drums from the canal required pulling the drums up and out of the canal without shielding and placing them into shielded casks waiting outside. To reduce the possibility of unnecessary exposure to uninvolved personnel, the transfer from the canal was performed on a weekend. The locations of the drums in the canal limited the extent of surveys. When the drums were pulled up, one at a time, the actual exposure rates where much higher than expected. Sand drum #1 (8 R h^{-1} partially submerged) measured 25 R h^{-1} at contact and 35 mR h^{-1} at 18 ft. Sand drum #2 (20 R h^{-1} partially submerged) measured 40 R h^{-1} at contact and 80 mR h^{-1} at 18 ft.

LESSONS LEARNED

During the performance of radiological work and the handling of radioactive materials, abnormal events may occur which could indicate a weakness or area of programmatic breakdown of radiological controls. Analysis of these events should reveal where improvements can be made or identify methods to prevent the recurrence of undesired results.[7] Some significant lessons learned from the analysis of the sediment removal operation are described below.

1. Deviations from Technical Specification[5] and Environmental, Safety and Health requirements were noted resulting in increased exposures to personnel, including internal contamination. In accordance with DOE Order 5480.19, "Guidelines for the Conduct of Operations at DOE Facilities," a well-established and maintained equipment labeling program was a requirement of the Technical Specification.[5] However, poorly labeled waste transfer lines contributed to an accident which contaminated an Operations Technician and a Radiological Control Technician when a pressurized line was breached. The Operations Technician ingested contamination resulting in a total committed effective dose equivalent of 2.5 mrem.
2. Portable shields to reduce personnel exposures should be used whenever practical. Insufficient use of shielding contributed to the elevated general area background in the canal room. Portable shields should have been used around contaminated equipment and waste receptacles.
3. To preclude unnecessary transfers and additional exposure to personnel, operations should ensure that the intended waste container meets the Waste Acceptance Criteria (WAC).[5] Additional exposure to personnel resulted during the transfer of contents from carbon steel drums to stainless steel drums. The carbon steel drums did not meet the WAC.
4. Prior to performing destructive analyses of samples, the extent of the analyses and the specific procedures to be followed should be clearly understood by the analytical laboratory. Insufficient analytical results required resampling drums for reanalyses. This resulted in increased personnel exposure and the increased potential for the spread of contamination.

WASTE MANAGEMENT

Waste generated and equipment used during the closure process was handled by either disposal at SWSA 6, storage at SWSA 5, or treated at the ORNL LLLW system. The resulting waste included 2,700 gallons of liquid low-level radioactive waste, four 55-gallon drums of transuranic-mixed waste, one 55-gallon drum of low-level mixed waste, and 1,152-ft^3 of solid low-level radioactive waste. The transuranic mixed waste is being stored at SWSA 5 until ultimate transfer to the Waste Isolation Pilot Plant near Carlsbad, New Mexico.

CONCLUSION

As part of the closure process, RCRA requires that the closure be certified by an independent professional engineer. Visual inspections were performed with the aid of underwater lighting. During final inspections, the water was exceptionally clear, and cracks, crevices, expansion joints, and concrete imperfections were easily discernible. During the final inspection, the entire canal floor and wall areas were examined, and no free sediment could be found. Analytical results of the last sediment and water samples were well below Toxicity Characteristic Leaching Procedure (TCLP) limits.[6]

The canal is presently being assessed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as part of Waste Area Grouping 1 (WAG). It is anticipated that the results of the WAG 1 Remedial Investigation/Feasibility Study will determine the priority and method for ultimate decommissioning of the canal.

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