ScanSort^{SM} at Whiteshell Laboratories for Sorting of Experimental Cesium Pond Soil

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Abstract

The ScanSort^{SM} soil sorting system is a unique and efficient radiological instrument used for measuring and sorting bulk soils and volumetric materials. The system performs automatic radioassay and segregation of preconditioned material using a gamma spectroscopy system mounted above a conveyor belt. It was deployed to the Whiteshell Laboratories site to process the excavated soils generated during the decommissioning of the former Experimental Cesium Pond. The ScanSort^{SM} system was utilized to segregate material with Cs-137 concentrations above the established site unrestricted release and restricted site reuse levels as well as demonstrated the ability to accurately determine the radioactivity concentrations of the radiologically-impacted material and to confidently segregate volumes of that material for appropriate final disposition.

1. Introduction

The Orion ScanSort^{SM} Soil Sorting System (ScanSort) [1] is a unique and efficient radiological instrument used for measuring and sorting bulk soils and volumetric materials. The system performs automatic radioassay and segregation of preconditioned material using a gamma spectroscopy system mounted above a conveyor belt. It was deployed to the Whiteshell Laboratories (WL) site to process the excavated soils generated during the decommissioning of the former Experimental Cesium Pond.

The WL site is a former Nuclear Research and Test Establishment operated now by Canadian Nuclear Laboratories (CNL), a wholly-owned subsidiary of Atomic Energy of Canada Limited (AECL), which has been in the active decommissioning process since 2003. Decommissioning activities are currently being performed by CNL under license from the Canadian Nuclear Safety Commission (CNSC).

Preliminary radiological surveys conducted by the CNL found that the radiological contaminants Cesium-137 (Cs-137), Strontium-90/Yttrium-90 (Sr/Y-90), multiple Plutonium (Pu) isotopes, Americium-241 (Am-241), Europium-154 (Eu 154), and Cobalt-60 (Co 60) were potentially present at levels above the existing guidelines for site soils. The remediation strategy selected at WL includes controlled, onsite, interim storage of radiological waste which carries significant radiological waste management costs. At the WL Experimental Cesium Pond Soil Sorting Project, the ScanSort^{SM} system demonstrated the ability to accurately determine the radioactivity concentrations (becquerels per grams [Bq/g]) of the radiologically-impacted material and to segregate volumes of that material for appropriate final disposition which reduces costs.

In addition to surveying the excavated Experimental Cesium Pond Soil material, a small amount of other soils were surveyed and sorted by the ScanSort^{SM} system. This additional soil came from the Shielded Modular Above-Ground (SMAGS) facility stock pile, located adjacent to the Experimental Cesium Pond Excavation Soil stock pile.

2. Background

Whiteshell Laboratories (WL) occupies approximately 4,400 hectares (ha) of land on the east bank of the Winnipeg River, near Pinawa, Manitoba, approximately 100 kilometers (km) northeast of Winnipeg, Manitoba. The WL site consisted of several nuclear facilities, including a research reactor, hot cell facilities and radiochemical laboratories. CNL elected to close the facility in the 1990s and decommissioning began in 2003.

The material designated as acceptable for release shall meet the Unconditional Clearance Levels (UCLs) for bulk materials as specified by the CNSC Nuclear Substances and Radiation Devices Regulations (SOR/2000-207) Schedule 2: Unconditional Clearance Levels [2]. Any material that failed to meet the UCL was classified as contaminated and ultimately placed into storage-with-surveillance in the WL Waste Management Area (WMA) Soil Storage Compound (SSC) using 1 m^3 bulk material storage bags.

Because the cost of waste management of radiologically-contaminated material is often quite significant relative to the overall decommissioning costs, the planning of remedial activities for soil focused on technical approaches that minimize radiological waste. The decommissioning strategy must balance activities achieving the dual objectives of minimal waste and acceptable as-left site conditions. The conservative radioactivity concentration limits ratchet “acceptable” to a very low threshold. While this ratcheted threshold bounds the uncertainty in the soil material determined to be below criteria (and the certainty of regulatory release), it also ensures an increase in volumes and cost associated with radiological waste management activities.

Approximately 1,667 m^3 of known cesium 137 (Cs-137) contaminated soil material was generated during the excavation of soils from the WL former Experimental Cesium Pond Project. The material was a mixture of heavy clay, rocks, some topsoil and organic material and was located within a radiological Supervised Area just outside of the WMA. During excavation of the cesium pond soils, radiologically surveys were performed of the excavation face to determine the extent of soil contamination and identify the appropriate stopping point for the excavation. Pre-excavation radiological characterization of the former Experimental Cesium Pond (known to be contaminated with Cs-137) indicated Cs-137 activity concentrations ranged from background levels to ~2,900 Bq/g within the boundary of the former Experimental Cesium Pond.

For the WL soil remediation project, the overarching objective of the soil sorting task was to accurately measure Cs-137 radioactivity, one of the primary contaminants of concern (COC) in excavated, potentially radiologically impacted soils and earthen materials, and to simultaneously segregate these materials for appropriate future disposition. Materials with measured Cs-137 activity levels below the site-specific action levels were to be discharged into the below criteria pile and staged for beneficial reuse. Materials with measured Cs-137 levels above the site-specific action levels were to be diverted into the above criteria pile and staged for on-site storage-with-surveillance.

2.1 Radiological Criteria

CNL determined that clean material will meet the UCL for bulk materials as specified by the CNSC Nuclear Substances and Radiation Devices Regulations (SOR/2000- 207) Schedule 2: Unconditional Clearance Level [2]. Soil declared as clean must be demonstrated to have activity concentrations less than the volumetric clearance levels for the radionuclides of interest identified in Table 1 below. Any material that failed to meet the UCLs was classified as contaminated.

Table 1 Soil Sorting Unconditional Clearance Levels

Radionuclides of Interest	Average activity concentration (Bq/g)
Co-60	0.1
Sr-90	1
Cs-137	0.1
Eu-154	0.1
Pu-238	0.1
Pu-239	0.1
Pu-240	0.1
Pu-241	10
Am-241	0.1

The COCs identified at WL are Cesium-137 (Cs-137), Strontium-90/Yttrium-90 (Sr/Y-90), Plutonium-238 (Pu-238) isotopes, Plutonium-239 (Pu-239), Plutonium-240 (Pu-240), Plutonium-241 (Pu-241), Americium-241 (Am-241), Europium-154 (Eu-154), and Cobalt-60 (Co-60). The relative activity of each isotope is given in Table 2.

Table 2 Relative Radionuclide Activities

Radionuclides of Interest	% of Total Activity
Cs-137	48.8
Sr/Y-90	31.1
Pu-241	13.8
Am-241	3.6
Pu-239+240	2.2
Pu-238	0.34
Eu-154	0.15
Co-60	0.03

The Critical Concentration was determined by appropriately de-rating (or lowering) the UCL for the Cs-137 isotope, based on its relative activity to the suite of nuclides identified. The ScanSort[SM] system can divert soil using the de-rated Cs-137 UCL to account for the sum-of-ratios (SOR) activity for the remaining suite of nuclides. The general SOR formula for use with the UCLs in Table 3 1 is shown as Equation 1.

$$SOR_{UCL} = \frac{Cs-137}{0.1} + \frac{SR/Y-90}{1} + \frac{Pu-241}{10} + \frac{(Pu-239)+(Pu-240)}{0.1} + \frac{Pu-238}{0.1} + \frac{Am-241}{0.1} + \frac{Eu-154}{0.1} + \frac{Co-60}{0.1}$$

The concentration terms used in the numerators of Equation 1 are the concentrations relative to Cs-137. SOR values averaged over a Critical Volume must be less than or equal to 1.0. A SOR of > 1.0 indicates that total activity concentration of the radionuclides of interest (ROI) in the material is greater than the appropriately averaged UCL, and the material represented by that measurement is not in compliance with the release criteria.

The relative isotopic contributions to the UCL SOR, shown in Table 3, were determined using the relative activity levels found in Table 2, and the UCLs listed in Table 1.

Table 3 Relative Isotopic Contribution to Unconditional Clearance Limit Sum-of-Ratios

Radionuclides of Interest (ROI)	Total Activity (%)	Relative (to Cs-137) Activity	Net Activity (Bq/g)	UCL (Bq/g)	Isotopic Contribution to UCL SOR (net activity/ UCL)
Cs-137	48.8	1.00	0.08	0.1	0.800
Sr/Y-90	31.1	0.64	0.05	1	0.051
Pu-241	13.8	0.28	0.02	10	0.002
Am-241	3.6	0.07	0.01	0.1	0.059
Pu-239+240	2.2	0.05	0.00	0.1	0.036
Pu-238	0.34	0.01	0.00	0.1	0.006
Eu-154	0.15	0.00	0.00	0.1	0.002
Co-60	0.03	0.00	0.00	0.1	0.000
		UCL Sum Of Ratios			**0.957**

The SOR approaches 1 (0.96) when the activity concentration of Cs-137 is equal to 0.08 Bq/g. Thus, the Critical Concentration for this SSOP is 0.08 Bq/g Cs-137. If the average net Cs-137 activity concentration measured by the soil segregation system is < 0.08 Bq/g, the SOR is assumed to be < 1, and the soil represented by that measurement is determined to be below criteria (clean).

3. ScanSort^{SM} System

The ScanSort^{SM} system is a unique and efficient radiological instrument used for measuring and sorting bulk soils and soil material. It is the industry leading, state-of-the-science, radioactive soil sorting system consisting of gamma spectroscopy detectors mounted above a conveyor belt, resulting in dramatically improved certainty in the assessment of residual radioactivity in excavated volumes of soil. By confidently and accurately segregating materials with low radioactivity from those that exceed specified limits, the ScanSort^{SM} system is capable of reducing volumes of radiologically impacted materials that require management as radioactive waste to the minimum practicable, while achieving the site's remediation objectives and requirements.

The ScanSort^{SM} system is capable of processing and segregating large volumes of soil with relatively high throughput rates. Commercially available material processors and conveyors are utilized to physically manage the movement and flow of soil. The processors prepare and condition material for scanning, providing "flowable" material, such that it can be placed on the survey conveyor belt and assayed in a technically-qualified manner. The survey conveyor transports the material past various radiation-detecting sensors and provides the physical means to sort material based on detector readings (activity concentration).

The ScanSort^{SM} system utilized four conveyors for the WL Soil Sorting Project; the survey conveyor, the reversing conveyor and two stacking conveyors, the below criteria being a radial stacker. Figure 1 illustrates the general layout of the system components within the soil sorting area.

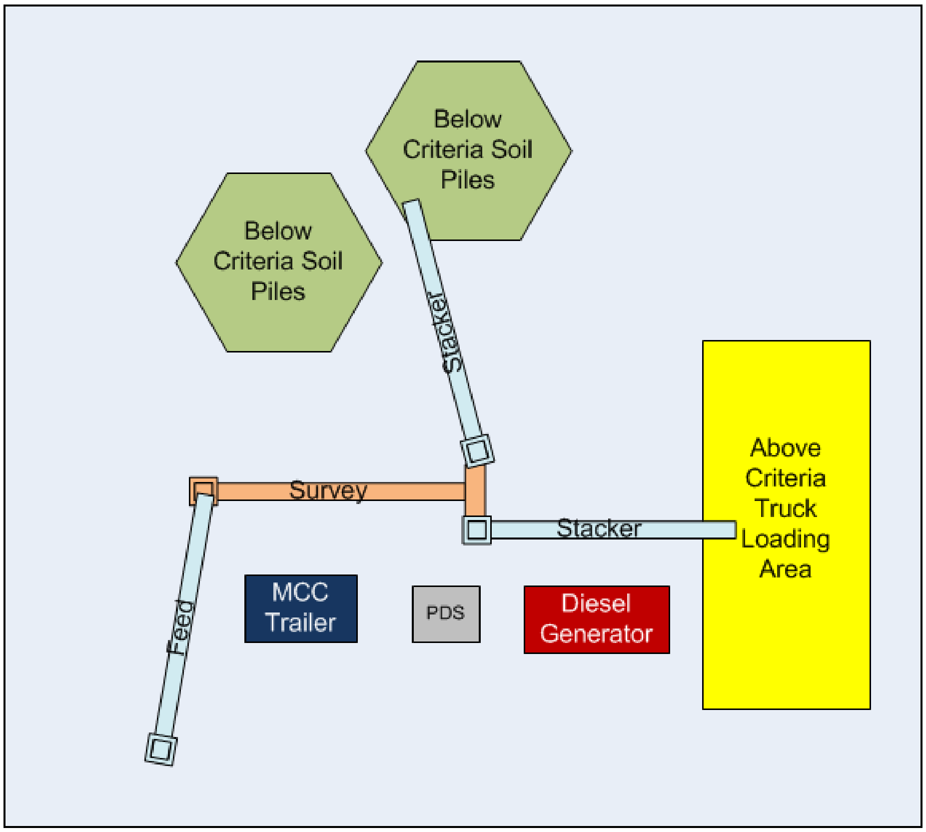

Figure 1 General Schematic of Conveyor System at Whiteshell Laboratories

Calibration to large volumes of site soils with known Cs-137 concentrations was considered the most accurate method of system calibration. Three distinct volumes of soil standard material were collected from locations on site and selected based upon their activity concentration relative to the action level or decision criteria (low, medium, and high activity concentrations). Homogenization of the three standards was performed by repeatedly handling and processing the Standards material through the ScanSort^{SM} system.

In order to account for variability in soil materials on the conveyor and the effects on accuracy of the ScanSort^{SM} system, a real-time mass measurement is performed. The degree of attenuation is sensitive to the variances in the bulk soil density (including the soil moisture content) and the thickness of the soil on the survey belt. This provides continuous measurement of the mass of soil and provides corrections factors that normalize the detectors to their "belt-full" geometry response established during calibration. In this manner, variability in bulk soil density, moisture content, and survey belt fill height are automatically and continuously compensated.

4. Results

The Whiteshell Laboratories soil sorting project consisted of two distinct phases, based on the origin of the material being processed, Cesium Pond material or SMAGS material. Over 2,300 metric tons of Cesium Pond material was assayed and sorted during the Cesium Ponds phase and over 163 metric tons of SMAGS material was assayed and sorted during SMAGS phase.

Measurements taken by the ScanSort^{SM} system were corrected for onsite background radiation levels observed during calibration and throughout the project. More than 65,000 measurements were taken by the ScanSort^{SM} system during this time.

While in the Cesium Pond phase, materials that were determined to be above the diversion control setpoint were discharged to the above criteria side (into waiting dump trucks) and added to the waste pile for waste disposition. Virtually all of the Cesium Pond material was diverted to the above criteria side, only 34 kg out of ~2,300 metric tons were discharged to the below criteria side.

While in the SMAGS phase, materials that were determined to be above the DCS were discharged to the above criteria side (into waiting dump trucks) and added to the waste pile for waste disposition. Over 56 metric tons of SMAGS material (~35%) was discharged to the below criteria side.

5. Conclusion

The WL Soil Sorting Project proved to be successful. The ScanSort^{SM} system collected more than 65,000 high quality radiological measurements and sorted over 2,466 metric tons of staged or stockpiles material. The ScanSort system demonstrated the ability to accurately determine the radioactivity concentrations in radiologically impacted material, and confidently and quickly segregate small volumes of that material for appropriate final disposition.

In addition to the overarching objective, the use of the ScanSort^{SM} system resulted in the opportunity to realize a key advantage. Uniquely, the ScanSort^{SM} system provides a comprehensive and robust characterization of the soil volume processed. On the WL Soil Sorting Project, the ScanSort^{SM} system made approximately 65,000 gamma spectroscopy measurements of the soils surveyed during the project duration. Such a robust and complete dataset engenders confidence that the reported radioactivity concentration in the below criteria soils are within the site's standards and results in a radiologically safe end state for the future use of these soils. Similar to the below criteria soils, the above criteria soils also have this robust and complete dataset generated by the ScanSort^{SM} system. Knowing and understanding the radioactivity concentration of the above criteria soils is essential to ensure that the site's WMA storage facility waste acceptance criteria is not exceeded for the soil being stored there.

6. References

[1] ScanSort^{SM}, Amec Foster Wheeler proprietary system, Grand Junction, Colorado, United States of America.

[2] Canadian Nuclear Safety Commission (CNSC), “Nuclear Substances and Radiation Devices Regulations (SOR/2000-207)”, 2000.