UTILIZATION OF RISK-BASED METHODOLOGY AND NON-DESTRUCTIVE ASSAY TECHNOLOGIES TO CHARACTERIZE AND DISPOSTION LEGACY LOW-LEVEL RADIOACTIVE WASTE

J. Wolf
CHMM
Lawrence Livermore National Laboratory
7000 East Avenue, L-623, Livermore, CA 94550

ABSTRACT

A scaled risk and technology based disposition path was developed to characterize and certify Lawrence Livermore National Laboratory (LLNL) legacy waste (LW) for disposal at Envirocare of Utah and the Nevada Test Site (NTS). A combination of LLNL and commercially provided non-destructive assay (NDA) techniques were utilized to characterize waste and facilitate the safe, efficient and cost-effective characterization and disposition of 490 cubic meters of LW in Fiscal Year (FY) 2004. The approach and technologies described in this paper are adaptable to most waste characterization programs and will be utilized to meet future project milestones.

INTRODUCTION

For more than 50 years scientists at the LLNL have been at the forefront of nuclear design, chemistry, physics, biological research, computations, laser development, homeland defense, non-proliferation and stockpile stewardship. Global advances in science and technology came with a local price: 2,500 cubic meters of radioactive LW generated in hundreds of labs by thousands of generators. A new generation of LLNL scientists are challenged to characterize and disposition this LW in the face of accelerated schedules and reduced budgets.

Fig. 1. Aerial photograph of Lawrence Livermore National Laboratory, Livermore California

LLNL LW presents a unique radiological and chemical characterization challenge because it was generated in a research setting, prior to the existence of the rigorous characterization, documentation, and waste management requirements presently in place. Waste was generated by dozens of programs, in hundreds of laboratories by thousands of generators, and placed in packages of all shapes and sizes. The variety, complexity and configuration of the wastes are immense. The very nature of research produces unexpected and unknown results. This differs from most Department of Energy (DOE) LW generated at production facilities, as the mission-related isotopic distributions are uniform.

The diversity and duration of the LLNL mission also contributed to the unique waste management problems. Subsurface contamination from pre-LLNL naval operations, including the burial of waste and the use of solvents, is still being identified and remediated. Often these types of State and Federally regulated chemical wastes were not segregated, and many of them are considered prohibited by many treatment storage and disposal facilities (TSDF). Although chemical constituents were a major component to the overall waste characterization process, this paper focuses on the challenges and solutions developed to address deficiencies in the radiological characterization process.

Past waste characterization techniques facilitated safe storage and management on-site but were not of sufficient rigor to meet the waste acceptance criteria (WAC) of current off-site TSDFs. The lack of defensible radiological data excluded many waste packages from traditional destructive sampling and analysis, as there was insufficient data to adequately assess the potential hazards of opening the packages.

Goals

The ultimate goal of the LW Project (LWP) was to disposition all LLNL LW. To this end, the LWP evaluated current disposal options and given the nature of the waste, determined that the optimal disposal path for the majority of Legacy LLW was at the commercial disposal facility, Envirocare of Utah. Envirocare of Utah was selected because the acceptance process was streamlined and less restrictive than the Nevada Test Site (NTS) waste repository. The Envirocare waste acceptance process is flexible and accommodates waste characterized using data collected following waste generation. In addition, some LW contains State and Federally regulated hazardous chemical contaminants that are prohibited by NTS. The goals of the non-destructive assay program were to:

- Quantify all radionuclides including the errors, both random and systematic;
- Identify and segregate TRU waste for Waste Isolation Pilot Project certification at a future date;
- Identify and segregate waste based on disposal site and/or performance assessment limitations (i.e. greater than Class C (GTCC) and Class A LLW);
- Provide sufficient radioassay data to safely handle and/or open selected waste packages at a future date;
- Identify packages requiring future destructive analysis and/or repackaging;
- Facilitate profile completion and disposition at Envirocare of Utah, NTS and/or other disposal sites;
- Disposition all Class A waste at Envirocare of Utah; and
- Develop characterization strategy with sufficient rigor to disposition of greater than Class A (GTCA) waste at the NTS.

Approach

A risk and technology based disposition path was developed to characterize and certify LLNL LW for disposal at Envirocare of Utah and the NTS. Process knowledge, history of operations, and existing real-time radiography and characterization data were compiled and utilized to segregate waste populations. The quantity and quality of this information served as input to a graded approach in attaining characterization of sufficient rigor to comply with off-site the TSDF WAC. This path forward was implemented by utilizing in-house and NDA techniques, complemented by limited destructive analysis to meet characterization objectives required to complete the waste certification process.

Commercial NDA services were applied to high-risk buildings, generators, and processes where characterization on a package-to-package basis was critical. Initially, the Radioactive and Hazardous Waste Management (RHWM) NDA Unit was used to collect data to screen low-risk buildings, where only qualitative measurements were required to verify existing process knowledge. Later the RHWM NDA Unit was utilized to conservatively quantify contained nuclides to confirm and supplement the records completed by the waste generators.

Schedule considerations greatly affected the development of the approach. The traditional approach of developing a sampling plan, collecting samples, sending the samples off-site for analysis, validating analytical data, and tabulating and interpreting that data would have provided sufficient data, but at a high cost and at a considerable burden to the schedule. This process can take 6-9 months. The LWP needed to think outside the traditional characterization and disposition model for newly generated waste at LLNL. LWP assembled all of the existing information and data and developed a new streamlined approach. Risk was tempered with cost and schedule considerations. In order to meet the aggressive schedule, it was decided to characterize the waste items and request approval for their disposal at Envirocare of Utah. This differs from the current LLNL model for newly generated waste where waste generating processes are evaluated, and a path for disposal is identified and approved by the LLNL Waste Certification Program (WCP) and the NTS disposal site prior to the generation of waste. There is an advantage to this system in some cases, but not when the waste was generated prior to or outside of the approved LLW WCP.

The major technical requirement of the NDA campaign was the low minimum detectible activities (MDA) required of the instrument to make a Class A sort. Quantification of TRU nuclides to less than Class A quantities was essential. The threshold for assay of the sum of the contained TRU nuclides was 370 becquerels (Bq) per gram (g) (10 nanocuries [nCi]/g) to meet the definition of Class A. Typically assay systems are utilized to sort Class C and TRU waste at the 3,700 Bq/g (100 nCi/g) threshold. Not only did the LWP require a defensible, flexible assay system, we required a 10-fold increase in sensitivity over the traditional assay projects throughout the DOE complex. The assay program had to meet Class A detection limits in order to safely send waste to Envirocare of Utah, but had to meet the rigorous quality assurance requirements of NTS thereby allowing waste characterized as GTCA to be accepted at NTS given the other NTS requirements were satisfied.

Budget considerations were a major driver in the development of the risk and technology based radiological characterization plan. The original estimate to assay the LW was $1.5 million. The LWP realized this number was not attainable and would not be funded. Therefore, the resultant approach was required to focus limited funds on the critical waste items. A calculated risk, as a result of reduced assay frequency, was accepted for waste items where the history of operations suggested consistency in the waste generation process and thereby a lower probability of wide variations in the waste stream. The consequence of error if the characterization was not correct would be low for these waste items. An example of a low consequence of error would be exceeding a waste profile limit but not violating the TSDF license limit. Examples of high consequences of error would be exposure to workers collecting samples or repackaging, incorrectly identifying the waste type, not identifying all the reportable nuclides, United States Department of Transportation (DOT) violations and TSDF license violations.

The core of the risk and technology based approach to radiological characterization was the allocation of limited resources to the waste populations requiring the greatest scrutiny. The LWP developed the following plan.

Review of Radiography Data

The first step in the risk-based process was to evaluate existing radiography data to determine the most appropriate path forward for disposition. If the packages had radiography data, then they were assigned into the following categories:

- Repackaging required
- Required segregation of prohibited items
- No repackaging required

Additional chemical and/or radiological characterization were indicated by the radiography results. Although the presence of prohibited items in a waste package had no impact on the radiological characterization, it would necessitate opening the package to remove the item in question. Therefore, defensible radiological data was required for safety reasons. Defensible data was also required if no radiography data was available because opening the packages and conducting a visual inspection of the contents was required to determine if there were prohibited items.

Review of Existing Analytical Data

Evaluation of existing analytical and radiochemistry data was the next step in the waste disposition process. Old and ancillary data was often attached to the waste disposal requisitions (WDR), the waste tracking document generated by LLNL. The existing chemical data often supported categorization of packages for disposal at either Envirocare of Utah or the NTS. Waste packages that were generated from a building known to work with constituents regulated as hazardous either by the State or by the Federal Government, required additional scrutiny. In many instances, destructive analysis was required to confirm the presence of the regulated constituents. If sufficient radiological and chemical data were present, the waste package was readied for certification, shipment and disposition.

Process Knowledge and History of Operations Evaluation

The evaluation of process knowledge and the history of operations review were crucial elements of the risk-based radiological characterization plan. Interviews were conducted with lab employees and retirees who were associated with operations of the individual buildings.
A list of buildings of origin for waste items was compiled from the waste management database. A search was conducted yielding a master list of buildings, rooms and workstations. Complicating this process was that the mission of a particular building, room or workstation changed over the years. Buildings where neither records nor interviews revealed the nature of the activities or material handled there were assigned into the high-risk category. The results were compiled in a working table that documented building, rooms and associated nuclides.

Assignment of Risk

A master table compiled the source of generation, if radiography data was available, and what nuclides were expected or anticipated from specific locations. The overall risk was determined by summing the assigned risk for the nuclides used in the facility and the results of any available radiography data. Risk associated with radionuclides was based on the potential radionuclide inventories associated with each building and the technical challenges of identifying them, combined with the consequence of error if the radionuclides were quantified incorrectly. A high risk was assigned based on the degree that the nuclide inventories could impact safe handling practices, shipping requirements, TSDF requirements, and license limitations. The risks are summarized below and an excerpt from the risk assignment table is in Table I.

- Low risk = presence or potential for natural or depleted uranium, tritium, carbon-14, phosphorous-32, sulfur-35;
- Moderate Risk = presence or potential for enriched uranium; and
- High Risks = presence or potential for transuranic nuclides.

Table I. Excerpt from Risk Assignment Table for Legacy Low-Level Radioactive Waste.

Building	Potential Radionuclide	Operational History	Risk Associated with Radionuclides	Radiography Results	Overall Risk Using Existing Data
A	Uranium Isotopes	Isotope Separations	Low	100% with radiography, 0% failure	Low
B	Uranium and Thorium Isotopes	Chemistry	Moderate	33.33% with radiography, 12.5% failure	Moderate
C	H-3, Cs-137, U-232, U-236, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-243, Cm-244 (All nuclides used at LLNL)	Waste Characterization Laboratory	High	78% with radiography, 56.8% failure	High

The overall risk considered risk associated with radionuclides, plus the percentage of containers that had radiography data and failure rates. The overall risk was at least equal to the risk associated with the radionuclides, but was increased in some instances where there was a high percentage of radiography failures. For instance, a waste package generated from a building that primarily used uranium isotopes that passed 100% during the radiography evaluation, were assigned to a low-risk category. By contrast, waste packages from a materials management vault, where only 20% of the packages had radiography data and 50% failure during the radiography review, were assigned as a high risk. The risk evaluation was carried into the next step in the process: batching for radiological characterization.

Batching Strategy

Batching was completed based on the compilation of the existing analytic data, history of operations, process knowledge, radiography data, and the overall risk assignment. Waste packages were batched by program of origin, building, lab, glove box, specific isotopes, specific generator and specific dates the waste packages were generated. The LWP assumed that waste generated from a specific building, in a specific room, and at similar times contained the same contaminants. The generators did record waste information, including expected nuclides, at the time the waste was packaged. This was used to make the final batching determinations. The batching yielded discrete populations of waste that were carried forward to determine the frequency of assay.

Assay Program and Representative Assay Selection

An assay program that analyzed 100% of the waste packages was not feasible from a budgetary and schedule perspective. The program would have been required to spend millions of dollars and take many months to assay the waste. The program decided to use a tiered approach, assaying different percentages of waste packages depending on the level of risk. Lower risk packages, whenever possible, would be screened with the on-site RHWM NDA Unit. By contrast 100% of waste packages from high-risk buildings would be assayed using rigorous commercial NDA services. In addition, the LWP decided to screen 100% of small parcels (114 liters/30gallons or less) because often times sealed sources and other high-activity items were packaged in these small containers. Table II relates the assigned risk to the assay tool. The table was used as a starting point to evaluate risk, but the percent assayed was increased as needed by the waste coordinator managing a batch of waste items through the characterization process.

Table II. Non-Destructive Assay Tool and Assay Percentage Based on Risk.

Risk	**Assay Instrument**	
	RHWM NDA (Qualitative Screen)	MCS Provided ISOCS/Q2 (Quantitative Assay)
High	Not Applicable	100%
Medium	Not Applicable	20%
Low	10%	10%

The LWP developed the following methodology to select representative samples from waste batches. The LWP decided upon a 90% confidence level when comparing assay data to what was recorded on the waste disposal requisition. The 90% level assumed some risk and is an industry accepted standard of confidence.

1) Determine if container fails based on the correlation of assay data to generator records.

2) Determine if Batch passes the 90% confidence interval via the following, IF

$$\left[\frac{\#SS - \#F}{\#SS}\right] \geq 0.9, \qquad \text{(Eq. 1)}$$

THEN, Batch passes

Where:#SS = Number of containers in randomly selected sample set

#F = Number of containers that fail WDR evaluation

3) If Batch fails based on above, then select additional containers to be screened or assayed to achieve the 90% criteria, per the following:

$$\#AC = [\#F \times 9] \qquad \text{(Eq. 2)}$$

Where:#AC = Number of additional containers
#F = Number of containers that failed WDR evaluation

If (#F x 9) is greater than the number of containers in the batch, the entire batch will be required to undergo screening or assay.

4) Reevaluate whether the given batch passes based on this additional screening or assay per the following:

$$\text{IF: } \left[\frac{(\#SS_1 + \#SS_2) - (\#F_1 + \#F_2)}{\#SS_1 + \#SS_2}\right] \geq 0.9, \qquad \text{(Eq. 3)}$$

THEN: Batch passes
Where: $\#SS_{1 \text{ or } 2}$ = Number of containers in randomly selected sample set 1 or 2
$\#F_{1 \text{ or } 2}$ = Number of containers that fail WDR evaluation in 1 or 2

If the batch fails the second round of screening, then the entire batch was determined to be a failure and a 100% assay was required.

Contract Award

An aggressive schedule was approved to locate and qualify vendors for the NDA project. The procurement process was completed concurrently with the review of existing data and batching as described above. The award was based on the following criteria:

- Demonstrated compliance with the requirements set forth in each part of section 5.0 of the NTS WAC;
- Demonstrated familiarity and compliance with the LLNL Quality Assurance Plan (QAP) and Waste Certification Procedures;
- Ability to assay waste packages to detection limits associated with Class A LLW. Assay to Class A levels is required for United States Nuclear Regulatory Commission Table I and Table II nuclides as appropriate;
- Ability to assay for all the radionuclides listed by the LWP;
- Demonstrated familiarity and experience with the waste acceptance process at Envirocare of Utah and NTS;
- Approval by DOE Environmental Management Corrective Action Plan (EM CAP) program or by a Waste Isolation Pilot Plant (WIPP) certified vendor;
- References from work of similar size and scope (a minimum of three references);
- Quality of the proposed team;
- Quality of the Subcontractor's QAP (must meet the substantive requirements of LLNL QAP); and
- Price per package.

Following an extensive review and interview process, LWP selected Mobile Characterization Services (MCS) to support the LW disposition project. The LWP requested that MCS mobilize a three detector, shielded, Qualitative and Quantitative (Q2) gamma assay system and a tandem of portable In-Situ Object Counting System (ISOCS) gamma assay detector system. The vendor identified that certain isotopes, such as Pu-238 and Cm-244, would be difficult to detect, regardless of count time. Together the LWP and MCS addressed certain deficiencies with the assay technology and developed a characterization strategy of sufficient rigor to meet the requirements of both Envirocare of Utah and the NTS. The ability of MCS to mobilize quickly, provide defensible data obtained through a rigorous quality assurance program, and a proven record of performance was critical to the success of the assay program.

Assay Process

The assay equipment selected provided the LWP with high throughput and also the flexibility to assay multiple packages. The need for commercial, defensible, neutron counting capabilities was evaluated and cost was too high to justify deployment. Instead, the in-house RHWM NDA Unit was selected as a qualitative assay tool to screen for neutron emitters. The assay tools are described in the following sections.

RHWM NDA Unit

The RHWM NDA Unit consisted of 2, sodium iodide detectors and a bank of 10 helium tubes in a 150-millimeter (6-inch) steel and high-density polycarbonate shielded vault. The instrument was designed and assembled in-house by LLNL. This instrument was originally designed to be a qualitative screening tool used for safety evaluations of waste packages. Simple pass/fail functionality was developed, where items were screened and if they contained elevated gamma activity, or more importantly, elevated neutron counts, the packages were not opened or processed in the waste management area without additional controls. The LWP realized that this simple screening process could be adapted to fit the needs of the program. The LWP needed a simple way to qualitatively analyze waste packages to confirm if they contained the isotopes that were recorded on the waste disposal requisition by the generator. The LWP wanted to confirm the process knowledge, and provide confidence and assurance that the waste packages could be shipped to an offsite TSDF with little risk. The program realized that this tool would save the program thousands of dollars compared to robust characterization methods provided by the mobile vender or the in-house LLNL radiochemistry laboratory.

Fig. 2. Dale Hankins completing start-up of the RHWM NDA Unit, a shielded gamma and passive neutron assay unit, Lawrence Livermore National Laboratory, Livermore California.

The LWP developed a methodology to compare the waste assay data from the RHWM NDA Unit to the nuclides listed on the WDR. Screening criteria was established that compared the gamma signatures of the nuclides to those expected from the WDR. LLNL retiree, Dale Hankins, provided the LWP with a spectral fingerprint library of common isotopes that were expected in the waste items (Figure 2). Gamma assay results were compared to the fingerprint library and the contained isotopes were identified. The RHWM NDA Unit was operated with short count times (i.e. < 20 minutes) that facilitated a technically qualified person to quickly verify that the assay fingerprint matched the data recorded on the WDR. The verification was performed on containers equal to or smaller than a 208-liter (55-gallon) drum, which contained no gamma emitters (per the generator), and/or contained moderate to strong nuclides, which were easy to identify with the RHWM NDA Unit (i.e. depleted uranium, natural uranium, cesiums-137, cobalt-60, radium-226).

The RHWM NDA Unit was also used to screen packages/parcels that contained beta emitters as a simple verification step to assure that only beta emitters were present. Quantification of these nuclides was completed either by process knowledge evaluations or through destructive analysis. In these cases, the consequence for characterization error was low and the nuclides were determined to be low-risk per the risk matrix.

If the spectra identified by the RHWM NDA Unit were not recorded on the original WDR or if the activity was significantly higher, the package failed the screening process. The packages were then assayed through either the Q2 or ISOCS units and the entire batch was re-evaluated.

Another important screening feature of the RHWM NDA Unit was that it was also equipped with a passive neutron counter. Therefore, if spontaneous fission nuclides (for example, curium-244) or other alpha emitters (for example, californium-249) were present that would escape detection by the gamma system, these problematic isotopes could be qualitatively identified. If an alpha emitter was listed on the requisition and the RHWM NDA Unit identified no alpha activity, the activity recorded on the WDR was conservatively retained and not modified. If elevated neutron activity was observed, the packages were segregated for further evaluation, as the risk was high based on the risk matrix. If elevated neutron activity was observed, but no alpha emitters were recorded on the WDR, the packages were segregated for rigorous characterization. No definitive statement about the source of the neutrons could be produced; there was no way to correlate the neutron assay results to a quantity of a fissionable nuclide.

Due to the sensitivity of the sodium iodide detectors, the LWP experienced a high failure rate of the screening criteria. Nuclides were regularly detected that were not recorded on the WDR by the generator. The LWP retained the services of Dale Hankins, who designed the RHWM NDA Unit, to develop a methodology to use the instrument to grossly quantify the detected nuclides. The fingerprint library was expanded and a series of measurements were collected to relate the strength of the gamma and the attenuation due to waste type and density of the package. The results of the study yielded correction factors that were used to and produce a conservative estimate of contained radioactivity. These results were updated onto the waste disposal requisitions as appropriate. High-risk nuclides, such as TRU nuclides were not quantified in this manner. Moderate to high-risk packages were not quantified in this manner, only packages with a low consequence of error. This provided added flexibility to the program to not only screen packages, but to conservatively characterize them and bound them within the waste profiles.

The RHWM NDA Unit was a very useful tool, 282 drums were assayed in late FY04. A $100,000 cost savings was realized using the RHWM NDA unit compared to using the Q2 unit with similar assay durations. This estimate assumes that the level of effort to support the commercial Q2 unit and the effort to operate the RHWM NDA Unit were equivalent. In addition, this valuable unit provided needed neutron counting capability with no additional cost to the LWP.

ISOCS

The mobile ISOCS system provided the most flexibility for assaying waste packages of all sizes. Two units were deployed and integrated. This approach allowed a waste package to be assayed simultaneously from two directions, cutting the count time in half. The data was integrated and analyzed with Canberra Industries Inc. proprietary software called NDA 2000, in conjunction with Genie 2000 and In-Situ Object Counting Software.

The ISOCS units consisted of cart mounted, high-purity germanium detectors. The detectors were shielded and collimated, so that the direction of gamma assay was controlled in a specific plane. However, the portability comes with a price, less shielding. The ISOCS and waste items were not shielded as a single unit as is the case with the Q2. Because the project was set-up in a waste storage area, the background was relatively high, at about 160 counts per minute. Normally, subtraction of the background from the final measurement provided results that were acceptable, but because of the low MDAs required the LWP and MCS needed to lower the background in the assay area. The site decided to use surplus wastewater storage tanks to provide necessary shielding (Figure 3). The tanks were already in the storage yard and were filled with city water to provide shielding. After strategically placing the water tanks along the perimeter of the assay area, the background was reduced by 50% to 80 counts per minute. This reduction in background was sufficient to facilitate the reduction in the MDA.

Fig. 3. MCS Technical Supervisor Richard Machado analyzing waste box using tandem ISOCS units, Lawrence Livermore National Laboratory, Livermore California.

Each of the ISOCS detectors was characterized at the Canberra factory prior to shipment to the job site. Canberra completed the characterization using National Institute of Standards and Technology (NIST)-traceable sources and the Monte Carlo N-Particle modeling code. Specifically, the radiation response profile of each individual detector was determined for a 500 meter diameter sphere around the detector over a 45 keV through 7 MeV energy range. The results of this characterization were delivered to LLNL as part of the ISOCS software. When multiple detectors are characterized, all were available for selection by the ISOCS user, and the spectra are summed together. By characterizing each detector, efficiencies were modeled for multiple gamma energies and the data were used to calculate activity levels that factored in the calculated efficiency of the detector along with geometry, density and attenuation factors. No on-site calibration was required; the detectors were evaluated on a daily basis with a check source and a background quality control measurement.

The system proved very useful and over 100 waste boxes (2.7 cubic meters and 1.35 cubic meters) were assayed in FY04. Scaling also proved to be a very effective method to estimate the contribution of gamma emitting and non-gamma emitting TRU nuclides that were contained waste packages. A weapons grade distribution was assumed for waste packages containing Pu-

239. Scaling factors were developed from the known distribution. Results from the easily detectible gamma emitters, like Pu-239 or Am-241, were input into a spreadsheet that would then calculate the activities of the other weapons grade constituents. This lessened the problem of assaying and quantifying hard to detect gamma emitters like Pu-238. This approach assumed some risk, but facilitated reduced count times and subsequently reduced assay costs.

Q2 Gamma Assay System

The Canberra designed Q2 non-destructive gamma assay system was selected for deployment. This instrument consisted of three high-purity germanium detectors enclosed in a 25-millimeter thick, low-background steel vault with an integrated turntable and scale. The main advantage of this instrument was the rapidity in which it met MDA requirements for certain key isotopes, such as Pu-239 and Am-241.

Fig. 4. MCS assay operator Tracy Jue securing drum to Q2 waste assay system turntable, Lawrence Livermore National Laboratory, Livermore California.

The system was calibrated on-site using several calibration drums at densities typically found at LLNL. Six line sources, spanning the height of the drum, were placed in the drums in a helical fashion. Measurements were collected and the assay software used the efficiencies of the detectors as determined in this calibration cycle. The system comes with an integrated scale to provide density data for the 208-liter (55-gallon) drums. This feature was disabled at LLNL and weights collected on scales that are calibrated, inspected and maintained by the WCP were input into the assay program at the time of assay.

The LWP and MCS achieved a reasonable throughput with this instrument. Up to 10 drums were counted in a shift. Others, with key isotopes with low-energy, and low-abundance gammas took significantly longer. Packages with multiple isotopes compounded the difficulties in assaying low-energy and low-abundance gamma rays because of interfaces and higher energy gamma rays that raised the overall "background" of Compton continuum of the spectra. That is, peaks were identified, such as those from Th-232, but the noise from theses gammas prevented quantification of Cm-244 for example, at the extremely low levels that the LWP required. Increasing count times to lower the MDA was implemented whenever practical. MCS calculated count times for these isotopes and evaluate the count times needed to meet the required detection limits. If the projected count time was greater than 8-hours, the assay was terminated. The LWP instructed MCS to provide results for all gamma emitters listed on the WDR and to identify all gamma emissions. To maximize throughput, MCS utilized the NDA 2000 count to MDA feature. The LWP provided key isotopes and the required MDAs for the limiting isotopes to MCS for input into the software. When the instrument counted for a minimum assay time and determined if the MDA had been met. If the MDA was met, the assay terminated, otherwise the software calculated the assay time needed and increased the count time accordingly. This process was repeated until the MDA was met or an 8-hour assay time was reached. This reduced the expected assay durations; assay costs and accelerated the schedule.

In general, the LWP required MCS to assay the waste to 222 Bq/g (6nCi/g) for conservatism. The LWP did not want to violate the Class A license limits of the intended disposal facility. Detection limits of 111 Bq/g (3 nCi/g) were achieved regularly from the contract-required minimum count time of 20 minutes on low-density materials (lab trash).

A limitation of the Q2 used by the LWP was that the instrument could only accommodate 208-liter (55-gallon) drums. This was a function of the Q2 detectors and the calibration method and materials. The instrument was calibrated to one container size. The 208-liter (55-gallon) drum was selected to represent the most common package utilized at LLNL. Had the Q2 been outfitted with ISOCS characterized detectors, any waste package could have been input into the system, provided it could fit inside the shielded vault. The data could then be collected and analyzed with NDA 2000, Genie 2000, and the ISOCS software packages. The detectors would be ISOCS calibrated at the factory and the only source checks and operational checks would be required at the site.

The Q2 unit proved to be very efficient and 95 drums were assayed in August and September of 2004. The same scaling factors were applied to waste assayed with the ISOCS units that were utilized for the Q2 unit, reducing assay durations and subsequently assay costs.

Results

Following a 6-month start-up process involving the approval of the MCS site-specific operating procedures and QAP, LLNL safety basis authorizations, site-specific training, physical delivery and set-up of the equipment, and the calibration cycle, the assay program kicked in and realized the following results:

Assay Totals

- Assayed 100 waste boxes using ISOCS in remainder of FY04.
- Assayed 282 drums using 612 NDA Unit in remainder of FY04.

- Assayed 95 drums using Q2 in remainder of FY04.

Waste Classification
- Approximately 92 percent of waste packages were characterized as Class A LLW.
- Approximately 6 percent of waste packages characterized as GTCA LLW.
- Approximately 2 percent of waste packages characterized as TRU waste.

Production Rates
- RHWM NDA Unit - 8 packages/day.
- ISOCS - 2 packages/day.
- Q2 - 1 to 10 packages/day.

Schedule reduction
- 2-week turn-around-time (TAT) with MCS data, a reduction of the typical 60-180 day TAT for validated results; and
- 1-week TAT for RHWM NDA Unit a reduction of the typical 60-180 day TAT for validated results.

Cost Savings and Cost Avoidance
- Avoided $100,000 in assay costs using RHWM NDA Unit instead of commercial assay services; and
- Reduced overall assay budget from $1.5 million to $600 thousand using the risk-based characterization strategy.

Lessons Learned

Based on the results of the LWP risked-based assay strategy, the following lessons were learned:

- Assay all packages from high-risk processes. Batching was attempted initially in some of the high-risk buildings but after redundant failures the entire population was assayed. This provided increased confidence that the waste was characterized properly and that no incidents involving health, safety or TSDF licenses would be realized.

- Assay all packages containing parts of glove boxes. Batching failed for waste packages containing glove boxes. Because of the nature of work conducted in glove boxes, relatively high levels of contamination were found. Several boxes assumed Class A wastes were later identified as being Class C.

- Assay all packages from waste consolidation projects. Batching was also attempted on waste packages originating from waste consolidation and handling areas. As it was later determined, waste from multiple buildings was packaged into boxes or drums that had void space. Prior to the implementation of the current WCP, it was acceptable to place waste from multiple generators in these packages to consolidate waste and minimize void space. Several boxes assumed Class A wastes were later identified as being Class C. Had 100% assay not been completed, the packages may have been sent to Envirocare of Utah, in violation of their Class A License.

- Request ISOCS characterized detectors for Q2 unit. The combination of the shielded vault and the ISOCS characterized detectors will maximize throughput by reducing count times and provide flexibility to assay packages less than 208-liters (55-gallons).

CONCLUSIONS

The scaled and streamlined, risk-based process facilitated the safe, efficient and cost-effective characterization and disposition 490 cubic meters of LW to meet the aggressive fiscal year 2004 schedule. The approach and technologies are adaptable to most waste characterization programs and will be utilized to meet the fiscal year 2005 schedule. A combination of assay instruments and tiered pricing provided the flexibility needed to assay packages of multiple sizes for gamma and neutron emitters in a cost effective and expeditious manner. Turn around times of two weeks for validated data packages were achieved. The risk-based and scaled approach facilitated the allocation of scare resources to critical waste items and resulted in an overall cost savings from the baseline radiological characterization budget. By developing a characterization program of significant rigor and quality assurance standards to meet the waste acceptance criteria of NTS, LLNL was afforded much flexibility for disposition of waste items that exceed the radiological license limit of the primary disposal facility, Envirocare of Utah

ACKNOWLEDGEMENTS

I would like to thank the scientists, experts, coordinators, analysts, contractors, and support staff that comprise the LW Project team. The selection of assay technologies and the development of the risk-based characterization plan was truly a team effort.

- Trini Cardenas – LLNL, editing, publication
- Edward Chun – LLNL, Clean Harbors, graphics, photography
- Pat Epperson – LLNL, RHWM Deputy Division Leader, editing
- Stephanie Goodwin - LLNL, RHWM Division Leader, editing
- Dale Hankins, LLNL, RHWM NDA Unit designer and spectroscopy
- Rod Hollister – LLNL, TRU Project Leader, technical support, procurement
- Tracy Jue – Mobile Characterization Services, assay operator
- Craig Junio – Consultant, Innovative Waste Solutions, technical support
- Holly Killion– LLNL, lead editor, publication
- Richard Machado – Mobile Characterization Services/Canberra, technical support, management of LLNL/MCS projects, spectroscopy, editing, non-destructive assay expert.
- Ron Michels – LLNL, Quality Assurance Officer, procurement, quality assurance
- David Ochs – Consultant, Shaw E&I, technical support, editing
- Scott Pastor – Consultant, Innovative Waste Solutions, technical support, development of risk-based strategy and development of representative assay selection protocol
- Brian Perkins – LLNL, LW Group Leader, technical support, procurement, development of the risk matrix, editing
- Karen Riley – LW Coordinator, technical support, development of risk-based strategy
- Vicki Salvo – Environmental Analyst, technical support, development of risk-based strategy

DISCLAIMER

AUSPICES

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.