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Recovery, Minimization and Repackaging of 25 year old Low and Intermediate Level Solid Radioactive Waste

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ABSTRACT

Low and intermediate level solid radioactive waste generated between 1964 and 1976 at the Douglas Point and Pickering A Generating stations was stored in Radioactive Waste Operations Site 1 (RWOS-1) at the Bruce Power Site (formerly the Bruce Nuclear Power Development site).

During and after emplacement, groundwater monitoring was performed in the underlying carbonate bedrock, which has a very high normal flux. A shallow groundwater monitoring system was installed in the overlying gravels and sands in 1991. The new monitoring indicated that the aquifer downgradient of RWOS-1 was being contaminated with tritium and beta-gamma emitting radionuclides.

In the early 1990s, a project was initiated to remove the source of the groundwater contamination. For the summers of 1997 and 1998, this involved developing new methods for retrieving solid low and intermediate level radioactive waste from concrete trenches while minimizing worker and environmental hazards. The wastes were segregated and processed to achieve volume reduction prior to being repackaged and stored in above-grade Low-Level Storage Buildings (LLSBs) at the Western Waste Management Facility (WWMF, formerly RWOS-2).

This paper will describe the methodology and equipment used for retrieving, segregating, processing and repackaging 25 year old solid radioactive waste while controlling worker dose and environmental impact.

INTRODUCTION

Low and intermediate level solid radioactive waste generated between 1964 and 1976 at the Douglas Point and Pickering A Generating stations was stored at RWOS-1. RWOS-1 is owned and operated by Ontario Power Generation (OPG, formerly Ontario Hydro) under a cost-sharing agreement with Atomic Energy of Canada Limited (AECL) [1].

The RWOS-1 site is located in unconsolidated sands and gravels that were deposited as a former beach level on post-glacial precursors to Lake Huron [2]. The sands and gravels are underlain by Paleozoic-aged carbonate rocks. The geologic unconformity between these two strata indicates a long period of erosion has occurred, which has resulted in the development of high porosity and permeability in the upper layers of the carbonate rock.

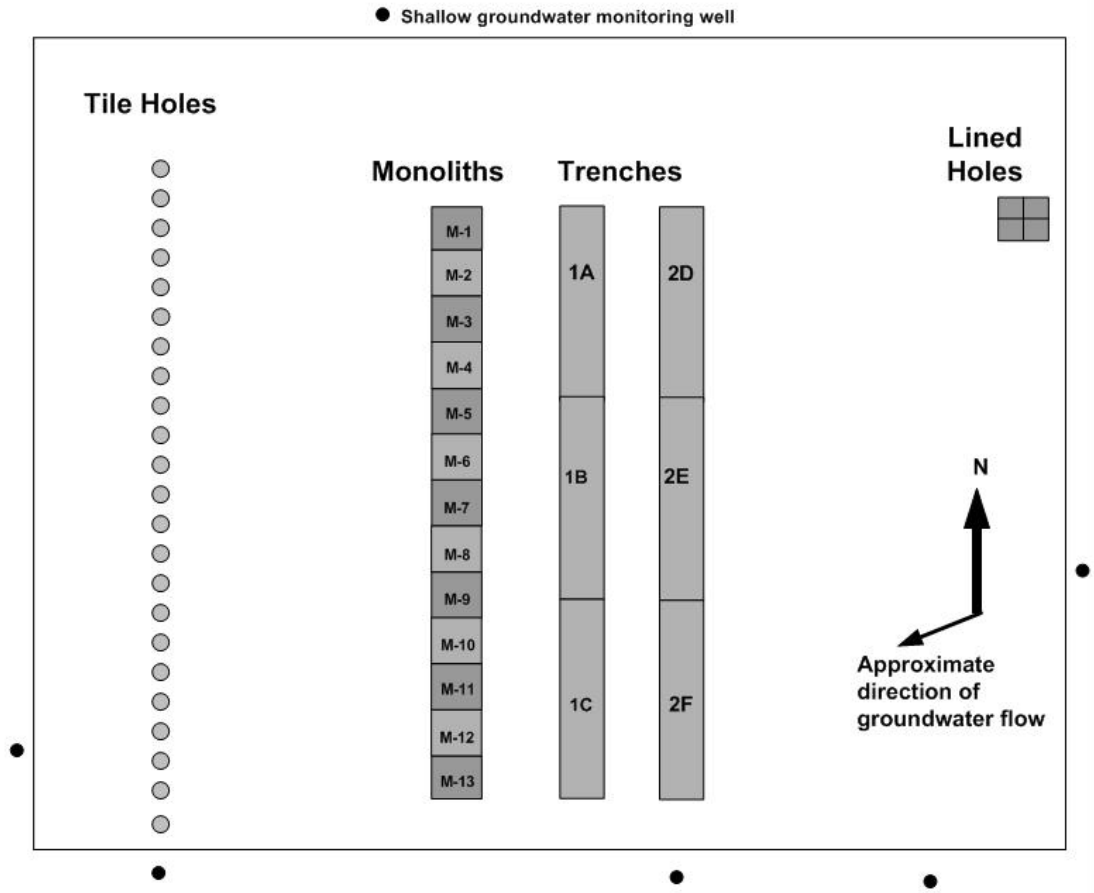
Until 1991, groundwater at RWOS-1 was monitored in the carbonate bedrock, which has a very high normal groundwater flowrate and flux. A shallow groundwater monitoring system was installed in the overlying gravels and sands in 1991[3]. One of the new monitoring wells indicated that the sand and gravel aquifer downgradient of RWOS-1 (towards Lake Huron) was being contaminated with tritium and beta-gamma emitting radionuclides [4]. It is possible that this contamination pre-existed the shallow monitoring wells, but was being diluted to below the lower limit of detection by the high groundwater flux in the carbonate aquifer.

A project was initiated to identify and remove the source of the groundwater contamination. The types of waste storage structures and nature of the stored waste was reviewed. This information is summarized in Table 1 and Figure 1. To identify the source of the contamination, the flowpath and seasonal variability of groundwater in the sand and gravel aquifer at RWOS-1 was mapped. The review concluded that the tile holes, monoliths and trenches were all possible sources of the groundwater contamination.

Table 1
RWOS-1 Waste Storage Structures

Type of structure	Wastes stored
Tile holes	Spent ion exchange resin from PNGD and DP moderator and primary heat transport systems in stainless steel pressure vessels, bagged filters from radioactive systems and a small volume of bagged waste.
Monoliths	Ion exchange columns, drums of solidified liquid chemical waste, sludge, bagged waste, filters.
Trenches	Bagged wastes, ion exchange columns, solidified liquid chemical waste, debris and parts from fuelling machine maintenance, end fittings.
Lined holes	Filters, shield plug.

Figure 1
Radioactive Waste Operations Site 1
(not to scale)



Since the probability of whole body dose to the workers was lower for the trenches, the decision was made to begin the waste removal there. Prior to 1997, waste was removed from Trench Section 1A using heavy equipment. It was loaded in bulk into metal bins, and transferred to the Western Waste Management Facility (WWMF).

For the rest of the trenches, Ontario Hydro looked for an opportunity to use improved technology and methods to minimize the volume of waste to be transferred and the impact on workers and the environment. Staff from the AECL CANDU Decommissioning group had performed radioactive waste removal and minimization work from trenches at Gentilly-1. This group was contracted through the CANDU Owner's Group (COG) to develop the procedures and assist in acquiring the necessary equipment and setting up the field site [5,6].

WASTE REMOVAL

The waste was removed from Trench Sections 1B and 2E in the summer of 1997, and from Trench 2D in the summer of 1998. Each trench section contained about 4000 ft^3 (113 m^3) of waste.

The historic waste records were reviewed to determine the requirements for radioactive contamination control, personnel radiation protection and environmental radiological monitoring. The anticipated radiological hazards included alpha, pure beta and beta/gamma contamination, and gamma whole body dose.

To ensure contamination control, a 60 foot by 80 foot (18m x 24 m) shelter composed of a polyvinyl chloride fabric on an aluminum I-beam frame was installed over the trenches. The shelter was crane-liftable, which allowed it to be moved to cover the trench sections. The ground surface was graded with crushed stone, and the shelter was held in place by a series of long spikes driven into the gravel. A representative from the manufacturer of the shelter was contracted to oversee the shelter installation, to ensure that the wind resistance specification (200 km/h) was met.

The site was organized into radiological zones with increasing requirements for monitoring people, the environment and materials as the risk of contamination increased (Figure 2). The radiation monitors used gas-flow proportional detectors, and had alarm setpoints for both alpha and beta-gamma contamination.

Field operations occurred during the summer months, so the impact of working in hot environments in protective clothing was assessed. Staff dressed in cotton surgical garments at the WWMF. In the Zone 2 change trailer, a breathable, washable overgarment and radioactive work shoes were added. Before entering the rubber area, a layer of Tyvek® overgarments, gloves and a respirator were also donned. Because there was no breathing air system at the site, staff used Portable Air Purifying Respirators.

These included a pump which produced positive air flow, reducing the effort required to breathe. A wet globe bulb thermometer was used to measure the combined impact of heat and humidity on the workers, and criteria were established for work/rest regimes based on the readings observed. During breaks, staff was encouraged to have sport drinks, water and frozen snacks in the lunch trailer.

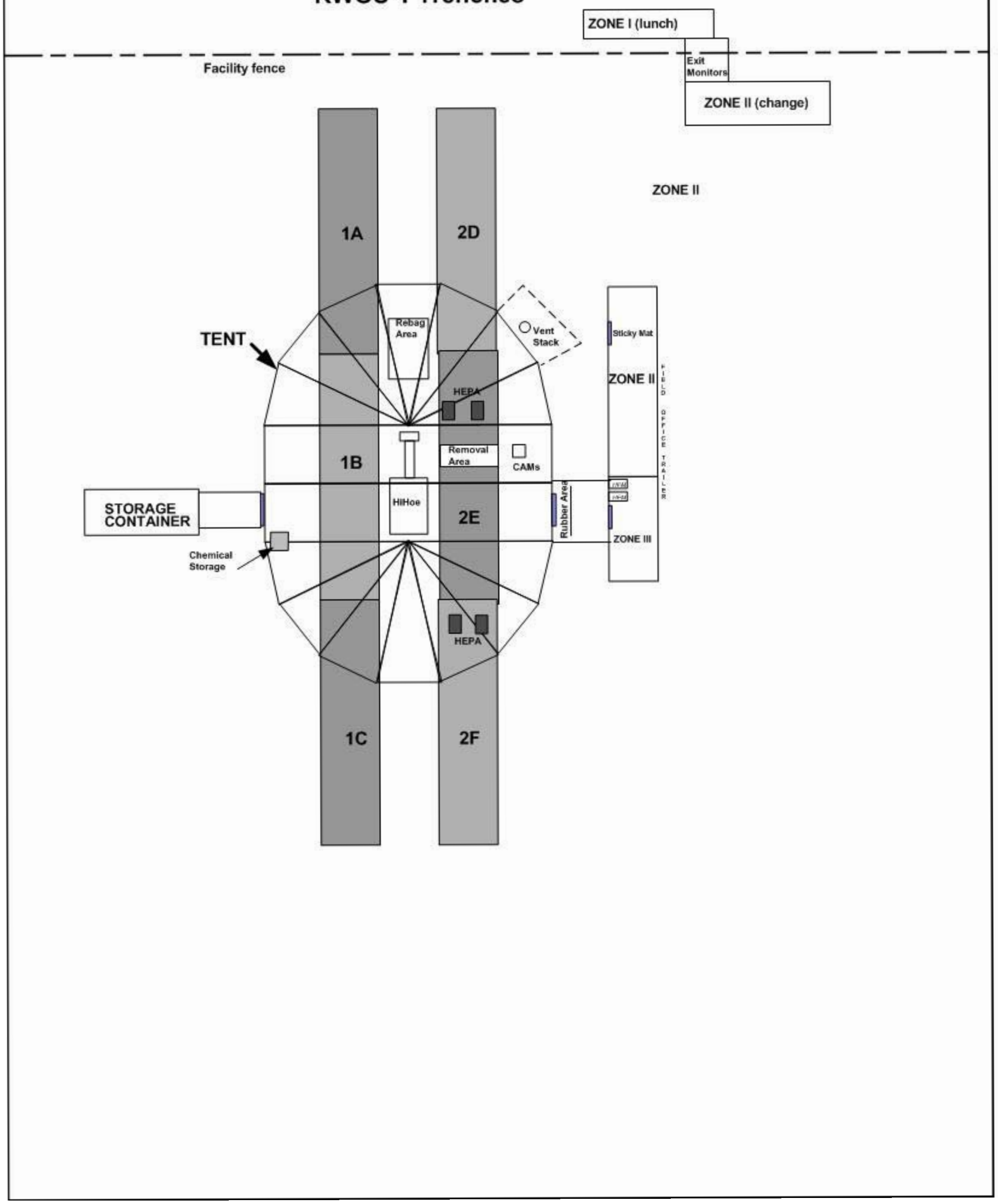
Non-radiological contaminants were also anticipated. Historical data from Douglas Point indicated the presence of scintillation cocktail in vials in the waste. The cocktail was made up in the Douglas Point laboratory, and the ingredients included solvents and dioxane. The waste was also known to contain bioassay, and had visible mould. Samples of solid materials and trench liquids were sent for bacterial analysis. Most of the identified bacteria present in RWOS-1 trenches were common environmental microorganisms, and they indicated the presence of anaerobic processes in the waste. However, some were known opportunistic pathogens. The report concluded that "there is low worker hazard attributable to these opportunistic pathogens . . . LLW in RWOS-1 trenches should be handled using appropriate hygiene practices." [7] This requirement was met using the barriers and Personal Protective Equipment (PPE) required for radioactive contamination control, and by requiring all staff to wash hands before eating or smoking.

The presence of solvents, and potentially other flammable liquids, along with combustible waste and electrical and mechanical equipment as a source of sparks required that measures be taken to monitor the potential for combustion. A combustible gas analyzer was installed in the trench during waste removal activities, with its visible/audible alarm set at 10% of the lower flammable limit. This alarm was not triggered during the project.

To minimize the spread of contamination inside the rubber area, a ventilation barrier was set up using four portable HEPA units, which operated at 1600 ft^3/min (45 m^3/min) each. The effectiveness of this barrier was ensured by removing a minimum number of trench lids at one time, and verified each morning using smoke tubes. Waste was removed from below the barrier using an excavator with a clamshell grapple, and brought to a sorting-repackaging area. In this area, a barrier of plywood covered in adhesive-backed canvas was used to protect the underlying site gravel. The concentration of both alpha and beta-gamma emitting radionuclides in air was measured at the workface using alarming Continuous Air Monitors (CAMs). These monitors did not alarm during the project.

To minimize the dose to workers, a doserate meter with a 10 foot (3 m) extension probe was used to measure the working-distance gamma doserate on the waste as it was being lifted from the trench. Waste with a gamma doserate exceeding a set standard was temporarily lowered back into the trench until shielding could be arranged.

Figure 2
RWOS-1 Trenches



The exhaust from the ventilation system was routed through a ventilation stack that ran in a duct excavated under the shelter wall. The effluent air was monitored for tritium in flow-proportional samples, and continuously for beta/gamma contamination. Results of the stack monitoring were compiled monthly. An exclusion zone was set up using rope and standards around the stack outlet. This minimized the risk of worker inhalation of chemical vapour contamination while walking past this area.

For Trenches 1B and 2E, waste bags that were intact were overbagged and sorted into incinerable, compactible and non-processible streams according to the waste acceptance criteria for the Western Waste Management Facility (WWMF). Intact drums and ion exchange columns were treated as non-processible waste. Most of the waste was not in intact packages, and was removed piece-by-piece. The goal of sorting was to determine the potential for waste volume reduction through processing at the WWMF prior to storage in the Low Level Storage Buildings.

As well as segregating incinerable waste from compactible waste, the waste segregation procedure took into account the possibility that those two waste types would be mixed within a bag of waste. A mobile waste sorting trailer was designed and built by the AECL CANDU Decommissioning team, and a procedure was written for the opening and segregation of bags of mixed incinerable/compactible waste [6]. The waste volume reduction achievable through incineration at the WWMF is more than an order of magnitude greater than through compaction.

During early waste removal operations in Trench 2D, asbestos was observed mixed in with the waste (Figure 3). A monitor to measure asbestos fibres in the air of the trench shelter was installed. Readings were taken using Phase Contrast Microscopy to count asbestos fibres on the filters. Work surfaces in the trench shelter were also assessed, and were found not to have been contaminated by asbestos. The volume of asbestos in the trench was calculated, and the classification of the asbestos removal as a Type II was concurred by the Ministry of Labour.

Waste removal procedures were modified to allow bulk removal of the waste into bins for storage as non-processible waste. A polyethylene barrier was installed around the immediate work area, and a wetting agent was used to minimize dust generation. Polyethylene was used to line the waste bins to prevent the migration of fibres through the welds once the bin lid was fastened in place. All bins containing asbestos-contaminated waste were identified on all sides.

Workers were sent for respirator fit and pulmonary function testing prior to beginning asbestos removal work. Only workers qualified in asbestos removal were used, and supplementary training on new access and waste removal procedures was provided. Workers were issued with Personal Air Samplers, which were analyzed twice daily. These sampled the raw air to which the workers were exposed, and did not take into account the benefit of their respirators, which were fitted with HEPA cartridges. An Asbestos Control Program was prepared and accepted by line management and the Joint Health and Safety Committee [8].

Figure 3
Asbestos-contaminated waste in Trench 2D

RESULTS

Trench 1B

A layer of dry beach sand was found on top of the waste in Trench 1B, and sand was mixed with the waste most for most of the depth of the trench. It was transferred into 36 drums using a HEPA-filtered vacuum-to-drum system. The sand near the bottom of the trench contained too much moisture to be vacummed, and had to be removed in bulk using the excavator. A sample of the sand in each drum was taken through a vertical section of the drum using suction and a plastic tube. For each drum, the samples were sent for gamma spectroscopy. The samples were grouped according to the gamma emitters present in each one, and a composite sample for each group was sent for beta and alpha analysis to determine scaling factors for the drummed sand. The radionuclides above minimum detectable levels for the sand samples were ^{60}Co, ^{137}Cs, ^{152}Eu and ^{154}Eu.

A gamma spectrometer for drums was used to analyze each of the drums, and the total radionuclide inventory by drum was calculated for the four radionuclides indicated above. The inventory was compared to the approved gamma-emitting radionuclide criterion for disposal of Likely Clean waste to the BNPD site landfill, at 50 nCi/kg (1.85 Bq/g). Thirty of the 36 drums met the criteria.[9] All of the drummed sand continues to be stored as low level radioactive waste.

Only 8% of the waste in Trench 1B was processible waste, about half incinerable and half compactible. This was due to the high degree of mixing with the backfill sand, and the degree to which the waste packages were broken open. This may also be due to open-air burning of radioactive waste at RWOS-1, which occurred in the 1960s and 1970s, and which reduced the relative proportion of incinerable waste. No bags of mixed incinerable and compactible waste were removed from Trench 1B [10].

Sixty-one ion exchange columns were retrieved, which is almost twice the number as indicated by the waste records. Three of the columns had a contact gamma doserate in excess of 2 rem/h, and were individually transferred to in-ground container storage at WWMF using in-station flasks.

The concrete of Trench 1B was in very good condition, with the original form marks still apparent. Approximately 8 drums of aqueous liquids were left on the bottom of Trench 1B after the waste and sand were removed. Samples were analyzed and accepted for treatment and release through the Bruce A Active Liquid Waste system (Table 2). The high radionuclide content of the trench water, and the good condition of the trench concrete, imply that there was a long period of contact between the water and the waste, and that water was not leaking out of the trenches.

Table 2
Sample Analysis, Liquids from Trenches 2E and 1B

Trench Section	Tritium (Ci/m^3)	Gross Gamma (Ci/m^3)	Total Gamma* (Ci/m^3)	Total Phosphorus (ppm)	Total Pet. Hydrocarbon (ppm)	Total Susp. Solids (ppm)	pH	BTEX (µg/L)	Zinc (ppm)	Iron (ppm)
2E	1.59	1.51E-05		0.49	1.2	137	7.94	<MDA	0.938	2.79
1B	2.62		5.39E-05	2.3	2.2	1319	8.91	3.32	3.3	70

*total gamma includes sum of ^{137}Cs and ^{60}Co

There were no measurable releases of radionulcides from the ventilation stack during the removal of waste from Trench 1B [11].

<u>Trench 2E</u>

In Trench 2E, a sheet of polyethylene separated the sand from the waste, resulting in cleaner sand and more intact waste packages. A total of 136 drums of sand, gravel and vermiculite were removed from Trench 2E. One hundred and thirty drums met the criteria for release to the site landfill [9]. All drummed materials from Trench 2E continue to be stored as low level radioactive waste [10].

Because there was less mixing of sand and waste, it was possible to segregate 31% of trench volume out as non-processible metal waste. In future, the release of this material as non-radioactive waste feed into metal recycling may be possible.

About 12% of the material in Trench 2E was incinerable or compactible. Two hundred and twenty-five of these waste bags (with a total volume of .135 m^3, or less than 1% of the original volume of waste in the trench) had a mix of both types. Since the new AECL mobile waste sorting facility had not yet been used to open and sort contaminated waste, a decision was made to compact these wastes. The small incremental volume for final storage did not merit contaminating the sort trailer and training the staff in the new procedure.

A total of 18 ion exchange columns were removed from Trench 2E. The waste records indicated that 10 should be present. All of these ion exchange columns were stored in non-processible waste bins in the LLSBs at WWMF.

The concrete of Trench 2E was also in very good condition. Approximately 8 drums of aqueous liquids were left on the bottom of Trench 2E after the waste and sand were removed. Samples were analyzed and accepted for treatment and release through the Bruce A Active Liquid Waste system (Table 2).

The volume of materials from Trench 2E increased by 13% due to removal and repackaging. When the volume reduction due to processing is added to the radwaste storage saved by the diversion of the drummed sand, gravel and vermiculite to the landfill, the volume reduction achieved is 25% of the original in-situ trench volume. This would be taken up to 50% if the decontamination and recycling of the metallic non-processible waste was achieved.

There were no measurable releases of radionulcides from the ventilation stack during the removal of waste from Trench 2E [11].

<u>Trench 2D</u>

For Trench 2D, bulk removal of the asbestos-contaminated waste meant that waste volume reduction was not achieved. The control measures already in place for radioactive contamination proved very effective in preventing worker exposure to asbestos fibres. Fibre concentrations in the Personal Air Samplers did not exceed 0.1 fibres/cc during the waste removal. When the waste removal from Trench 2D was complete, a final clearance survey for asbestos fibres confirmed that airborne levels were below 0.01 fibres/cc.

There were no measurable releases of radionulcides from the ventilation stack during the removal of waste from Trench 2D [11].

Radiological Dose

The collective worker dose due to the removal of waste from Trenches 1B, 2D and 2E was less than 200 mrem (2 mSv) as measured on Electronic Personal Dosimeters, with a mimimum recordable dose of 1 mrem (10 μSv). The average dose per worker for this project was 20 mrem (0.2 mSv) over two field seasons. There was no recordable thermoluminescent dosimeter dose (> 10 mrem/month or >100 μSv/month) during the removal and handling of the wastes from the trenches [11].

CONCLUSIONS

With careful planning, low- and intermediate- level radioactive waste can be removed from below-ground storage in concrete trenches after a considerable period of time with minimal worker dose and no environmental release. Volume reduction of the recovered waste is feasible through waste processing (incineration/compaction), the free release of uncontaminated materials and the decontamination and release of metallic wastes. The economic feasibility of waste minimization would have to be calculated on a case-by-case basis.

AFTERWORD

In the summer of 1999, planned waste removal from Trench Section 2F was about to begin when loose asbestos was identified on top of the backfill sand. Since the volume of asbestos in the trench was less certain than for Trench Section 2D, the asbestos removal was classified as a Type III. Standard procedures for Type III asbestos removal did not align with the procedures required for radiation protection. In order for the waste removal to continue, a consensus position had to be reached between the Canadian Nuclear Safety Commission and the Ontario Ministry of Labour.

However, a soil sampling program completed inside the RWOS-1 fence in September of 1999 indicated that contaminated soil was only found near the tile holes. Soil from around the trenches and monoliths did not contain detectable levels of tritium or beta/gamma-emitting radionuclides. [12] Waste removal efforts were then redirected to the encapsulation and removal of the tile holes. The results of the tile hole removal project have been published separately [13].

Since the removal of the tile holes in the summer of 2002, the concentration of tritium in the groundwater monitoring well downgradient of RWOS-1 has shown a downward trend [4].

ACKNOWLEDGEMENTS

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