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TECHNICAL NOTE
BIL-5148-TN-001

An NDA Technique for the Disposition of Mixed Low Level Waste at the Advanced Mixed Waste Treatment Project

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ABSTRACT

Bechtel BWXT Idaho, LLC (BBWI) manages the Advanced Mixed Waste Treatment Project (AMWTP) for the U.S. Department of Energy Idaho Operations Office (DOE-ID). The AMWTP is aggressively characterizing and shipping transuranic (TRU) waste to meet the DOE-IDs goal of 6000 m^3 of TRU waste to the Waste Isolation Pilot Plant (WIPP). The AMWTP shipping schedule requires streamlined waste movements and efficient waste characterization. Achieving this goal is complicated by the presence of waste that cannot be shipped to WIPP. A large amount of this waste is non-shippable due to the fact that no measurable TRU activity is identified during non-destructive assay (NDA). Waste that falls into this category may not be load managed to WIPP but instead must be shipped to an alternative, low-level waste, facility. Since the vast majority of waste at the AMWTP is classed as hazardous the choice of facility is essentially limited to Envirocare of Utah. When shipping waste to Envirocare the primary issue from an NDA perspective is to demonstrate that the waste contains less than 10nCi/g. This level is significantly lower than the 100nCi/g that is typically used as a decision point for TRU waste shipments to WIPP. Most NDA systems that are used to characterize TRU waste for WIPP have a lower limit of detection (LLD) that is below 100nCi/g but not low enough to meet the 10nCi/g level required by Envirocare. An analysis technique that qualifies waste for disposal at Envirocare using existing gamma-ray spectral data, collected during WIPP characterization, has been developed and successfully implemented at the AMWTP.

INTRODUCTION

The LLD associated with gamma-ray spectroscopy based NDA systems is dependent on several factors. Some of these such as the matrix attenuation, interference from other radionuclides, and nuclear data cannot be controlled by system design. Others, such as detector efficiency and count time can be controlled. A reduction in the LLD may be achieved by either increasing the detection efficiency or by increasing the data acquisition time of the measurement. Both of these methods, while simple to implement, do have other consequences that must be considered. The cost associated with increased detection efficiency can be quite high and the high efficiency may also degrade the high-end response of the system. Increasing the data acquisition time may have an unacceptable impact on the production throughput to the NDA system. Baring in mind these two constraints together with the fact that a large number of NDA measurements have been made at the AMWTP which fall below the established LLD, the bulk analysis technique described here was developed and successfully implemented.

The analysis technique combines spectral data associated with a group of individual waste containers and provides a single radioassay report for the entire group. The spectral analysis and the NDA algorithms that are applied to the composite spectrum are the same as those that are applied to individual assays. The technique takes advantage of the improved counting statistics associated with the combined spectral data. It has several distinct operational advantages; it is simple to implement, it does not require a specific calibration, it uses algorithms and a calibration that have withstood the rigorous review associated with WIPP certification, and it may be applied to existing data.

TECHNICAL BASIS

The technical basis for this analysis technique is quite simple; to reduce the LLD, the counting statistics must be improved. Typically, this improvement is achieved by either increasing the data acquisition time or by increasing the detection efficiency. However, since neither of these approaches may be applied after the spectral data is acquired, and they both require system modifications, a slightly more novel approach is required. The method used at the AMWTP involves a channel-by-channel summation of the spectral data associated with a group of waste containers, which individually have assay values that are below the LLD. The resulting spectrum, referred to as the composite spectrum, is then treated in the same way as any other spectrum acquired during the assay of an individual container.

Conceptually this approach may be viewed as a single assay event associated with a *virtual* waste container. The number of physical waste containers that are combined in the analysis defines the size of the virtual waste container and also the number of detectors that were used to assay it. To simplify the subsequent data analysis, it is assumed that the data acquisition time associated with the assay of the virtual waste container is the same as the data acquisition time associated with the individual assay events. In principle there is no limit to the number of waste containers that may be combined using this technique. However, once the counting statistics have been improved to the extent that a quantitative analysis is possible the advantages associated with adding in more containers are limited.

A review of the theory associated with the limits for qualitative detection, as presented by Currie [1], provides a useful formalization. This formalization introduces the *critical level*, L_C and the *detection limit*, L_D. The detection limit is typically referred to as the LLD in NDA applications. The required level of confidence that a measurement exceeds the critical level defines the detection limit. The required level of confidence that a background measurement is less than the critical level defines the critical level. This concept is best presented graphically as shown in fig. 1.

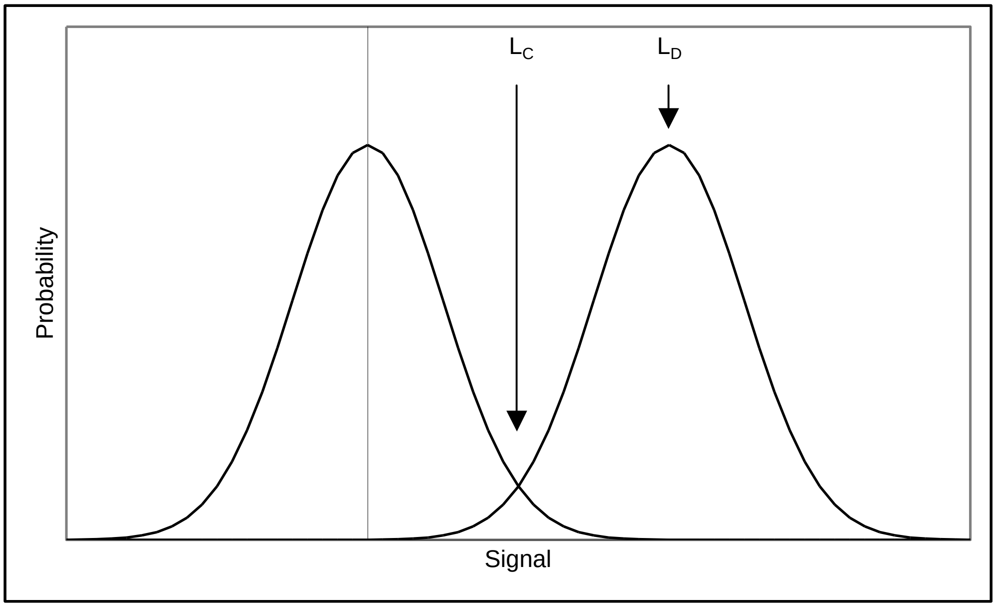

Fig. 1. The relationship between the critical level, L_C and the detection limit, L_D.

Equations 1–3, taken directly from Currie's paper, provide a basis for the variation in the LLD as a function of the observed background when the confidence limits $k_\alpha = k_\beta = k$ and Poisson statistics are assumed. Where, σ_0 is the standard deviation when the observed signal is zero and σ_D is the standard deviation when the observed signal is equal to the LLD. These equations are given here without proof and the reader is encouraged to refer to the referenced paper for a more in-depth discussion.

$$L_C = k_\alpha \sigma_0 \quad \text{(Eq. 1)}$$

$$L_D = L_C + k_\beta \sigma_D \quad \text{(Eq. 2)}$$

$$L_D = k^2 + 2k\sigma_0 \quad \text{(Eq. 3)}$$

In cases where the standard deviation in the background is large compared with k it is clear that the LLD is proportional to the uncertainty in the background. Figure 2 gives a graphical representation of how the LLD varies as the number of containers subjected to the bulk analysis technique increases. These graphs were developed based on the assumption that each of the containers considered in the group has a net weight of 30kg and an LLD of 1μCi TRU activity. It can be seen that as the number of containers in the group increases the LLD in terms of TRU alpha activity (μCi) increases as a function of the square root of the number of containers. However, due to the fact that the net weight of the group increases as a direct function of the number of containers, it can be seen that the LLD in terms of the TRU alpha activity concentration (nCi/g) is reduced as the number of containers increases.

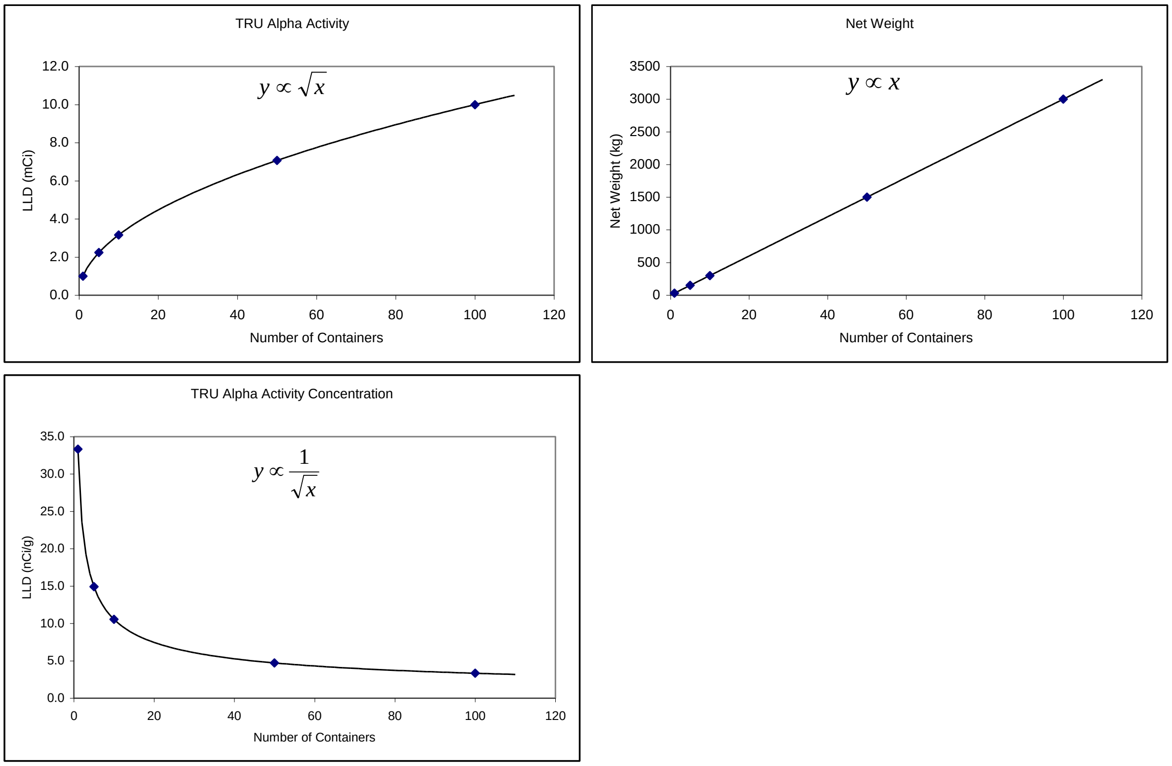

Fig. 2. The relationship between LLD and the number of waste containers analyzed.

VALIDATION

It is clear that the theory supports the application of this technique to reduce the LLD associated with a group of waste containers. However, in order to validate that the technique provides meaningful results in practical applications a series of validation exercises were designed and implemented. The validation exercises that have been completed to date include the analysis of several groups of drums that contain known quantities of various radionuclides. These known quantities were obtained in one of two ways; either from individual assay results of waste containers, or from the known quantity of source material within drums that are used for instrument performance checks. In both of these exercises the sum of the individual quantities compared very closely with the analysis result obtained from the spectral summation technique.

Although it is clear that any background effects would be considered conservative with regards to qualification of the waste for shipment to Envirocare. We have also applied the spectral summation technique to several groups of background spectra in an attempt to quantify the effects of the environmental conditions at the assay location. In each case no significant TRU activity was observed in the composite spectrum. For this reason, it was concluded that the analysis results could be used without applying any form of background subtraction.

WASTE SELECTION

Containers of waste are selected for this spectral summation technique if they fall below the LLD of the instrument on which they were measured. Additional selection and grouping has also been applied based on the waste matrix type, non-TRU radionuclide contents, and the generator site of origin. The waste matrix types are first separated into debris and non-debris to help ensure a reasonable level of homogeneity across the group. Further sub groupings are then defined so that similar waste matrix types are analyzed together. For example, newly generated debris waste from the AMWTP box-line is one such sub-group. Waste drums containing high levels of non-TRU isotopes such as depleted uranium have been grouped separately due to the impact that they have on the background in the key spectral regions associated with TRU radionuclides. We have also separated waste that contains primarily heat source plutonium from that which contains primarily weapons grade plutonium.

In addition to these basic waste selection practices we have also carried out a review of each individual spectrum to ensure that any radionuclides, whether TRU or not, that are observed and quantified in the individual spectra are reported.

IMPLEMENTATION

The application of this spectral summation technique requires a high level of control over the instruments that are used to collect the raw spectral data. In this respect we were fortunate to be using existing data that was acquired under the very strict measurement protocol required by WIPP. This protocol requires daily checks of the systems response with regards to detection efficiency, spectral resolution, and amplifier gain. In addition to the performance checks required by WIPP we also implement a short *standardization* measurement prior to each waste assay that further confirms the stability of the measurement system. These controls ensure that there is no significant unrevealed drift in the spectra that may spread out photopeaks in a composite spectrum. During the spectral summation process an algorithm is used to correct for small differences in the energy calibration that may occur when data from two or more different systems are used. This allows for the broadest application of the technique without having to group data by the instrument on which it was acquired.

Figure 3 shows the 414keV region of the gamma-ray spectrum that is to quantify Pu-239. The four spectra represent data acquired from a single container during a 700 second acquisition, and composite spectra that represent summation of 10, 50, and 100 such spectra. It is clear that in the case of the single spectrum and the 10 spectra composite no quantifiable 414keV photopeak is observed. However, as the number of spectra included in the composite spectrum increases it is clear that the 414keV photopeak is observed at a level that does allow for quantification. In this example the average LLD associated with the individual drums is in the region of 20 to 30 nCi/g. Following the summation of 50 or 100 such spectra the LLD is reduced to between 4 and 5 nCi/g, this reduction has allowed for the quantification of the TRU activity at a level of approximately 8 nCi/g.

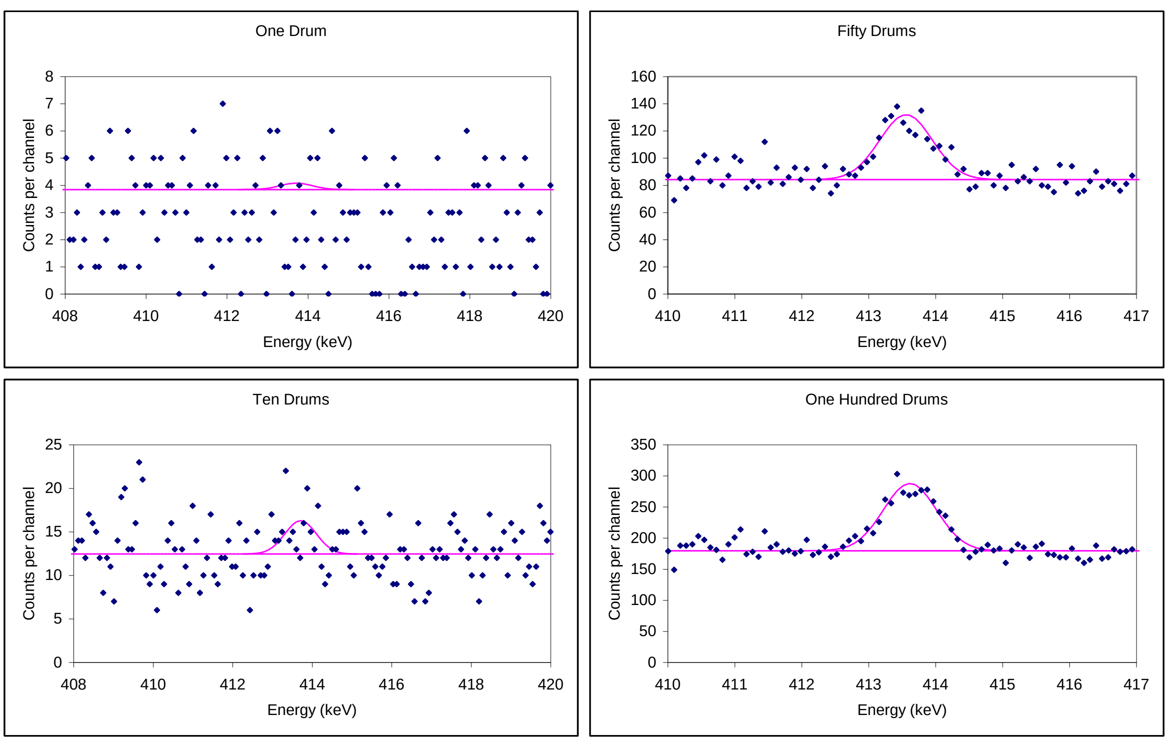

Fig. 3. The 414keV region of four example gamma-ray spectra.

CONCLUSIONS

We have developed and implemented a novel analysis technique that may be used to improve the sensitivity of NDA measurements. We have demonstrated that the results obtained from this technique may be used to support qualification for shipment to Envirocare. The simplicity of this analysis technique together with the fact that it can be applied to existing assay data has helped AMWTP meet a very ambitious goal of shipping $500m^3$ of low level mixed waste in the last two months of 2005. This achievement is even more impressive when it is considered that the project was only initiated in late September of 2005.

To date we have applied this spectral analysis technique to in excess of $1000m^3$ of waste contained in both drums and boxes. For a large proportion of this waste we have been able to demonstrate TRU activity levels that fall below the limits required by Envirocare. We have provided the required radioassay data that has been used to qualify and ship approximately $540m^3$ of low level mixed waste to Envirocare.

REFERENCES

1. Currie, L.A. (1968). Limits for Qualitative Detection and Quantitative Determination, Analytical Chemistry, Vol. 40, No. 3: 586-593.