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55-Gallon Drum Attenuation Corrections for Waste Assay Measurements

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Abstract

The present study shows how the percent attenuation for low-level waste (LLW), carbon-steel 55-gallon drums (44 and 46 mil) and for transuranic (TRU) DOT Type 7A 55-gallon drums (~61 mil) changes with gamma energy from 60 keV to 1400 keV. Attenuation for these drums is in the range of 5 to 15% at energies from 400 to 1400 keV and from 15 to 35 % at energies from 120 to 400 keV. At 60 keV, these drums attenuate 70-80% of the gamma rays. Correction factors were determined in order to correct for gamma attenuation of a TRU drum if a calibration is performed with a LLW drum. These correction factors increase the activities of the TRU drum by from 10% to 2% in the energy range of 165 to 1400 keV, with an increase of about 50% at 60 keV.

In cases where waste is assayed without a drum, the measured drum attenuations can be used to correct the calibrations that were done for drum assays. Correction factors to determine nuclide activities of samples without the drum attenuation were also determined in this study. These correction factors decrease the measured activities by 70% at 60 keV, by 30% to 9% at energies from 100 to 500 keV, and by about 7% for energies from 500 to 1400 keV.

Correction factors for TRU drums and for analyses without a drum were used to adjust the %yield for frequently measured gamma rays, so that the assay libraries could be modified to provide the drum attenuation corrections.

Keywords: 55-gallon Drum, Attenuation, Gamma PHA

1. Introduction

Transuranic (TRU) and low-level waste (LLW) at the Savannah River Site (SRS), packaged in 55-gallon drums, are assayed using Canberra Q^2 Waste Assay Systems. Standard drums, containing materials of varying density and National Institute of Standards and Technolgy (NIST) traceable radioactivity standards, are used to calibrate these waste assay systems.[1] For these calibrations, the attenuation of the drum is included in the calibration. LLW is assayed in carbon-steel drums that are about the same thickness (~44 mil) as the calibration drums (~46 mil) purchased from Canberra. However, TRU waste is assayed in DOT 7A drums that are considerably thicker (~61 mil) than the drums used for the calibration. Therefore the assay values for TRU waste will be biased low because there is more attenuation from the TRU drums than from the calibration drums. The present study measures the attenuation for gamma ray energies from 59 keV to 1408 keV for a LLW drum, a TRU drum, and the Canberra calibration drum to evaluate the attenuation corrections needed for routine assays. This correction is particularly important for measuring lower energy gamma rays from Am-241 (60 keV) and other TRU nuclides, such as Pu-239 (129 keV) and Pu-238 (99 keV and 152 keV), that are frequently assayed in SRS solid waste.

Also, there are LLW waste items, such as HEPA (High Efficiency Particulate Air) filters, that do not fit into a 55-gallon drum, but can be assayed with the Canberra Q^2. Measured activities for waste not in a drum are biased high because the calibration is done with a drum. The results from this study can be used to adjust the assay results for waste items not contained in a drum, so that the drum calibration can be used.

2. Experimental

The Canberra Q^2 Waste Assay System is a very low-level, quantitative and qualitative gamma pulse-height-analysis system and is shown in Figure 1. It contains three intrinsic germanium detectors with 7.5-liter cryostats. A low-level or TRU waste sample, usually in a 55-gallon drum, is placed on a turntable mounted on the door of the shielding. The turntable rotates at a nominal 10 RPM. An electronic load cell mounted on the turntable weighs the sample and displays the result. A 4-inch thick, low-background-steel shield surrounds the sample and detectors in all directions. The data acquisition system contains a PC-based Canberra AccuSpec Multichannel Analyzer (MCA) system, appropriate high voltage power supplies and amplifiers. The three AccuSpec boards are controlled by Canberra's NDA-2000 software running in a Windows-NT environment. For this study, NIST traceable standards, contained in a specially designed plastic holder that was representative of the drum geometry, were assayed with the 773-A Canberra Q^2 Waste Assay System for 600 seconds.

Figure 1. Canberra Q^2 Waste Assay System

The standards, obtained from North American Scientific, Inc., are composed of an epoxy matrix cast in a 9.53 mm OD by 813 mm long aluminum tube. Subsequently, the plastic holder and standards were inserted into a 55-gallon drum and assayed again for 600 seconds.


CALIBRATION DRUM
22.27 KG
0.00 KG
0.000 G/CC

Figure 2. Standards in Holder


CALIBRATION DRUM
MATRIX WEIGHT 22.27 KG
MATRIX WEIGHT 0.00 KG
MATRIX DENSITY 0.000 G/CC

Figure 3. Holder Placed in Drum

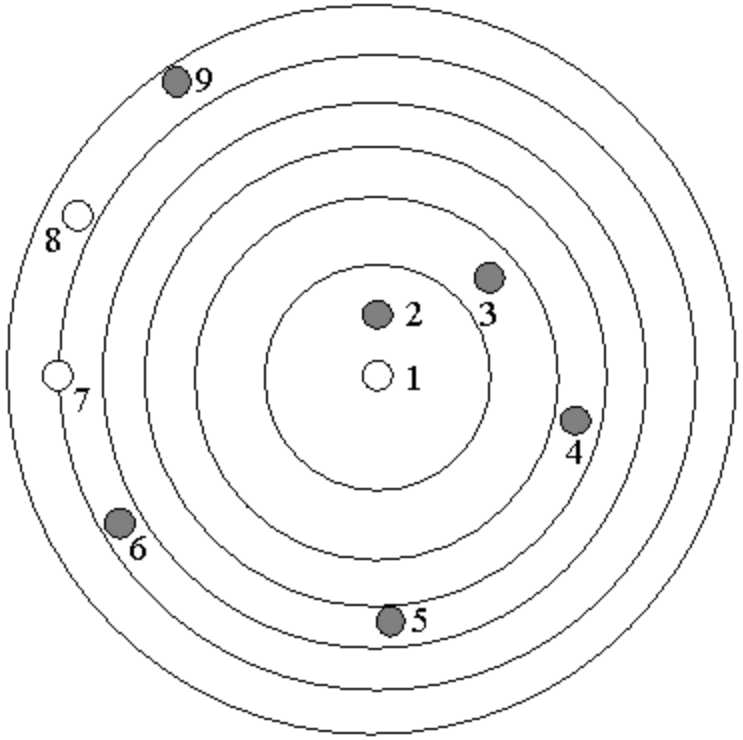

Figure 4. Top View of Arrangement of Rod Standards in Positions 2, 3, 4, 5, 6 and 9 to Represent a Full Drum

Figures 2 and 3 show how the plastic holder and standards were inserted into each drum, while Figure 4 shows the top view of the plastic holder and standards that were used in this study. The standards and holder were assayed inside a LLW drum (43 mil thickness), the Canberra standard drum (46 mil thickness) and a TRU drum (61 mil thickness) and the holder without a drum was assayed. The results of these assays were used to determine the attenuation of gamma rays over the energy range from 59 keV to 1408 keV for each drum.

3. Results

Peak counts for Am-241, Cs-137 and Eu-152 gamma rays (600-second count) are shown in Tables 1 through 3. In columns two and three, peak counts and uncertainties are listed for the standards and holder placed inside the drum, while columns four and five list the peak counts and uncertainties for just the standards inside the holder. From these data, the drum attenuations and uncertainties are calculated and listed in columns six and seven.

Table 1. Activities and Percent Attenuation for LLW Drum (44 mil)

Gamma Energy (keV)	Peak Counts Drum+Holder+ Standards	Uncert.(2s) Drum+Holder+ Standards	Peak Counts Holder+Stds	Uncert (2σ) Holder+Stds	Drum Att. (%)	Drum % Att. Uncert. (2s)
59.5	9430	467	29800	570	68.4	3.6
121.8	122000	978	161000	1058	24.2	0.3
244.7	31400	578	35600	590	11.8	0.3
344.3	83600	664	93300	696	10.4	0.1
661.7	34300	381	37300	397	8.0	0.1
778.9	21500	350	22700	363	5.3	0.1
964.1	20300	322	21700	332	6.5	0.1
1112.1	16800	291	18200	300	7.7	0.2
1408.0	21500	297	23200	308	7.3	0.1

Table 2. Activities, Percent Attenuation and Correction Factors for Assay without a Drum and Calibrated with the Canberra Drum (46 mil)

Gamma Energy (keV)	Peak Counts Drum+Hldr+ Standards	Uncert.(2s) Drum+Hldr+ Standards	Peak Counts Hldr+Stds	Uncert (2σ)Hldr+Stds	Drum Att. (%)	Drum % Att. Uncert. (2s)	No Drum % Att. CF	Calc CF 46 mil Fe
59.5	8980	504	30300	575	70.4	4.2	3.37	2.89
121.8	125000	984	164000	1069	23.8	0.2	1.31	1.30
244.7	31300	560	36100	415	13.3	0.3	1.15	1.12
344.3	84700	660	96000	693	11.8	0.1	1.13	1.09
661.7	34500	368	37800	385	8.7	0.1	1.10	1.07
778.9	21400	351	23500	367	8.9	0.2	1.10	1.06
964.1	20700	329	22000	340	5.9	0.1	1.06	1.06
1112.1	17100	294	18500	304	7.6	0.2	1.08	1.05
1408.0	22200	301	23500	311	5.5	0.1	1.06	1.05

Table 3. Activities, Percent Attenuation and Correction Factors for the TRU Drum (61 mil) Calibrated with Canberra Drum (46 mil)

Gamma Energy (keV)	Peak Counts Drum+Hldr+ Standards	Uncert.(2s) Drum+Hldr+ Standards	Peak Counts Hldr+Stds	Uncert (2σ) Hldr+Stds	Drum Att. (%)	Drum % Att. Uncert. (2s)	TRU Canberra % Att CF	Calc CF 61 mil Fe
59.5	5880	440	30300	571	80.6	6.2	1.53	1.50
121.8	109000	947	159000	1059	31.4	0.3	1.11	1.11
244.7	29400	546	36500	572	19.5	0.5	1.08	1.04
344.3	79300	641	93700	684	15.4	0.2	1.04	1.04
661.7	33300	374	37400	397	11.0	0.2	1.03	1.03
778.9	20400	345	22900	364	10.9	0.3	1.02	1.02
964.1	19300	317	21900	339	11.9	0.3	1.07	1.02
1112.1	16600	289	18300	299	9.3	0.2	1.02	1.02
1408.0	21200	295	23200	308	8.6	0.2	1.03	1.02

The "No Drum" correction factor and the "TRU Drum/Canberra Drum" correction factor are given in column eight of Table 2 and Table 3, respectively. The "No Drum" correction factor referred to in Table 2 is calculated as follows:

$CF_{ND} = (1 / (1 \text{ } \blacklozenge \text{ } A_C))$

where:

A_C =the fractional attenuation for a given energy for the Canberra drum

while the "TRU Drum/Canberra Drum" correction factor in Table 3 is defined by the equation:

$CF_{T/C} = (1 / (1 \text{ } \blacklozenge \text{ } A_T) / (1 / (1 \text{ } \blacklozenge \text{ } A_C))$

where:

A_T= the fractional attenuation for a given energy for the TRU drum.

"No Drum" correction factors and the "TRU Drum/Canberra Drum" correction factors were calculated based on known mass attenuation coefficients[2] for iron and are given in column 9 of Tables 2 and 3. As expected, the calculated correction factors for iron show good agreement with the measured correction factors for the steel drums.

4. Analysis of Results

Plots of the gamma ray attenuation versus gamma ray energy for the Canberra drum, the LLW drum and the TRU drum are given in Figure 5 and plots of the "No Drum" and the "TRU Drum/Canberra Drum" correction factors are given in Figure 6.

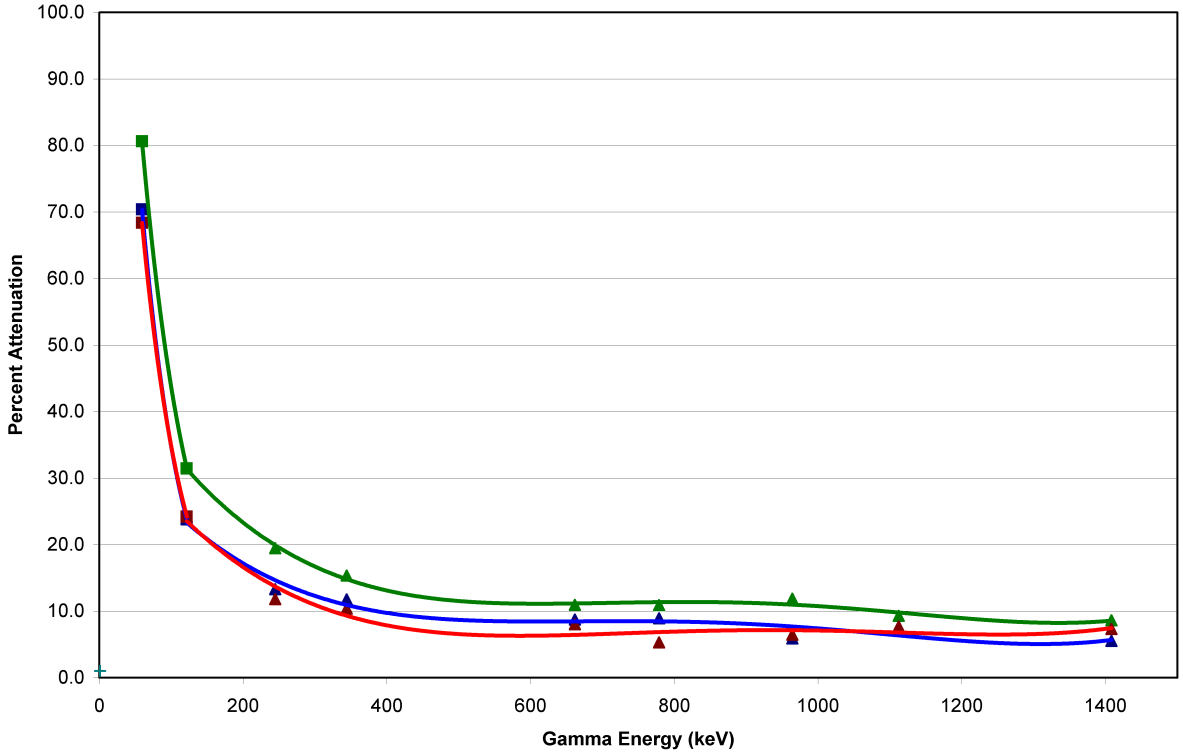

Figure 5. Gamma Ray Attenuation Versus Gamma Ray Energy for 55-Gallon Drums. (The Green (Top), Blue and Red Curves (Bottom) are for the TRU Drum, Canberra Drum and LLW Drum, Respectively.)

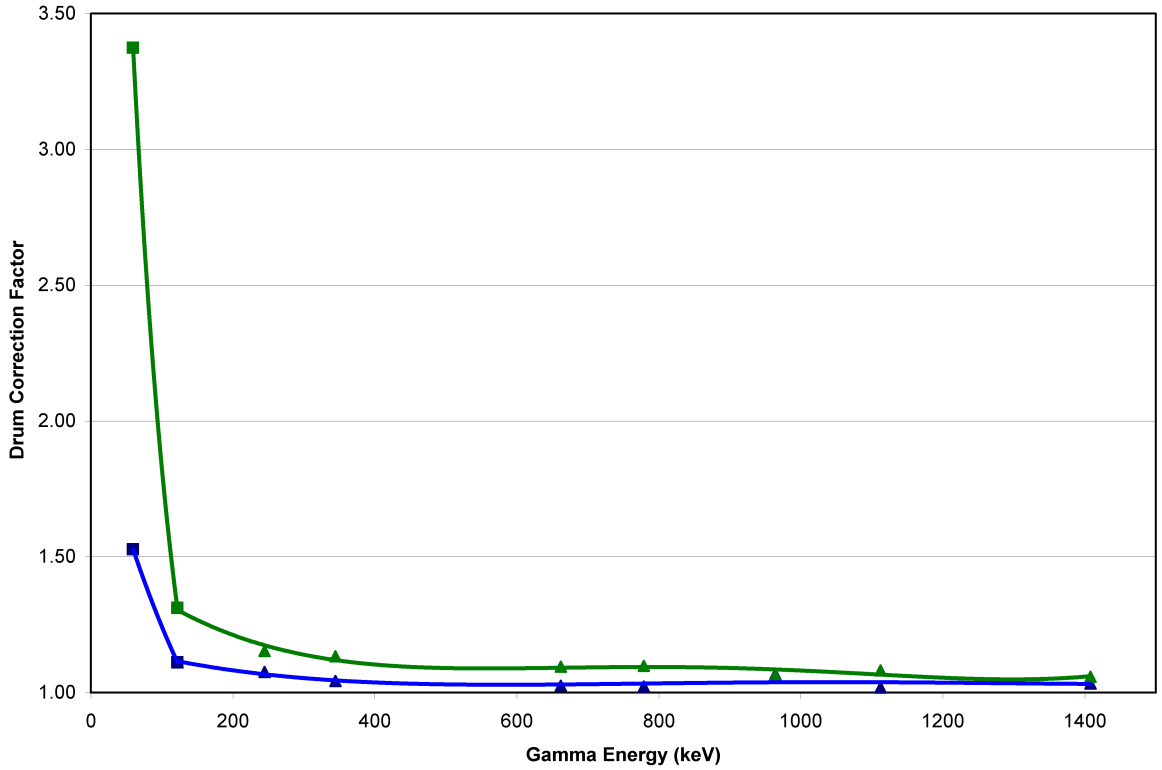

Figure 6. "No Drum" (Green; Top) and "TRU Drum/Canberra Drum" (Blue; Bottom) Correction Factors Versus Gamma Ray Energy

By using the known shape of the attenuation corrections for iron and the data shown in Figure 6, the "No Drum" and "TRU Drum/Canberra Drum" correction factors for the 60 keV to 1400keV energy range were determined and are given in Table 4 and shown in Figure 7.

The "No Drum" correction factors vary from 3.37 at 60 keV to 1.07 from 1000 to 1400 keV. For assays done without a drum, the measured activity would be divided by the "No Drum" correction factor for activities at a given energy.

"TRU Drum/Canberra Drum" correction factors are smaller than the "No Drum" correction factors because they represent a ratio of attenuation corrections. These correction factors vary from 1.53 to 1.03 and are less than 5% above 400 keV. "TRU Drum/Canberra Drum" corrections become especially important below 200 keV. The actual measured activities would be multiplied by "TRU Drum/Canberra Drum" correction factor for a given energy to obtain the correct measured concentrations for waste assay in a TRU drum.

Table 4. "No Drum" and "TRU Drum/Canberra Drum" Correction Factors using the Predicted Curve Shape of Fe to Obtain Values from 60 to 1400 keV

Gamma Energy (keV)	No Drum Corr. Factor	TRU/Canberra Corr. Factor	Gamma Energy (keV)	No Drum Corr. Factor	TRU/Canberra Corr. Factor
60	3.37	1.53	200	1.16	1.06
70	2.51	1.38	300	1.12	1.05
80	1.86	1.24	400	1.11	1.04
90	1.63	1.19	500	1.10	1.04
100	1.44	1.14	600	1.09	1.04
110	1.37	1.13	700	1.09	1.03
120	1.33	1.12	800	1.08	1.03
130	1.29	1.11	900	1.08	1.03
140	1.26	1.10	1000	1.07	1.03
150	1.23	1.08	1100	1.07	1.03
160	1.21	1.07	1200	1.07	1.03
170	1.19	1.07	1250	1.07	1.03
180	1.18	1.07	1300	1.07	1.03
190	1.17	1.07	1400	1.07	1.03

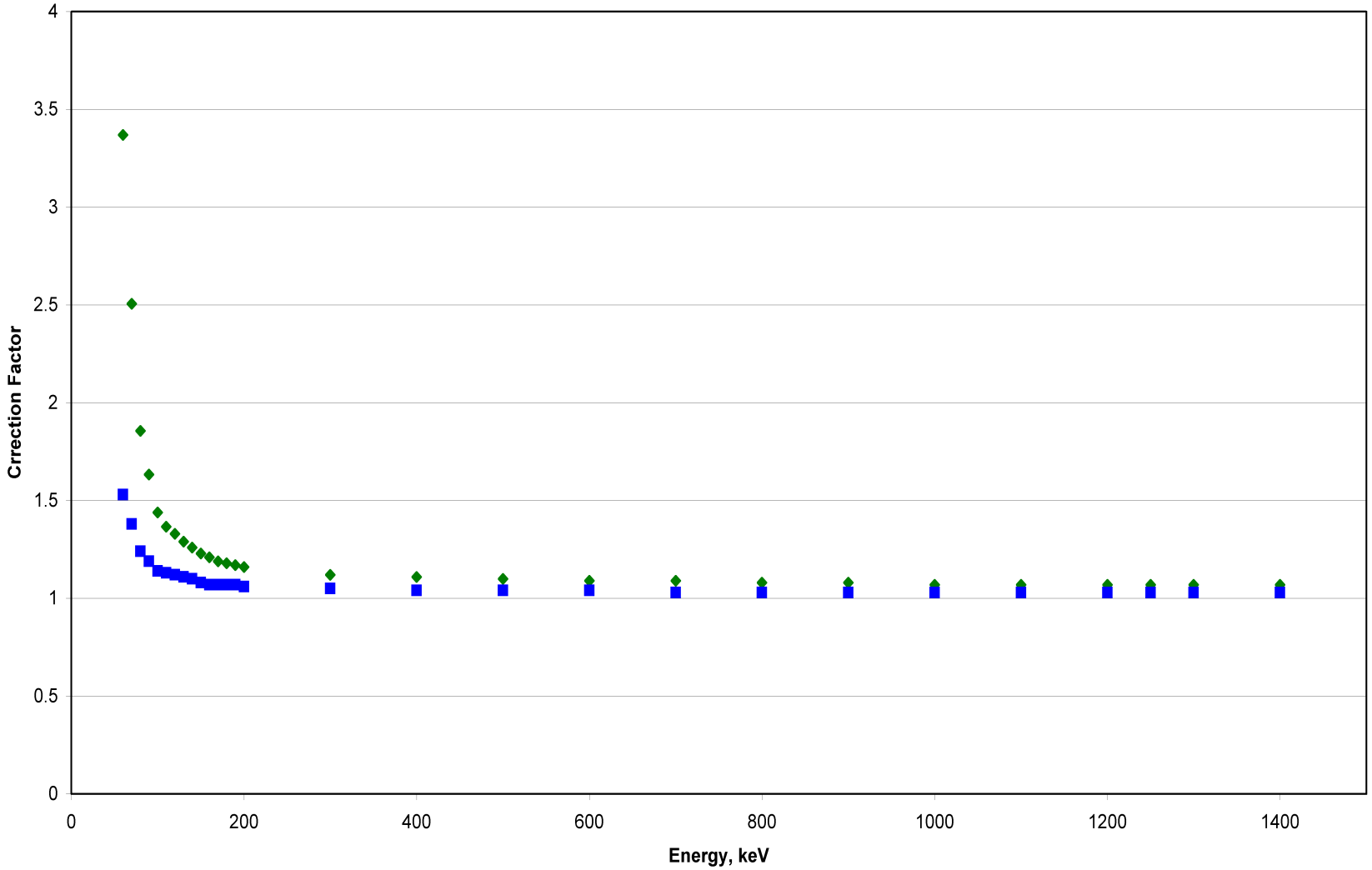

Figure 7. "No Drum" (Green; Top) and "TRU Drum/Canberra Drum" (Blue; Bottom) Correction Factors Versus Gamma Ray Energy using the Predicted Curve Shape of Fe to Obtain Values over the Energy Range of 60keV to 1400 keV

Anytime a TRU drum is analyzed the correction factors must be applied to preclude reporting erroneously low results. Rather than multiplying the TRU drum measured activities by the correction factors, the TRU library for the 773-A Canberra Q^2 has been adjusted so that the correction factors are included in the %yield values for all TRU waste assays. The library was adjusted because the 773-A Canberra Q^2 software does not have another way to include this correction.

As stated, if waste is analyzed without a drum, then the "No Drum" correction factors may be applied. This would be the case if the waste item were too large to fit into the drum. However, in this case, the correction factor lowers the measured activity. Since the actual result is conservatively high, the Cognizant Technical Function for waste assay may not deem it necessary to make this correction, especially if the assay yields very low nuclide activities.

The correction factors given in Table 4 would be applied for most nuclides determined at the 773-A Solid Waste Assay Facility.[3] These correction factors are used to modify the analysis libraries that are used for different waste streams.

Table 5. "No Drum" and "TRU Drum/Canberra Drum" Gamma Ray Correction Factors and Corrected % Yields for Analyses done at the 773-A Solid Waste Assay Facility

Nuclide	Gamma Energy (keV)	No Drum Corr. Factor	TRU/Canberra Corr. Factor	Gamma % Yield	No Drum (%Yield X CF)	TRU/Canberra (%Yield/CF)
Co-60	1173.24	1.07	1.03	9.9974E+01	1.07E+02	9.71E+01
Co-60	1332.50	1.07	1.03	9.9986E+01	1.07E+02	9.71E+01
Cs-137	661.65	1.10	1.03	8.51E+01	9.36E+01	8.26E+01
Eu-154	123.07	1.32	1.11	4.079E+01	5.38E+01	3.68E+01
Eu-154	723.30	1.09	1.03	2.022E+01	2.20E+01	1.96E+01
Eu-154	873.19	1.08	1.03	1.227E+01	1.33E+01	1.19E+01
Eu-154	996.26	1.07	1.03	1.059E+01	1.13E+01	1.03E+01
Eu-154	1004.73	1.07	1.03	1.801E+01	1.93E+01	1.75E+01
Eu-154	1274.44	1.07	1.03	3.519E+01	3.77E+01	3.42E+01
U-235	143.76	1.25	1.09	1.096E+01	1.37E+01	1.01E+01
U-235	185.72	1.18	1.07	5.72E+01	6.75E+01	5.35E+01
Np-237	86.48	1.12	1.05	1.24E+01	1.39E+01	1.18E+01
Np-237	103.97	1.42	1.14	8.7E-01	1.24E+00	7.60E-01
Np-237	300.34	1.12	1.05	6.62E+00	7.41E+00	6.30E+00
Np-237	312.17	1.12	1.05	3.86E+01	4.32E+01	3.68E+01
Np-237	340.81	1.12	1.05	4.47E+00	5.01E+00	4.26E+00
Np-237	375.45	1.11	1.04	6.79E-01	7.54E-01	6.53E-01
Np-237	398.62	1.11	1.04	1.39E+00	1.54E+00	1.34E+00
Np-237	415.76	1.11	1.04	1.745E+00	1.94E+00	1.68E+00
U-237	59.536	3.37	1.53	3.45E+01	1.16E+02	2.25E+01
U-237	97.066	1.50	1.16	1.60E+01	2.40E+01	1.38E+01
U-237	101.059	1.43	1.14	2.60E+01	3.72E+01	2.28E+01

U-237	164.610	1.20	1.07	1.852E+00	2.22E+00	1.73E+00
U-237	208.000	1.16	1.06	2.114E+01	2.45E+01	1.99E+01
Pu-238	99.853	1.44	1.14	7.35E-03	1.06E-02	6.45E-03
Pu-238	152.72	1.23	1.08	9.37E-04	1.15E-03	8.68E-04
Pu-239	77.59	2.02	1.28	4.1E-04	8.3E-04	3.2E-04
Pu-239	98.78	1.46	1.14	1.22E-03	1.78E-03	1.07E-03
Pu-239	103.06	1.42	1.14	2.3E-04	3.3E-04	2.0E-04
Pu-239	115.38	1.40	1.14	4.62E-04	6.47E-04	4.05E-04
Pu-239	116.26	1.40	1.14	5.97E-04	8.36E-04	5.24E-04
Pu-239	129.30	1.29	1.11	6.31E-03	8.14E-03	5.68E-03
Pu-239	144.2	1.25	1.09	2.83E-04	3.54E-04	2.60E-04
Pu-239	146.09	1.25	1.09	1.19E-04	1.49E-04	1.09E-04
Pu-239	161.45	1.21	1.07	1.23E-04	1.49E-04	1.15E-04
Pu-239	171.39	1.19	1.07	1.1E-04	1.3E-04	1.0E-04
Pu-239	195.68	1.17	1.07	1.07E-04	1.25E-04	1.00E-04
Pu-239	203.55	1.16	1.06	5.69E-04	6.60E-04	5.37E-04
Pu-239	332.85	1.12	1.05	4.94E-04	5.53E-04	4.70E-04
Pu-239	336.11	1.12	1.05	1.12E-04	1.25E-04	1.07E-04
Pu-239	345.01	1.12	1.05	5.56E-04	6.23E-04	5.30E-04
Pu-239	375.05	1.11	1.04	1.554E-03	1.73E-03	1.49E-03
Pu-239	380.19	1.11	1.04	3.05E-04	3.39E-04	2.93E-04
Pu-239	382.75	1.11	1.04	2.59E-04	2.87E-04	2.49E-04
Pu-239	392.91	1.11	1.04	5.53E-04	6.14E-04	5.32E-04
Pu-239	413.71	1.11	1.04	1.466E-03	1.63E-03	1.41E-03
Pu-239	422.60	1.11	1.04	1.22E-04	1.35E-04	1.17E-04
Pu-239	451.48	1.10	1.04	1.894E-04	2.08E-04	1.82E-04
Pu-240	104.23	1.41	1.14	7.08E-03	9.98E-03	6.21E-03
Pu-240	160.31	1.21	1.07	4.02E-04	4.86E-04	3.76E-04
Am-241	59.5	3.37	1.53	3.59E+01	1.21E+02	2.35E+01
Am-241	98.97	1.46	1.14	2.03E-02	2.96E-02	1.78E-02
Am-241	102.98	1.42	1.14	1.95E-02	2.77E-02	1.71E-02
Am-241	125.30	1.31	1.11	4.08E-03	5.34E-03	3.68E-03

Am-241	208.01	1.16	1.06	7.91E-04	9.18E-04	7.46E-04
Am-241	335.37	1.12	1.05	4.96E-04	5.56E-04	4.72E-04
Pu-241	103.68	1.41	1.14	1.017E-04	1.43E-04	8.92E-05
Pu-241	148.57	1.23	1.08	1.855E-04	2.28E-04	1.72E-04
Pu-242	158.80	1.21	1.07	4.536E-04	5.49E-04	4.24E-04
Am-243	74.66	2.21	1.32	6.82E+01	1.51E+02	5.17E+01
Am-243	99.52	1.44	1.14	1.50E+01	2.16E+01	1.32E+01
Am-243	103.73	1.42	1.14	2.39E+01	3.39E+01	2.10E+01
Am-243	106.12	1.40	1.13	2.72E+01	3.81E+01	2.41E+01
Am-243	209.75	1.16	1.06	3.42E+00	3.97E+00	3.23E+00
Am-243	228.18	1.15	1.06	1.076E+01	1.24E+01	1.02E+01
Am-243	277.60	1.13	1.05	1.438E+01	1.63E+01	1.37E+01
Cm-243	99.52	1.44	1.14	1.44E+01	2.07E+01	1.26E+01
Cm-243	103.73	1.42	1.14	2.30E+01	3.27E+01	2.02E+01
Cm-243	209.75	1.16	1.06	3.29E+00	3.82E+00	3.10E+00
Cm-243	228.18	1.15	1.06	1.0569E+01	1.22E+01	9.97E+00
Cm-243	277.60	1.13	1.05	1.3959E+01	1.58E+01	1.33E+01

5. Conclusions

The present study shows how the attenuation for low-level waste (LLW), carbon-steel 55-gallon drums (44 and 46 mil) and for transuranic (TRU) DOT Type 7A 55-gallon drums (~61 mil) changes with gamma energy from 60 keV to 1400 keV. Attenuation for these drums is quite significant (5-15%) at energies from 400 to 1400 keV, and becomes very significant at energies from 120 to 400 keV (15-35%). At 60 keV, these drums attenuate 70-80% of the gamma rays. Correction factors were determined in order to correct for gamma attenuation of a TRU drum if a calibration is performed with a LLW drum. The correction factors require an increase in the activities of the TRU drum of from 10% to 2% in the energy range of 165 to 1400 keV, while an increase of about 50% is required at 60 keV.

In cases where waste is assayed without a drum, the measured drum attenuations can be used to correct the calibrations that were done for drum assays. Correction factors to determine nuclide activities of samples without the drum attenuation were also determined in this study. These correction factors decrease the measured activities by 70% at 60 keV, by 30% to 9% at energies from 100 to 500 keV, and by about 7% for energies from 500 to 1400 keV.

Correction factors for TRU drums and for analyses without a drum were calculated for gamma rays of most nuclides determined at the 773-A Solid Waste Assay Facility. These correction factors were used to adjust the branching intensities for the gamma rays, so that the assay libraries could be modified to make the drum attenuation corrections.

6. References

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