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Title: **Waste Reduction by Separation of Contaminated Soils during Environmental Restoration**

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ABSTRACT

During cleanup of contaminated sites, Sandia National Laboratories, New Mexico (SNL/NM) frequently encounters soils with low-level radioactive contamination. The contamination is not uniformly distributed, but occurs within areas of clean soil. The standard protocol is to excavate the entire volume of soil within the boundary of the contamination. This practice results in the commingling and disposal of clean and contaminated material as low-level waste (LLW) , or possibly low-level mixed waste (LLMW). To reduce the amount of LLW and LLMW generated during the excavation process, SNL/NM is evaluating two alternative technologies.

The first of these, the Segmented Gate System (SGS), is an automated system that locates and removes gamma-ray emitting radionuclides from a host matrix (soil, sand, dry sludge). The matrix material is transported by a conveyor to an analyzer/separation system, which segregates the clean and contaminated material based on radionuclide activity level. The SGS was used to process radioactively contaminated soil from the excavation of the Radioactive Waste Landfill (RWL), ER Site #1, located in Technical Area II (TA-II), and the Open Dump site at Arroyo Del Coyote, ER Site #16. Partial funding ($60K) was obtained from the DOE high Return on Investment (ROI) program to demonstrate the technology at Site #1. Of the 1,270 cubic yards of contaminated soil processed at Site #1, 70.5% was released at clean fill, avoiding $884,000 in disposal costs. (Implementation costs were $200,000). Of the 661 cubic yards processed at Site

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#16, 99% was released as clean fill, avoiding $493,000 in disposal costs. (Implementation costs were $160,500).

Use of the SGS was successful; however, its field application may be limited by one of the following factors: inability to segregate soil with mixtures of some radionuclides, resulting in reprocessing of the same material; and high mobilization (in excess of $100K) and operational costs, requiring accurate waste estimates and previously excavated soils for cost-effective implementation.

The ER project staff identified a second field separation technology that is thought to produce results comparable or superior to that of the SGS. This technology, Large Area Gamma Spectroscopy (LAGS), utilizes a gamma spec analyzer suspended over a slab upon which soil is spread out to a uniform depth. A counting period of approximately 30 minutes is used to obtain a full-spectrum analysis for the isotopes of interest. The LAGS is being tested on the soil that is being excavated from the Classified Waste Landfill (CWL), ER Site #2, located in TA-II.

INTRODUCTION

During cleanup of contaminated sites, Sandia National Laboratories, New Mexico (SNL/NM) frequently encounters soils with low-level radioactive contamination. The contamination is not uniformly distributed, but occurs within areas of clean soil. Because it is difficult to characterize heterogeneously contaminated soils in detail and to excavate such soils precisely using heavy equipment, it is common for large quantities of uncontaminated soil to be removed during excavation of contaminated sites. This practice results in the commingling and disposal of clean and contaminated material as low-level waste (LLW), or possibly low-level mixed waste (LLMW). Until recently, volume reduction of radioactively contaminated soil depended on manual screening and analysis of samples, which is a costly and impractical approach and does not uphold As Low As Reasonably Achievable (ALARA) principles. To reduce the amount of LLW and LLMW generated during the excavation process, SNL/NM is evaluating two alternative technologies. These technologies are the Segmented Gate System (SGS) and the Large Area Gamma-Spec System (LAGS).

SITE HISTORIES

The Radioactive Waste Landfill (RWL)

The Radioactive Waste Landfill (RWL), ER Site #1, located in the eastern portion of Technical Area-II (TA-II) was identified in the Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) as Solid Waste Management Units (SWMUs) #32 through #37. The RWL consisted of three pits and three trenches where low-level radioactive waste was disposed of from 1949 to 1959. The waste was not containerized before disposal, and the unlined pits and trenches did not contain leachate detection or collection systems. During their use, the active pits and trenches were temporarily covered with plywood. The pits and trenches were filled, and then covered with native soil and capped with 3 feet of concrete. Metal pipes were originally installed to mark the corners of the concrete caps. The excavated pits and trenches were estimated to be 15,952 cubic feet and 21,225 cubic feet. No detailed records of waste

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material disposed in the RWL are available. However, US DOE Solid Waste Information Management System (SWIMS) records show that an estimated 11,110 cubic feet of radioactive waste was buried in the landfill, with an estimated total activity of 2,847 curies (Ci).

Excavation of the RWL was completed in late 1996. The waste materials (weapons components, irradiated and neutron activated material, plutonium metal slag, neutron generators, irradiated material from nuclear rocket tests, cobalt sources, cesium-containing gap tubes, radium beryllium neutron pellets and other radioactive material formerly buried at the Coyote Test Field) were removed, containerized and disposed as Low-Level Radioactive Waste (LLW). Radioisotopes consisted of uranium-238, tritium, radium, cobalt-60, nickel-63, cesium-137, strontium-90, and plutonium. The excavated soil was segregated for separate processing.

The Open Dumps (Arroyo del Coyote)

The Open Dumps (Arroyo del Coyote), ER Site #16, is located along Arroyo del Coyote northeast of the access road to Technical Areas III/V. Dumping and quarrying began between 1959 and 1967. The site is no longer active, and access is uncontrolled. Process knowledge indicated that the following were dumped on the site:

- Construction demolition debris from facilities known to have used depleted uranium, such as Building 9939 and the TA-III sled tracks;
- Concrete laser targets;
- Large concrete crucibles used to test concrete-sodium reactions (Building 9939);
- A concrete septic tank
- Piles of fire bricks (2 piles contained asbestos);
- A pile of oil shale and slag dumped between 1983 and 1985;
- Numerous piles of soil apparently from the large excavation to build the TA-V facilities deposited between 1959 and 1967;
- Rocket debris, foam insulation, cans, wood, and rebar;

In January 1994, a visual surface inspection found no unexploded ordinance or high explosives. In February 1994 and June 1996, radiological surveys located 23 anomalies consisting of debris piles and depleted uranium fragments. In November 1994, a photographic interpretation was completed. In May 1995, soil vapor and geophysical surveys were completed with no significant findings. In November 1995, soil samples were taken and analyzed for metals and volatile organics. In March 1995, June, October, and November of 1996 and October 1997 through April 1998, voluntary corrective measures removed all the surface radiation anomalies except two which were determined to be naturally-occurring geologic material.

The Classified Waste Landfill (CWL)

The CWL, ER Site #2, located in the eastern portion of TA-II and covering approximately 2.5 acres, is part of a locked, controlled-access, fenced area. Classified waste, defined as surplus material that by shape or content contains information important to national security, was buried in the landfill from the early 1950s through 1990; however, classified material may have been disposed of in the CWL as early as 1947. The majority of classified waste in the CWL is composed of metal, plastic, and paper. Until 1958, no records were maintained for material disposed of in the landfill. An inventory of the classified material buried prior to June 1972 was apparently destroyed during file purging following a DOE paperwork reduction initiative.

At the CWL, waste material was buried in unlined trenches with no leachate containment or monitoring devices. During disposal operations, the trenches were backfilled one section at a time after waste emplacement, and each section was covered with at least 6 ft of native soil. Steel pipes placed at the end of each section as it was filled were labeled with reference to their location.

Historical information suggests that some tubes (possibly glass) containing nickel and strontium radioisotopes may have been buried in the landfill, as well as other components that may have contained tritium. Lead, PCBs, depleted uranium (DU), beryllium, and chlorinated solvents, including TCE and 1,1,1 TCA, are among the potential contaminants. Other items buried in the landfill include weapon cases, shells, and related components, lasers, furnace parts, radar equipment, aluminum parts, and test panels. Radioactive calibration sources were also buried in the CWL. Some classified material contained gold plating, silver, and platinum; it was often buried if it was associated with classified parts or material. Most items in the CWL are labeled as security containers, hoppers, missiles, skids, and wooden boxes.

TECHNOLOGY DESCRIPTIONS

Segmented Gate System (SGS)

The SGS is a transportable gamma radiation detector system with motorized conveyor belts, a variable belt speed motor controller, air actuated segmented gates, a radionuclide assay computer system, and two sets of radiation detector systems applicable to radionuclides that emit low and high energy gamma rays. The mobile unit includes a material feed conveyor, a sorting conveyor coupled to a motor control unit and material conveyors for below criteria (clean) and above criteria (contaminated) material (See Figure 1).

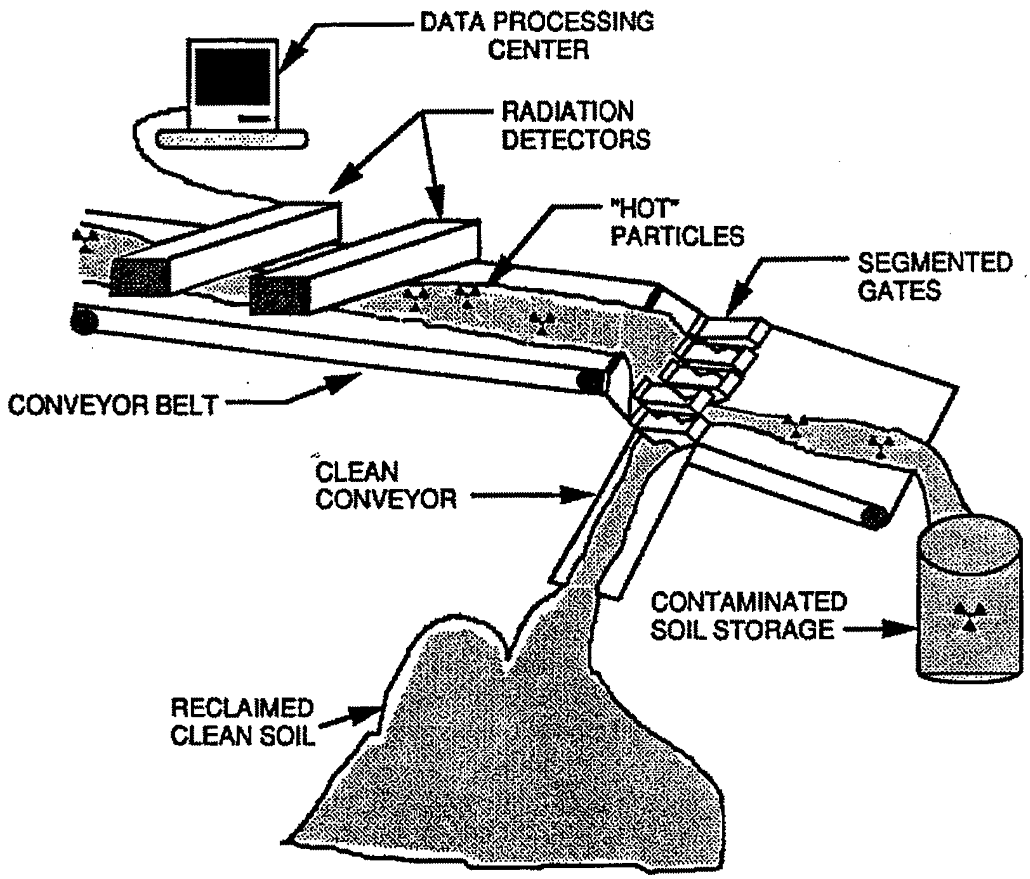

Figure 1. Component Schematic of the Segmented Gate System.

The SGS is controlled through the use of an on-board computer, and a monitor computer console housed in a mobile van adjacent to the unit. Three technicians to operate the conveyor belt systems and monitor soil-processing activities. An on-site health physics technician provides radiation worker safety support.

The process material is screened through a hammermill plant to remove rocks and debris then conveyed underneath the detector arrays at a speed selected for the specific radioisotope of interest and the soil characteristics. These arrays are linked to a control computer, which toggles pneumatic diversion gates located at the end of the sorting conveyor. Contaminated material that exceeds the criteria for radioactive materials is diverted to the contaminated material conveyor, where it is transferred to one of two stacking conveyors. The below criteria material falls directly onto the below criteria conveyor which transports it to the other stacking conveyor (See Figure 2).

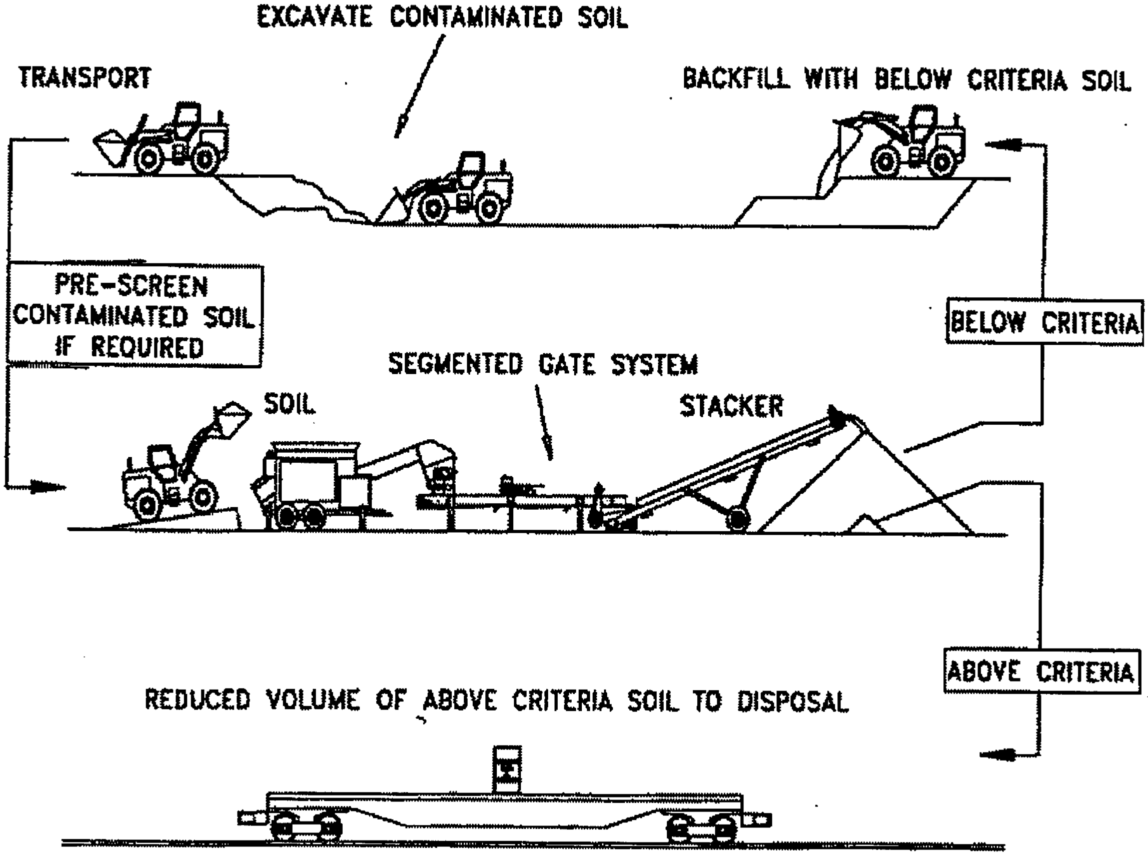

Figure 2. Process Flow for Segmented Gate System.

Two sets of gamma radiation detector arrays are housed in shielded enclosures that can be adjusted vertically above the flat assay conveyor belt allowing for various soil thicknesses. All diversions will divert two or four seconds worth of soil. The detector systems microprocessor obtains a net count from each detector at the end of every count period and sends it to the control computer. The control computer analyzes the shape of the activity peak generated by the signal and actuates the appropriate gate(s).

The control computer records the date, time, activity, gates used, and mass of each contaminated soil diversion. This information is tabulated by the control computer and stored on the internal hard disk for data archiving and report generation. The data is also backed up daily on removable storage media. Upon command the control room computer can generate production reports.

Large Area Gamma-Spec System (LAGS)

The LAGS utilizes a high purity germanium(Li) gamma spectroscopy analyzer system that can be used for routine laboratory sample analysis or used for environmental in-situ analysis of soil in the field. At SNL/NM, an artificial field setup was designed and built adjacent to the remediation excavation of Site #2, The CWL. This design included suspending the germanium(Li) detector over a concrete slab (33 ft by 33 ft) upon which soil from the excavation is spread out to a uniform depth of 3 inches (total batch volume of 10 cubic yards. The soil is counted for a period of approximately 30 minutes to obtain a full-spectrum analysis for the isotopes of interest.

Batch procedures automate sample analysis for the LAGS using Canberra Genie-PC software. The batch procedure used for routine sample analysis prompts the user for sample information, automatically clears the multi-channel analyzer (MCA), acquires a spectrum for the entered live time, saves the spectrum, analyzes the saved file, and prints detailed and summary reports. A similar batch procedure reanalyzes a saved spectrum. This procedure prompts the user for sample information, analyzes the saved file, and prints detailed and summary reports. During analysis of a saved file, a peak search is performed to locate all the peaks in the spectrum. Next, if environmental background subtraction is utilized, the net area of the environmental peaks is subtracted from the sample peaks. The remaining peaks are filtered further to eliminate peaks below a pre-determined critical level. The remaining peaks are matched against a user-defined library to identify candidate isotopes. Candidate isotopes are then corrected for nuclides with interfering lines. Using the sample count time and system efficiency, the peak areas are converted to activity. The calculated peak activities are then decay corrected to the time of sample collection. Lastly, detailed and summary reports are generated which include sample information, activity and the 2-sigma error associated with the isotopes found, and a minimum detectable activity (MDA) value for all nuclides in the library.

In addition, portable germanium(Li) systems have been calibrated for environmental in-situ spectroscopy using the Department of Energy (DOE) Environmental Measurements Laboratory (EML) HASL-258 method. The technique is particularly well suited for quickly determining the level of contamination over a large area, screening for establishment of soil sampling locations, monitoring the progress of cleanup activities, and establishing that acceptable activity levels have been met. Currently, systems are calibrated assuming a uniform depth distribution for the quantification of natural gamma emitters and associated external radiation exposure. During in-situ analysis in a non-standard counting geometry, the user is prompted whether or not to perform a disc source-solid angle correction. For a measurement where the sample approximates a disc source and is counted at a known distance from the detector face, the correction is used to estimate the absolute efficiency of the system to yield more accurate activity results.

Using the Canberra Genie-PC software, batch procedures automate environmental in-situ gamma spectroscopy analysis. The batch procedures written allow for spectrum acquisition, saving of an acquired spectrum, viewing the spectrum collected or acquired on the detector, and analysis of a saved spectrum. During environmental in-situ spectrum analysis, the user is prompted for the number of files to be analyzed, the name of the first file to be analyzed, and the sample information for each file to be analyzed. Next, assuming a uniform source distribution, the program locates spectral peaks, quantifies the peak area, matches the peaks against a user defined library to identify candidate isotopes, and converts peak count rate to radionuclide concentration in activity per unit mass and peak count rate to exposure rate in μR/hr. A detailed summary report is printed which includes sample information, exposure rate, radionuclide concentration, and the 2-sigma concentration error associated with the isotopes found, and a MDA value for all nuclides in the library.

RESULTS

SGS and the Radioactive Waste Landfill (TA-II)

A total of 26 individual soil piles (numbers 1 through 26) were generated from the excavation of the RWL. Additionally soils suspected of plutonium and americium contaminated were placed in Wrangler™ Supersacks™ to prevent spread of airborne contaminants. Pile numbers 4, 15, 20, and 25, and the Supersacks™ (total volume = 1270 cubic yards), were sorted using the SGS. Release limits were based on the Department of Energy (DOE) RESRAD soil Radiological Risk Based Preliminary Remediation Goals (PRG) for volume reduction.).

Pile 4 was sorted by the SGS for U-238, and achieved a 99 plus percent cleanup efficiency (CE). Pile 15 was sorted for Cs-137 with a 98.8 percent CE. Pile 25 was sorted for Cs-137 with a 55.8 percent CE. Piles 20 and Supersacks™ were sorted for Pu-239 with a 25.8 percent and 82.8 percent CE, respectively.

Table 1 shows a breakdown of the soil separation results for the Radioactive Waste Landfill SGS operation.

Table 1. RWL Soil Separation Results

Soil Source	Total Volume (yd^3)	Volume Reduction (percent)	Radionuclide of Interest
Pile 4	51	99+	U-233,234,238
Pile 15	164	98.8	Pu-239,240
Pile 20	151	25.8	Pu-239,240
Pile 25	348	55.8	Cs-137
Supersacks™	556	82.8	Pu-239,240
	Total Volume 1,270 yd^3	Total Volume Reduction 895 yd^3	

SGS and the Open Dumps (Arroyo del Coyote)

At the Open Dumps (Arroyo del Coyote), Site #16, a total of 661.8 cubic yards were processed through the SGS, with an estimated 25 percent additional volume in oversize material, which was not sorted through the SGS. Total volume reduction reported by the SGS was in excess of 99 percent. Actual volume reduction for the first pass was closer to 97.5 percent after accounting for the volume of soil that was sent to the above criteria path due to unscheduled operational halts. Total volume sent to the above criteria path due to unscheduled halts was 15.8 cubic yards.

The 16 cubic yards in the above criteria pile was processed again to remove the soil generated from unscheduled operation halts. This resulted in a total of 0.32 cubic yards (slightly more than one 55-gallon drum) of above criteria soil requiring off-site disposal.

SGS Cost-Benefit Analysis

Table 2, below summarizes the economic benefit realized from using the SGS at the two SNL/NM sites. Two different scenarios are presented. The DOE model uses the DOE Life Cycle Waste Disposal Costs, Source: Avoidable Waste Management Costs, INEL-94/0250, January 1995. The Sandia model uses disposal and shipping costs that the SNL/NM ER project incurs. These costs are nearly three times less than the estimated DOE life-cycle costs. The DOE model should be used to estimate true life-cycle costs, and to standardize savings to compare similar projects at different sites. However, it should be noted that these are estimated savings to DOE, and not to the site. A project manager considering remediation alternatives must be able to justify up-front implementation costs, based only on the project budget.

Table 2. SGS Economic Benefit Summary

	Site #1, Radioactive Waste Landfill	Site #16, Arroyo Del Coyote
VOLUME REDUCTION (yd^3)	895	662
IMPLEMENTATION COSTS	$200,000	$160,500
COST AVOIDANCE		
DOE $988/yd^3$	$884,260	$653,000
SANDIA $340/yd^3$	$304,000	$225,000
[illegible]		
DOE $988/yd^3$	$684,000	$492,500
SANDIA $340/yd^3$	$104,000	$64,500
PROCESSING COST ($/yd^3$)	$157	$242

While use of the SGS saved money for both Site #1 and Site #16, additional funds were required to fund the use of SGS at SNL/NM. This was largely due to the high implementation costs, and the uncertainty of successful site application. Funding ($60K) was obtained from the DOE high Return on Investment (ROI) program to support RWL, and Environmental Restoration Technology Department 6131 provided approximately $140K to Site #16.

A key, determining factor in deciding whether or not to use the SGS is the contaminated soil volume. Despite some operational problems (see below), the processing costs were less (and the cost savings more) at the RWL. This is due to the larger volume of soil processed.

SGS Separation Limitations

The SGS has a proven track record in separating above criteria material from below criteria material. However, it works best in a situation where the contaminant radionuclides are well known and their energy spectra are compatible with the calibration constraints of the system.

A positive example is the experience with the SGS at the Open Dumps (Arroyo del Coyote). The only known radionuclide in the contaminated soils was depleted uranium (U-238). The SGS was calibrated for the spectrum of U-238 and processing began and was completed with no major problem. Examination of the above criteria and below criteria fractions showed a successful operation.

A negative example occurred during the SGS operation on the soils of the Radioactive Waste Landfill (TA-II). It was anticipated that a specific pile of soil was contaminated with radionuclide A. The SGS was calibrated to detect A. Processing began and A was not being seen. However, using a portable gamma-spec system, the soil was scanned and it was determined that radionuclide Z was the main contaminant. The SGS was recalibrated to detect Z and processing continued. When processing was completed, the below criteria fraction and the above criteria fraction were scanned and it was found that A was indeed in the soil and could be found in relative abundance in the below criteria (clean) fraction. The SGS was then recalibrated for A and the below criteria (clean) fraction was reprocessed.

An additional factor inherent in the operation of the SGS in any situation is the mobilization/demobilization cost. To get the SGS onto your site, setup and ready to operate will cost in excess of $100,000.

LAGS and the CWL (TA-II)

In developing the remediation plan for the CWL it was anticipated, from the review of records, that there would be no significant radioactive contamination of the soil. Also, it was anticipated that if there was soil contamination, the potential for multiple radionuclides (U, Th, Pu, Ra, ...) could be high. It was with this in mind that the LAGS was selected as a means for reducing the amount of clean fill material being disposed of as LLW.

To date, all the material that has been removed from the landfill has been in the form of discrete artifacts. As excavation proceeds the artifacts are separated from the soil. The separated soil is sent to the LAGS. The LAGS is used as a means to screen, one batch at a time, 10 cubic yards of this separated soil. If the analysis shows any activity, the batch of soil is then screened by hand to find the hot spot(s). The hot spot(s) are removed and remaining soil is moved to an area reserved for excavation backfill material.

Additionally, the LAGS is being proposed as a means of doing artifact characterization. Correct geometry and counting parameters are being studied to determine the feasibility of determining the radionuclides and their quantities to provide definitive waste characterization data. The remediation activities at the CWL are ongoing and have yet to show any radioactive soil contamination above relevant criteria.

Since the remediation activities at the CWL are ongoing, a cost analysis cannot be completed. However, the following system costs should be noted. The LAGS consists essentially of a high purity germanium(Li) detector at a cost of $40K, a multi-channel analyzer at a cost of $20K, and a computer with software to run the system at a cost of $5K. The total cost for the gamma-spec system less the concrete slab to spread the soil out on is approximately $65K. Additional costs include labor; the technicians to run the system and operators for the heavy equipment to move the soil.

LAGS Separation Limitations

The experience with LAGS at the CWL (TA-II) to date has shown the system to be simple and relatively flexible in its operation. LAGS is well adapted to materials contaminated with multiple radionuclides with gamma emission energies varying over the spectrum. Its potential to be used as a waste characterization system for artifacts excavated is showing promise. A drawback that may be experienced with the system is the batch mode operation that must be used. At the CWL a batch of 10 cubic yards of soil is counted for 30 minutes. Additionally, labor is involved in transporting the soil to the counting pad and spreading it to the required thickness for the counting parameters involved. Once counting is completed, the soil must then be removed and a new batch of soil moved to the pad.

CONCLUSIONS

Even though sufficient data has not yet come from the remediation activities at the CWL to support a complete cost analysis for LAGS, preliminary conclusions can be drawn.

First, both systems work well but work best for different situations. The SGS works best when soils are contaminated with radionuclides of similar emission energy spectra. The SGS has a clear cost benefit analysis when a large amount of contaminated soil is present. The LAGS works best when multiple radionuclides are present. Use of the LAGS is warranted when a small amount of contaminated soil requires processing.

The professional judgment of SNL/NM ER personnel who have done rough calculations indicate that about 1,500 cubic yards of soil for processing is required for a clear cost saving benefit to be obtained for the SGS. Lesser amounts require a thorough cost benefit analysis to be done before a decision to use SGS is made.

Both SGS operations (Radioactive Waste Landfill and Open Dumps) benefited from external funding to subsidize the use of the SGS. Funding ($60K) was obtained from the DOE high Return on Investment (ROI) program to support the use of SGS at the Radioactive Waste Landfill. The use of the SGS at the Open Dumps was proposed and predominantly supported by the Environmental Restoration Technology Department 6131 at SNL/NM. Of the $160.5K used for the SGS, Environmental Restoration Technology Department 6131 provided approximately

$140K and the Environmental Restoration for Technical Areas and Miscellaneous Sites Department 6133 (the SNL/NM organization responsible for the remediation of the Open Dumps) provided the balance. The LAGS operation at the CWL benefited from the free use of the system from the Personnel Monitoring and Lab Services Department 7578 at SNL/NM.

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