Soil Characterization by Large Scale Sampling of Soil Mixed with Buried Construction Debris at a Former Uranium Fuel Fabrication Facility – 9331

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ABSTRACT

Recent soil excavation activities on a site identified the presence of buried uranium contaminated building construction debris. The site previously was the location of a low enriched uranium fuel fabrication facility. This resulted in the collection of excavated materials from the two locations where contaminated subsurface debris was identified. The excavated material was temporarily stored in two piles on the site until a determination could be made as to the appropriate disposition of the material. Characterization of the excavated material was undertaken in a manner that involved the collection of large scale samples of the excavated material in 1 cubic meter Super Sacks. Twenty bags were filled with excavated material that consisted of the mixture of both the construction debris and the associated soil. In order to obtain information on the level of activity associated with the construction debris, ten additional bags were filled with construction debris that had been separated, to the extent possible, from the associated soil. Radiological surveys were conducted of the resulting bags of collected materials and the soil associated with the waste mixture. The 30 large samples, collected as bags, were counted using an In-Situ Object Counting System (ISOCS) unit to determine the average concentration of U-235 present in each bag. The soil fraction was sampled by the collection of 40 samples of soil for analysis in an on-site laboratory. A fraction of these samples were also sent to an off-site laboratory for additional analysis. This project provided the necessary soil characterization information to allow consideration of alternate options for disposition of the material. The identified contaminant was verified to be low enriched uranium. Concentrations of uranium in the waste were found to be lower than the calculated site specific derived concentration guideline levels (DCGLs) but higher than the NRC's screening values. The methods and results are presented along with a discussion of the implications for ultimate disposition of the material.

INTRODUCTION

Soil excavation activities at a site identified the presence of buried uranium contaminated building construction debris. The site previously was the location of a low enriched uranium fuel fabrication facility. Several trenches were being dug on the site and the trench activity located contaminated debris buried at a depth of about 2 feet below ground level. This resulted in the establishment of two piles of excavated materials from the two locations where contaminated subsurface debris was identified. It was necessary to stockpile the excavated material on the site until a determination was made as to the appropriate disposition of the material.

This paper presents the results of a radiological survey and the soil sampling program conducted to characterize the stockpiled material. Characterization activities included both radiological surveys of the two piles using an In-Situ Object Counting System (ISOCS) to measure the U-235 concentration in 1 cubic meter size bags and also sample analyses of soil by both alpha and gamma spectroscopy methods.

Three different sample sets were taken in this project:

1. Twenty bags of soil and debris that were representative of the "as excavated" material. These were analyzed using the ISOCS system. Conservative U-235 concentrations were assigned to each bag. The bags were Super Sacks of 1 cubic meter volume. When filled, the bags weighed approximately 1,000 kilograms.
2. Ten bags of separated debris that would be representative of what might be shipped off-site if an effort were made to separate the debris from the soil with the intent of leaving the remaining soil on-site. These were analyzed using the ISOCS system. Conservative U-235 concentrations were assigned to each bag. The bags were Super Sacks of 1 cubic meter volume. When filled, the bags weighed approximately 1,000 kilograms.
3. Forty samples of the soil (approximately 800 grams each) that would be representative of what the separated soil concentration would be if the debris was completely separated for disposal and the soil was left on-site. These were counted in the on-site laboratory and four samples were selected to also be counted at an off-site laboratory.

It was found that a complete separation of soil from the building debris would not be realistic due to the varied size of the debris and the clay content of the soil.

SUMMARY OF MEASUREMENTS

Characterization of the excavated material was undertaken in a manner that involved the collection of large scale samples of the excavated material in 1 cubic meter bags. Twenty bags were filled with excavated material that consisted of a mixture of both the construction debris and the associated soil. In order to obtain information on the level of activity associated with the construction debris, ten additional bags were filled with construction debris that had been separated, to the extent possible, from the associated soil. The 30 large samples (approximately 10% of the total excavated material), collected as bags, were counted using an ISOCS unit to determine the quantity of U-235 present in each bag. The measurements were made using a 40% Coax detector placed in a standard ISOCS shield with the 90 degree 2" lead collimator. The detector was located about one meter from the side of the bag. The counting time was 1,000 seconds except for two repeat measurements that used a count time of 3,600 seconds. Each bag was weighed and the average concentration of U-235 (in pCi/g) was calculated for each bag. A number of the measurements were also duplicated for comparison of results. The minimum detectable activity (MDA) reported by the ISOCS system for the bag measurements, and used in this paper, are based on the Currie method for the determination of MDA using the L_D (Limit of Detection) with a 3% Type 1 error and a 3% Type 2 error..

The soil associated with the waste mixture was sampled by the collection of 40 samples of soil for analysis by gamma spectroscopy in the onsite laboratory. Four samples were also sent to an off-site laboratory for additional analysis by alpha spectroscopy. This project provided the necessary soil characterization information to allow consideration of alternate options for disposition of the material. The suspected contaminant was verified to be low enriched uranium.

All references to the uncertainty of a measurement in this paper are for the 2 sigma or 95% confidence level.

ISOCS MEASUREMENT RESULTS FOR BAGS

Each of the 30 bags was counted at least twice on opposite sides of the bags. Measurements were made on two sides of each bag as a means to determine the homogeneity of the material contained in each bag. Additional measurements were made for other reasons such as duplication of measurements, recounts when it was determined that the instrument gain shifted for the original measurement, or for longer count times in two cases. Most of the measurement results were less than the MDA for the measurements.

(Approximately 60% of the ISOCS measurements resulted in a "not-detected" result for U-235 and only seven measurements were greater than the MDA.) For comparison purposes, a conservative approach was taken to assigning a U-235 concentration to each bag where the higher of either the measurement result or the measurement MDA is used as the conservative value of the result. Then the average of the results for the two sides was calculated and this value is used as the concentration for that bag. This conservative approach was used because the purpose of the measurements was to demonstrate that the excavated material was less than either or both the Waste Acceptance Criteria (for disposal) and the site specific DCGLs (if left on site). This approach results in assigning a higher concentration than would actually be present but is acceptable for the stated purpose.

Comparison of Results for Different Contaminated Zones

Figure 1 provides a comparison of the U-235 concentration for the waste materials in the two piles of collected excavated material. The results have been arranged from lowest to highest. This comparison is made to determine if there is any significant difference between the waste materials that were excavated from two different locations on the site. There were 15 bags loaded with waste (10 bags of soil and 5 bags of separated debris) for each of the two soil piles. From the graph, it is evident that there is no significant difference in the average U-235 concentration for the two soil piles. A formal statistical comparison between these two sample populations is not appropriate because each of the two sample populations contain bags with different waste materials (soil or soil plus debris).

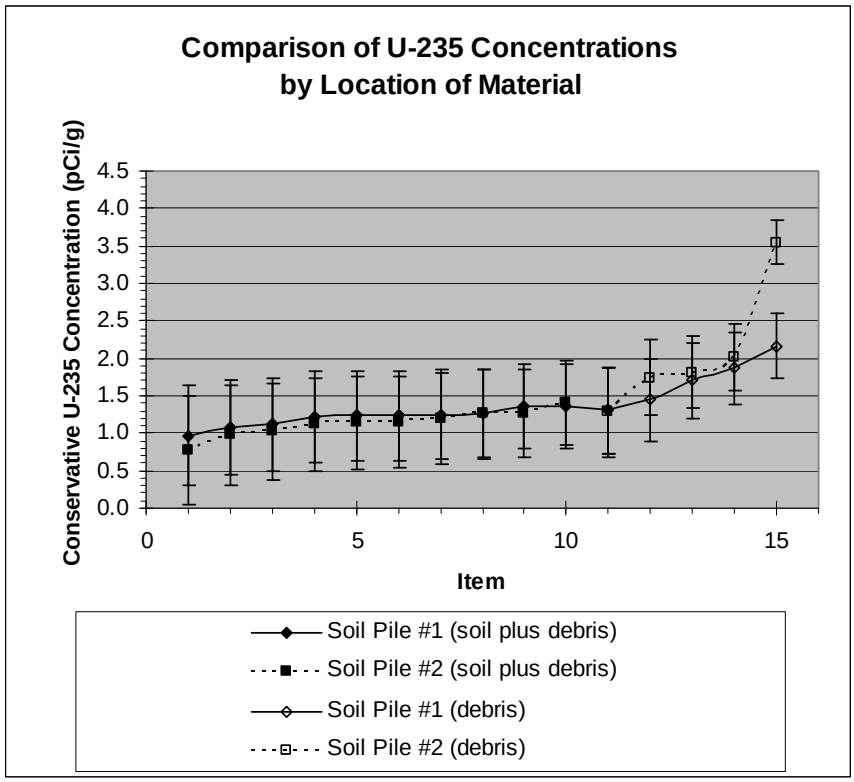

Figure 1: U-235 Concentration in soil/rubble mixture for each stockpile

Comparison of Results for Different Bag Contents

Of the 30 bags, 20 were loaded with excavated material (a combination of soil and debris) and 10 were loaded with debris that had been separated from the soil to the extent possible. Figure 1 also provides the

comparison of the U-235 concentration for these two waste components where the results have been arranged from lowest to highest. This comparison is made to determine if the concentration for bags of separated debris would result in a waste stream that would require a different disposal pathway than for the un-separated waste material.

The difference in the average U-235 concentration is 0.72 pCi/g between the bags that were loaded with separated debris and those loaded with the "as excavated" soil and debris. There is a significant difference between the concentrations of U-235 in the two types of bag contents. The t-value (Student t-test) for these two piles is calculated to be 3.4 (Critical t-value = 2.26 for a two tailed test) which demonstrates that the soil in the two piles do have significantly different concentrations of U-235 present at the 95% confidence level.

Comparison of Results for Different Sides of Bags

Figure 2 provides a comparison of the measurement results for the two sides of each bag. These plotted values are based on a conservative average concentration of U-235 (pCi/g) where the higher of the measurement result or the measurement MDA is plotted. The package exhibiting the largest difference between the two sides is bag #08 which contained separated debris. The maximum ratio between the two sides is about a factor of four. A difference between the two sides should be expected because of the inhomogeneous nature of the waste material, especially for those bags that are filled with the separated debris. The largest ratios between the side A and B for the bags are for Bag #07 (ratio = 2.48) and Bag #08 (ratio = 3.80). Both of these bags were filled with the separated debris. For Bag #07, side A has a measured value of 5.05 with an uncertainty of 26.56% and for side B the measured value is 2.04 with an uncertainty of 37.33%. For this comparison, the z value is 2.06 with z-critical = 1.96. Therefore, these two measurements are significantly different at the 95% confidence level. For Bag #08, side A has a measured value of 2.73 with an uncertainty of 32.22% and for side B the measured value is 0.719 with an uncertainty of 68.84%. For this comparison, the z value is 1.72 with z-critical = 1.96. Therefore, these two measurements are not significantly different at the 95% confidence level. For all the other bags the difference between the two sides is not statistically significant. However, the reported results were deliberately selected on a conservative basis such that both sides may be the MDA value. This artificially makes the comparison look better than it might if actual measurement results were available for both sides. This data does establish that the contents of the bags were uniform within the uncertainty of the measurements with the bags of debris showing the largest variation between sides. Depending on the criteria to be met, it may be possible that future measurements could be made on only one side of a bag with reasonable certainty that the measurement on one side is reasonably representative of the average contents of the bag.

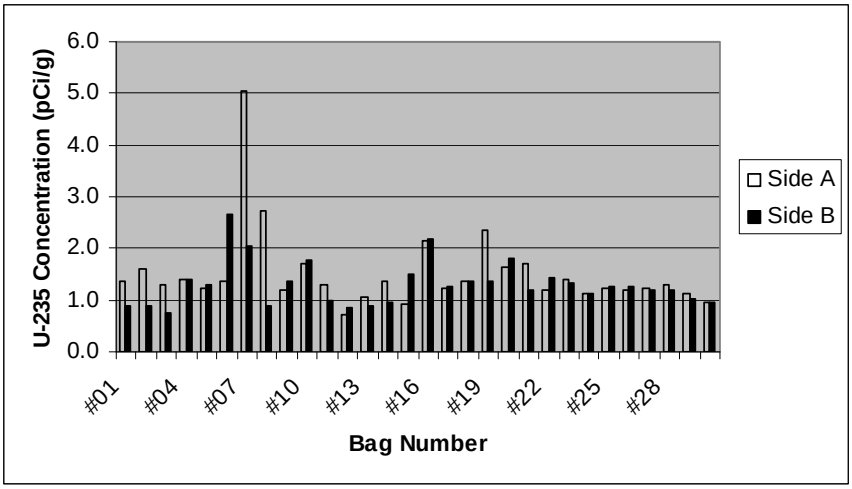

Figure 2: Comparison of Measurement Results (pCi/g of U-235) for Sides A and B of Each Bag

Comparison of Duplicate Count Results

Table 1 provides a comparison of the original and recount data for some of the sides of the bags. The recount results are comparable to the original data. Statistically the recount data for these bags is not significantly different from the original measurement. For example, measurement #06B has an original value of 2.65 with an uncertainty of 38.71% and the recount is 1.42 with an uncertainty of 51.10%. For this comparison, the z value is 0.93 with z-critical = 1.96. Therefore, these two measurements are not significantly different at the 95% confidence level.

Table 1: Comparison of Original and Recount Data for Bags

Bag #/Side	Original Data (pCi/g for U-235)	Recount Data (pCi/g for U-235)		
06B	2.65	1.42		
07A	5.05	3.72		
07B	2.04	1.63	1.87	1.76
08A	2.73	2.04		
09A	0.68	0.55		
11B	0.65	0.61		
15A	0.65	0.59		

SOIL SAMPLING AND ANALYSIS OVERVIEW

Forty soil only samples were taken from the two stockpiles (twenty samples from each). These samples would be representative of what would remain if the rubble were completely separated from the excavated material. These samples were analyzed by gamma spectroscopy using the on-site laboratory counting system. Splits from four of the samples of the separated soil were also sent to an off-site laboratory for a more detailed radiochemical analysis using alpha spectrometry. These four samples were chosen by selecting the highest two results from the on-site laboratory analysis for each of the two piles.

Samples were taken from each pile essentially using a grid pattern with a random start point. The samples weighed on average approximately 800 grams and were collected in a 500 ml jar. The samples were counted in the on-site laboratory by placing the jar in direct contact with the HPGe detector for a 1,800-second count time. These on-site laboratory measurements results are therefore based on the wet weight of the sample. For the off-site laboratory analysis of four selected samples, a 20-gram split of the sample volume was sent to the laboratory and analyzed. Those results are reported on the dry weight basis.

Results of Gamma Spectroscopy Analysis by the On-Site Laboratory

The results of the gamma spectroscopy analysis conducted in the on-site laboratory are presented in Figure 3. From the figure, it is apparent that there is a significant difference between the concentrations of U-235 in the two piles that represent soils that were excavated from the two different locations on the site. The t-value (Student t-test) for these two piles is calculated to be 8.6 (Critical t-value = 2.06 for a two tailed test) which demonstrates that the soil in the two piles do have significantly different concentrations of U-235 present at the 95% confidence level. The average U-235 concentration is 0.176 pCi/g for Soil Pile #1 and 0.402 pCi/g for Soil Pile #2. The average concentration of all 40 soil samples is 0.29 pCi/g for U-235. This average U-235 concentration of 0.29 pCi/g is lower than the ISOCS measurements of the bags as would be expected since the soil samples do not include the rubble material that is included in the bag measurements..

The data in Figure 3 might seem to be in conflict with the data shown in Figure 1 since Figure 3 indicates that the two soil piles are different whereas Figure 1 indicates the two piles are the same. There is no conflict between the figures. Figure 1 shows the results for field measurements of the large bags containing either soil and debris or debris only. These measurements were made using the ISOCS unit that has an average measurement MDA of 1.35 pCi/g. Figure 3 shows the measurements that were made on soil only samples from the two piles. These measurements were made using a laboratory counting system with a better discrimination capability. Thus, there is no conflict between the figures because the two figures are measurements of different materials. Also, the field unit did not have an adequate discrimination capability (MDA = 1.35 pCi/g for U-235) to have ever been able to detect the difference shown in Figure 3 for the soil measurements.

These soil samples were taken by hand to determine what the residual soil of enriched uranium would be if a 100% separation of the soil from the debris could be obtained. Field experience indicated that such a complete separation would probably not be feasible.

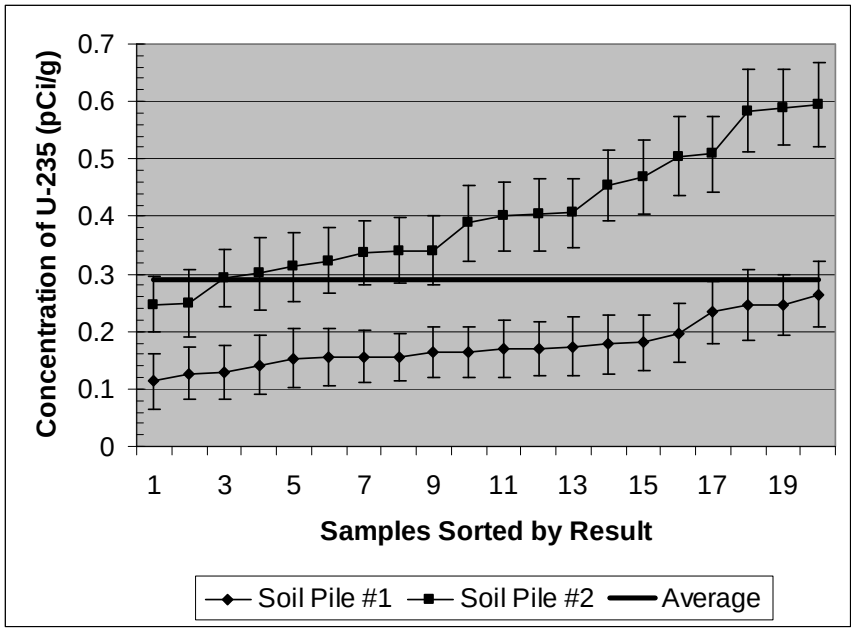

Figure 3: Gamma Spectroscopy Results for U-235 Concentration Measurements for Soil Fraction

Results of Alpha Spectrometry Analysis by the Off-Site Laboratory

The results for the five samples are presented in Table 2 including the comparison with the onsite measurement for that sample. Statistically the U-235 results for these samples are not significantly different between the off-site and on-site laboratory measurements. For example, Sample #195 (the largest difference) has an on-site measurement result of 0.59 with an uncertainty of 0.067 and the off-site measurement result of 1.14 with an uncertainty of 0.537. For this comparison, the z value is 0.0.71 with z-critical = 1.96. Therefore, these two measurements are not significantly different at the 95% confidence level

Table 2: Results of Offsite Soil Sample Measurements & Comparison with Onsite Results

Sample Identification		**Offsite Laboratory Result**			**Onsite Measurement**	**Ratio of U-235 Results**	**Enrichment**
Number	Location	U-234 (pCi/g) (dry weight)	U-235 (pCi/g) (dry weight)	U-238 (pCi/g) (dry weight)	U-235 (pCi/g) (wet weight)	Onsite/Offsite	% U-235
195	Soil Pile #2	9.61	1.14	2.97	0.59	0.52	5.64%
199	Soil Pile #2	11.4	0.7	3.74	0.595	0.85	2.83%
210	Soil Pile #1	4.97	0.206	1.32	0.265	1.29	2.37%
216	Soil Pile #1	3.75	0.272	0.978	0.246	0.90	4.15%
Average		7.43	0.58	2.25	0.424	0.89	3.75%

Several comments on these results shown in Table 2 are appropriate:

1. The average U-235 concentration of 0.58 pCi/g for the four off-site laboratory measurement results is higher than the average for the 40 on-site laboratory measurements (0.29 pCi/g) of Figure 3 because the four samples were a biased selection of the higher results from the 40 gamma spectrometry results.
2. The comparison between the on-site and off-site laboratory measurements of the U-235 concentration is good with the ratio (on-site/off-site) ranging from 0.52 to 1.3 with an average ratio of 0.89. The difference between the reported results is probably due to two factors: 1) the on-site results are reported on a "wet basis" and the off-site results are reported on a "dry weight" basis, and 2) the off-site sample was a split from the original.
3. The enrichment level of the uranium calculated using the off-site laboratory analysis data is consistent with low enriched uranium as expected from historical information. For the separated soil material, the average is about 3.8 percent U-235.

COMPARISON AGAINST SITE RELEASE CRITERIA

The measured enrichment level of the uranium (see Table 2) is consistent with what was anticipated based on historical information with an average value of about 3.8 percent U-235. Based on the calculated surrogate DCGL for U-235 of 12.7 pCi/g, all of the excavated material is lower than the site-specific unrestricted release criteria, but the waste material is not less than the NRC screening value for unrestricted release (approximately 0.68 pCi/g for U-235). The calculated site specific DCGLs and the NRC screening values (provided in NUREG-1757, Volume 2, Appendix H) are given in Table 3. The average U-235 concentration for the soil only fraction is less than the NRC screening value but it is unlikely that such a clean separation of soil from debris is cost effective.

Table 3: Comparison with Soil Release Criteria

Uranium Isotope	NRC Screening Value (pCi/g)	Proposed Site Specific DCGL (pCi/g)
U-234	13	343
U-235	8	60
U-238	14	181
U-235 as Surrogate (for 3.8% enriched uranium)	0.68	12.7
Concentration of U-235 in soil fraction of waste	0.29	
Concentration of U-235 in mixture of soil and debris	1.17	

The surrogate DCGL for U-235 was calculated using the following equation:

$$DCGL_{235,mod} = \{1/DCGL_{235} + f_{234}/DCGL_{234} + f_{238}/DCGL_{238}\}^{-1}$$

Where:

$DCGL_{235,mod}$ = the modified DCGL for U-235 to account for the total activity
$DCGL_{234}$ = the established DCGL for U-234 as a single radionuclide
$DCGL_{235}$ = the established DCGL for U-235 as a single radionuclide
$DCGL_{238}$ = the established DCGL for U-238 as a single radionuclide
f_{234} = the activity ratio of U-234 to U-235 (= 12.8 for this uranium)
f_{238} = the activity ratio of U-238 to U-235 (= 3.9 for this uranium)

For 3.8% enriched uranium the U-235 contributes only about 6% of the total activity. Therefore the calculated $DCGL_{235,mod}$, or surrogate DCGL for the U-235, is much lower than the DCGL for U-235 calculated for the single radionuclide.

CONCLUSIONS

Survey results for the average concentrations for the various material fractions are presented in Table 4. These results are considered conservative since concentration estimates for each sample bag were conservatively assigned.
Attempting to separate out the debris did not result in a large increase in the concentration of U-235 in the packaged waste (about 0.72 pCi/g U-235).

Table 4: Summary of Results

Material Category	**Conservative Average Concentration of U-235 (pCi/g)**
Debris and Soil	1.17
Debris fraction	1.89
Soil fraction	0.29

The concentration of U-235 in the soil was measured by both gamma spectroscopy (on-site laboratory) and alpha spectroscopy (off-site laboratory) systems. For those samples where direct comparison is possible, the results from the two measurements gave excellent correspondence within the differences of the two methods.

Based on the results of this sampling program, the remaining unexcavated material could be left in place since the concentration of licensed material is less than the site specific DCGLs which have been calculated. This option would of course require the approval of the Regulator. If the conservative NRC screening values were used as the release criteria, the excavated material would not meet those criteria.

If excavated, the soil and rubble mixture can be disposed as BSFR material (Bulk Survey for Free Release). This conclusion is based on discussions with possible vendors.

Separation of the contaminated building rubble from the soil does not seem to be a cost effective approach at this time but this option will continue to be evaluated as final decisions are made as to the disposition of the waste material.