COMPARISON OF WASTE MATRIX ATTENUATION CORRECTIONS USING GAMMA-RAY TRANSMISSION MEASUREMENTS VS A MATHEMATICAL MODELING APPROACH

Kathleen Gruetzmacher
Los Alamos National Laboratory, FWO-SWO

Steven Myers
Thermo Retec Inc.

ABSTRACT

The most significant source of error during gamma spectroscopy measurements of waste usually involves the determination of gamma-ray losses from attenuation. The current method employed by the Waste CharacterizationTeam at the Los Alamos National Laboratory (LANL) is to mathematically model attenuation losses using a method developed by Benchmark Environmental Corporation. Most non-destructive assay systems perform actual transmission measurements with relatively high-activity gamma-emitting sources. In most cases, correction factors for attenuation losses that are based upon actual transmission measurements will yield acceptable results for both homogenous and heterogeneous waste matrices. To determine the validity of using a mathematical model to calculate attenuation losses we performed transmission measurements on twelve 55-gal waste drums using a 550 μCi Ba-133 source. The effective waste matrix densities of the twelve drums ranged from 0.09 to 1.04 grams/cc. The comparison of the two assay methods indicates that the mathematical model can produce reasonably similar results to the transmission correction technique. The average absolute difference between the methods was 10.6 percent while the maximum difference was 25.8 percent (in the heaviest drum). Comparative results were more similar for low-density combustible drums (average difference of 2.7%) than for higher-density metal drums (average difference of 14.1%).

INTRODUCTION

The Waste Characterization Team for the Los Alamos National Laboratory's (LANL) Solid Waste Operations (SWO) group performs gamma spectroscopy measurements of waste items to determine their radioactive constituents. These measurements are performed at a variety of LANL facilities using portable high-purity germanium (HPGe) detection systems. The raw data from these measurements is analyzed with a mathematical modeling approach. The approach, developed by Benchmark Environmental Corporation, is known as SNAP: Spectral Nondestructive Assay Platform. To achieve reasonably accurate results, this method requires information about the waste matrix materials, the net weight of the waste, the volume of the waste container, and an estimate of the percent fullness of the container. The most significant source of error in gamma spectroscopy measurements of waste usually involves the determination of gamma-ray losses due to attenuation through the waste matrix. These attenuation losses are mathematically calculated with the SNAP modeling software, and then factored into an activity estimate. In contrast to this technique, traditional non-destructive assay systems perform actual transmission measurements with relatively high-activity gamma-emitting sources to determine attenuation losses. These "transmission correction sources" are usually chosen because they emit gamma-rays at energies similar to the gamma emissions of the isotope(s) of interest (i.e., those present in the waste). An accurate correction factor for attenuation losses can be calculated from the transmission results using a technique previously developed at LANL (Ref:\Parker, 1984). In most cases, correction factors for attenuation losses that are based upon actual

transmission measurements will yield acceptable results for both homogenous and heterogeneous waste matrices.

Although transmission measurements through waste drums provide very useful information they often prove to be cumbersome or impractical. Not only does the transportation of high-activity gamma-emitting sources from one site to another cause difficulties, but often a variety of gamma-ray energies are observed in any given spectrum which makes it necessary to extrapolate the transmission curve beyond it's calculated range. Extrapolation of these curves can introduce significant errors into the calculated result. Therefore, a mathematically derived estimation of the attenuation losses which gamma-rays experience in the waste matrix is often desirable and more practical. The unanswered question is whether mathematically modeled results will yield similar activity estimates as the standard transmission corrected results.

METHODS

To determine the validity of our mathematical modeling approach, transmission measurements on twelve 55-gal waste drums using a 550 μCi Ba-133 source were performed. The mass of waste in the drums varied across a wide range of values (from 18.6 kg to 216.4 kg). One drum contained a soil matrix, three drums contained combustibles, and eight drums were listed as containing metals. The combustible drums were modeled as containing cellulose and the metal drums were all modeled as containing only iron (more specific information was not available). All of the drums contained Pu-239 as a primary radiological constituent. Pu-239 emits a variety of gamma-rays, including one at 375.0 keV. The attenuation of the 375 keV gamma-ray through the waste matrix is calculated using data from two Ba-133 gamma-rays: a 356.0 keV gamma-ray and a 383.9 keV gamma-ray. The following method was used to determine the correction factor for attenuation losses (CFAT) associated with the Ba-133 transmission source:

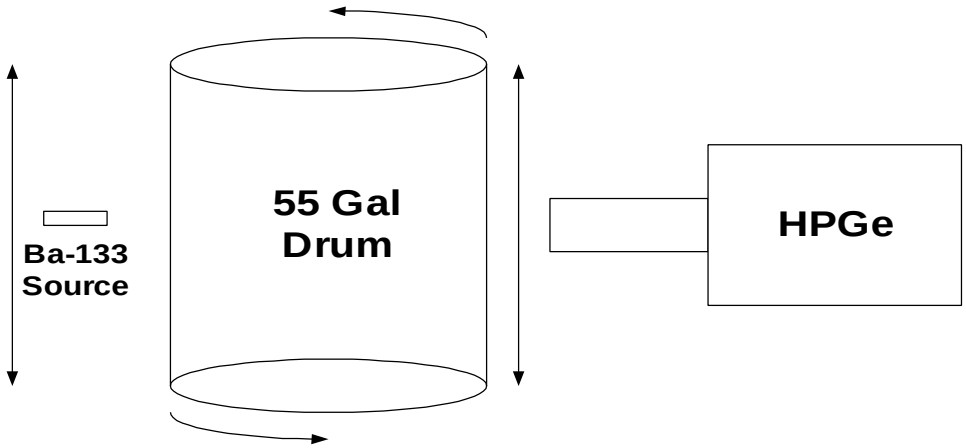

Figure 1. The HPGe detector and Ba-133 source scan vertically while the drum is rotated.

1. Two measurements were made of the Ba-133 source: one with the drum placed between the source and the detector (the attenuation measurement) and one with nothing between the source and detector (the "bare" measurement). Net count rates for the 356.0 keV and 383.9 keV gamma-ray peaks were determined for each of the two measurements.
2. The effective transmission of the two gamma-rays through the waste matrix was determined by dividing the attenuation measurement count rate by the bare measurement count rate.
3. The effective transmission for each gamma-ray was then corrected by dividing by the attenuation of those gamma-rays through one steel wall with a thickness of 0.0625 inches. This correction is necessary since

gamma-rays originating in the waste drum will pass through only one drum wall en route to the detector, while gamma-rays from the transmission source pass through two.

4. The effective transmission at 375.0 keV (T) was determined by interpolating between the calculated transmissions at 356.0 and 383.9 keV.

The CFAT for Pu-239 375.0 keV gamma-rays was determined with the following equation:

$$CFAT = \frac{-0.823 \ln(T)}{1 - T^{0.823}} \qquad (Eq.1)$$

The above calculated CFAT allowed us to compare transmission corrected results with mathematically modeled results. The mathematically modeled results were determined in the usual fashion with the custom SNAP analysis software. The SNAP activity calculations were based upon the net counts in the 375 keV peak. The transmission corrected results were derived in two steps. First, SNAP was used to determine the Pu-239 activity (using the 375 keV data) by modeling the matrix as a virtual vacuum (i.e. no matrix is present) and setting the drum wall thickness equal to zero (i.e. no attenuation losses in the wall). This activity estimate will be identical to the initial mathematically modeled result except for the correction factor for attenuation losses. To get a comparative value for Pu-239 the second activity estimate was multiplied by the CFAT to get a final corrected activity.

RESULTS

The absolute percent difference between these two methods is presented in Table I for the 12 measured drums. The comparison of the two assay methods indicates that the mathematical model can produce reasonably similar results to the transmission correction technique. The average absolute difference between the methods was 10.6 percent with a maximum difference of 25.8 percent (in the heaviest metal drum). The average difference for combustible drums was 2.7 percent while the average difference for metal drums was 14.1 percent. The higher discrepancy for the metal drums is expected as attenuation losses in higher density materials are more severe and the associated uncertainties with those losses are greater. However, even a difference of 14% between a measured result and a modeled result is not a large discrepancy considering the potential uncertainties in attenuation losses through waste matrices.

Table I: Transmission Measurement Comparisons

Item	Waste Matrix	Net Weight (kg)	Effective Density (g/cc)	Absolute Percent Difference
Drum 57795	Iron	18.6	0.09	**7.5%**
Drum 52655	Combustibles	20.4	0.10	**4.7%**
Drum 52665	Combustibles	21.8	0.10	**1.2%**
Drum 57189	Iron	29.0	0.14	**21.2%**
Drum 52727	Combustibles	33.1	0.016	**2.2%**
Drum 52720	Iron	63.0	0.30	**16.7%**
Drum 52725	Iron	64.4	0.31	**6.4%**
Drum 54811	Iron	66.7	0.32	**6.6%**
Drum 57182	Iron	94.3	0.45	**3.0%**
Drum 57194	Iron	95.7	0.46	**25.4%**
TWISP drum	Soil	201.8	0.97	**6.3%**
Drum 57190	Iron	216.4	1.04	**25.8%**

The drums measured had a variety of materials with effective waste matrix densities ranging from 0.09 to 1.04 grams/cc. Because specific details on the metals present in each container was lacking, iron was chosen to model the waste matrix. Most likely some of the metal drums contained a very heterogeneous distribution of materials.

CONCLUSIONS

Overall, the results strongly support the contention that a mathematical approach can produce reasonably accurate assay results, and therefore, adequately characterize a variety of low-level wastes for disposal. It is interesting to note that for 9 of the 12 drums the mathematical modeling technique produced higher estimates for activity than the transmission correction method. Therefore, there is a tendency for this method to err on the conservative side when used for making decisions on whether wastes should be classified as TRU or LLW.

REFERENCES

Parker, Jack L. August, 1984. "The Use of Calibration Standards and the Correction for Sample Self-Attenuation in Gamma-Ray Nondestructive Assay," Los Alamos National Laboratory, LA-10045, Los Alamos, New Mexico.