DETECTION AND CORRECTION OF INHOMOGENEITIES IN DRUM WASTE ASSAY SYSTEMS

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ABSTRACT

Traditional gamma drum assay systems were designed to measure process material. Accurate results were claimed using the assumption of a uniform radial distribution of source activity in the drum. However, for radioactive waste measurements this assumption is generally not valid. Non-uniform distributions of source material are frequently the largest source of error in gamma waste assay systems and in extreme conditions can exceed order of magnitude levels. Non-uniformities in the matrix density also add to the measurement error.

Most of the proposed solutions to these problems have focused on tomographic techniques. Although these would tend to produce the most accurate results, they typically are very expensive and require long assay times. This paper describes a study which tests a technique utilizing multichannel scaling (MCS) of transmission and assay data to identify inhomogeneities in both the matrix and the source. This technique is inexpensive, and does not increase the throughput time for assays.

Results of the MCS data can be used either to set warning or error levels which will indicate to the operator that the results are questionable, also the matrix data can be combined with the source data to generate additional correction terms for the nonuniform source distribution to reduce the error.

This study is still in progress. Early results which quantify the range of errors for sample inhomogeneity, and improvements in accuracy which can be obtained using this correction term are presented here.

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INTRODUCTION

Traditional measurements of gamma wastes for safeguard purposes have usually been performed using segmented gamma scanning systems. These systems were used to assay a rotating drum in well defined vertical segments. For each segment a matrix corrected assay value was determined. The matrix density was determined from the attenuation of an external source on the opposite side of the drum. The accuracy of this technique was based on the assumption that both the sample matrix and the sample activity were uniform in a segment. This assumption tended to be reasonable for assays of process materials, but it is not necessarily true for assays of waste or scrap. (Tables 1A and 1B show the maximum errors when a single detector is used) that occur when a point source of activity is located in various radial positions of rotating 120 L drums of various densities.

The data indicate that the measurement error increases as the density increases, particularly for low energy nuclides. These errors are larger for 200 L drums. The activity of a point source in the center of the drum will be underestimated, while the activity of a point source at the outside edge of the drum will be overestimated.

Errors associated with radial non-uniformities of matrices can be significant but are difficult to quantify. Using traditional transmission correction techniques, the matrix density of the drum is averaged radially, whereby the effects of off-axis high density materials are underestimated. Therefore, source material located inside off-axis high density materials will not be detected in the assay or will be underestimated significantly.

In a number of research facilities, both emission and transmission tomography techniques are being studied as a means of improving the assay measurement and minimizing errors. Once these techniques are fully developed, they may provide the most accurate assay measurements. However, the projected costs of a tomographic scanner are 1.5 to 3 times higher than those of a standard Segmented Gamma Scanner (SGS) system, and the assay time for a tomographic scanner will typically be two to five times that for a standard SGS system.

An approach by which the measurement accuracy is improved over that of the traditional SGS, without significantly adding to the price of throughput of the system, is discussed in the following sections.

CORRECTION TECHNIQUE

To determine the sample distribution in the matrix, the correction technique stores count rate information on key nuclides for rotational increments of the drum, using multichannel scaling (MCS). This is done in conjunction with the standard gamma assay data collection and does not increase the assay time. Uniform source and matrix distributions will yield constant MCS data. Non-uniform distributions will exhibit varying intensities of maxima and minima.

To collect these data, Canberra Industries is developing a software multichannel scaling package. This package will store data from defined regions of interest, in precise time increments. The stored data are then displayed as counts/time or, in the case of a rotating drum, as counts/rotational increment. Figure 1 shows an output of these data for a ^{152}Eu point source at several radial positions in a drum of 0.8 g/cm^3 density. The variation of the height of the curve provides an indication of the radial position of the source.

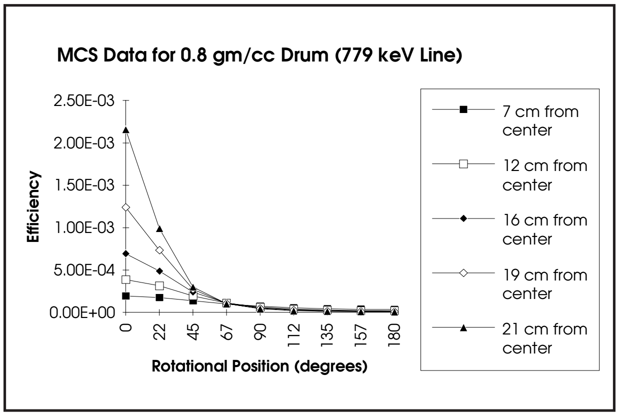

Figure 1.
MCS data for various point sources in a drum of 0.8 g/cm^3 density (779 keV line) for various point sources

The MCS data can be used to define the existence of error conditions and to apply correction terms. Deviations from a mean value can be used to set a warning flag that indicates inhomogeneity. The transmission MCS data are used to determine the location and density of off-axis shielding material which makes the accuracy of the assay suspect.

The amplitudes of peaks in the MCS data are based on a combination of source position and matrix density. Therefore, both pieces of information are required. Data on the average, based on the transmission correction results, provide the necessary information on the density of the drum. A correction algorithm can be developed with this information to reduce the measurement bias caused by the non-uniformity of the radial source. It is hoped that, as this project develops, the MCS transmission data can also be used as a part of the correction technique.

STUDY

The initial application of this correction technique is to minimize the potential radial errors on assay systems for customer's who utilize the Q^2 counting geometry of Canberra Industries for the quantification of 118 L drums. Therefore, initial studies have been performed using this geometry. In the Q^2 geometry, three uncollimated germanium detectors are placed at a distance of 5 cm from the side of the drum in vertical positions at the center and 30 cm above and below the cental detector. These vertical positions optimize the uniformity of the detection system.

Monte Carlo simulations have been performed to model point sources in various radial positions of drums with matrices of uniform density. Sources were also moved vertically off axis. Four simulations have been performed to date using drums of 0.1, 0.4, and 0.8 g/cm^3 density. In addition, some data were taken using point sources in empty drums and in drums filled with water (1.0 g/cm^3).

The study will also include measurements with a non-uniform drum matrix. These data have not yet been collected and analyzed.

RESULTS

The MCS data have been used in various ways to indicate the necessary corrections. These data have been compared with the ratio of the measured values to the expected values. By performing a regression analysis on these data, a set of equations is obtained which can be fitted reasonably to a set of algorithms. Table 2 shows that the corrections from these algorithms works well for the point source data.

Data were also collected for different detector and sample geometries. These data indicate that the coefficients used in the correction algorithms are dependent on the measurement geometry and must be recalculated when the geometry is rearranged.

These algorithms are being applied to various combinations of point sources to determine their limitations. The initial data indicate that the technique works best for single point sources, but it appears that it is also

Table 1A.
Ratio of Measured Value to Actual Value for 0.4 g/cc Drums

Distance from the center of the drum (cm)	Assay energies (keV)						
	122	244	345	779	965	1112	1408
7	0.38	0.47	0.52	0.6	0.63	0.64	0.64
12	0.59	0.64	0.68	0.75	0.75	0.79	0.79
16	0.87	0.89	0.92	0.96	0.95	0.98	0.98
19	1.3	1.26	1.28	1.24	1.25	1.27	1.24
21	1.94	1.82	1.8	1.65	1.69	1.66	1.64
25	3.63	3.33	3.18	2.76	2.8	2.67	2.6

Table 1B.
Ratio of Measured Value to Actual Value for 0.8 g/cc Drums

Distance from the center of the drum (cm)	Assay energies (keV)						
	122	244	345	779	965	1112	1408
7	0.24	0.32	0.37	0.49	0.49	0.52	0.54
12	0.47	0.55	0.59	0.69	0.69	0.72	0.72
16	0.87	0.92	0.94	0.97	0.98	0.99	0.99
19	1.58	1.54	1.52	1.43	1.41	1.41	1.39
21	2.85	2.57	2.47	2.11	2.1	2.03	1.97
25	no data	no data	no data	no data	no data	no data	no data

Table 2.
Corrected and Uncorrected Data for the 345 keV Gamma Line

Distance from the center of the drum (cm)	Max/Min ratio	Uncorrected results	Corrected results
7	2.64	0.52	1.17
12	5.4	0.68	0.98
16	8.5	0.92	0.97
19	13.7	1.28	0.99
21	19.9	1.8	1.08
25	35	3.18	1.26

fairly suitable for more complex distributions of sources. Additional tests are in progress to study refinements of the correction algorithms for handling the more complex distributions and to develop criteria for determining automatically when the technique can be applied.

One significant problem is differentiation of a point source in the center of the drum from a uniform source distribution. It is most important to detect the uncorrected assay value for the point source in the center of the drum because the result is under-corrected. One way of detecting this is to use the ratio of the measured values to the expected values to obtain the ratio of multiple peaks such as the 129 and 414 keV peaks from ^{239}Pu. The same effect, however, would be seen in the case of self-absorption in the sample. Other techniques being considered include variations in the collimator field of view; determining the ratios of the differences in the activity calculations for the top, center and bottom detectors to indicate non-uniformity; or utilizing inexpensive detectors focused at various angles to provide additional information.

CONCLUSIONS

The correction technique under study can be used to detect sample non-uniformities in drums or the presence of off-axis high density materials. This technique can provide a significant improvement in the detection of necessary corrections compared with the standard assay method for point source distributions. Further criteria need to be developed in order to define the limits of this technique.

More work is required for correction of assay data for inhomogeneous matrices and for differentiation of a point source of activity in the center of a drum from a uniform distribution of activity.