# WM2015, Management of Plutonium Heterogeneity in Soil – 15429

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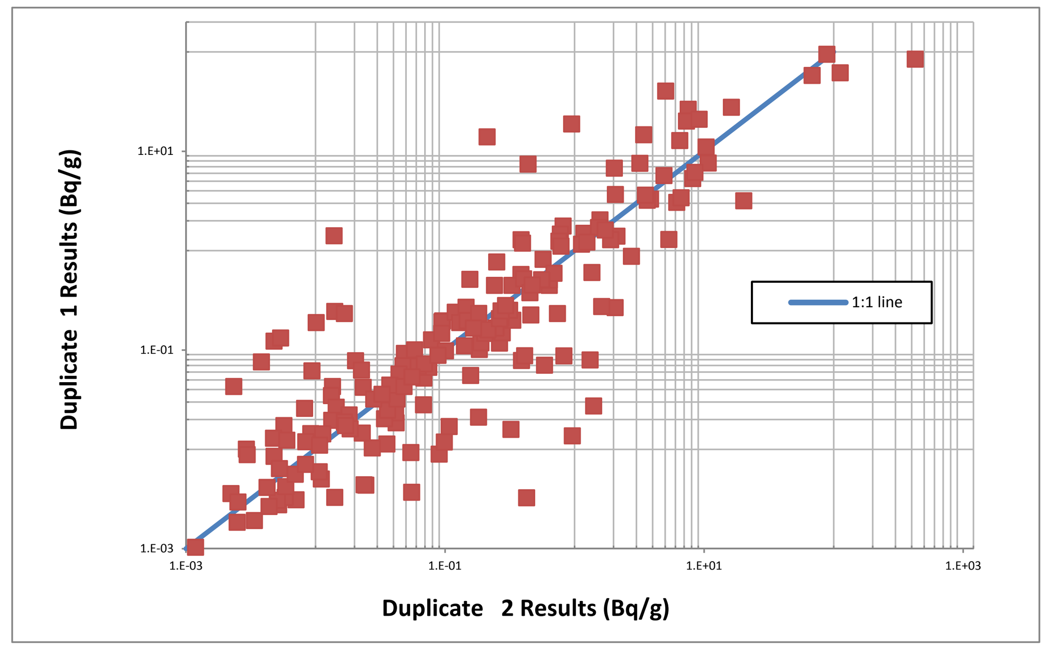
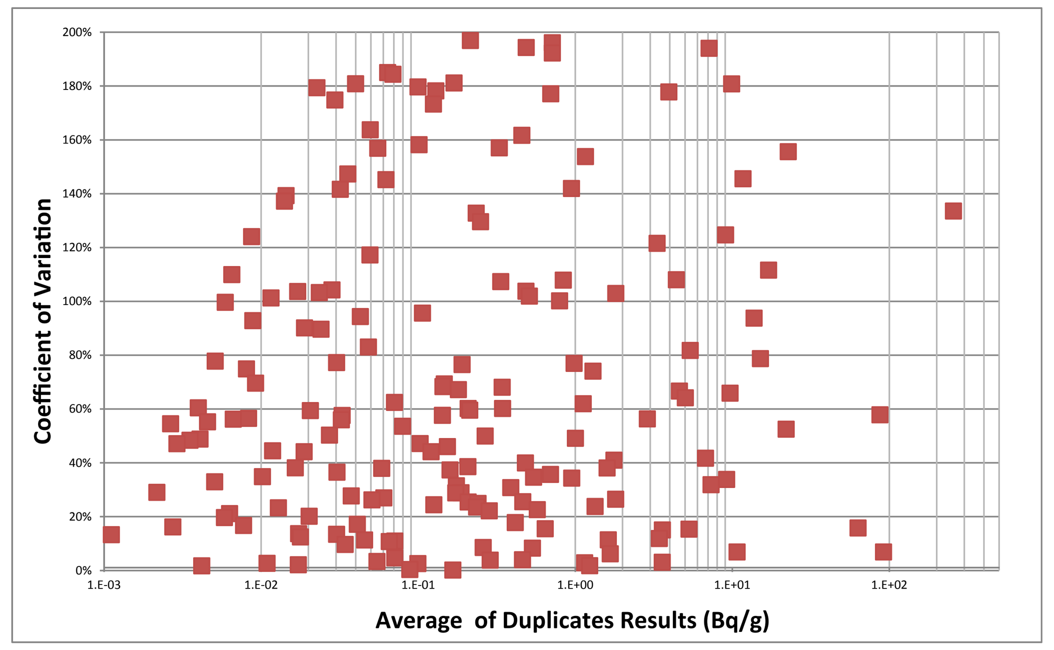
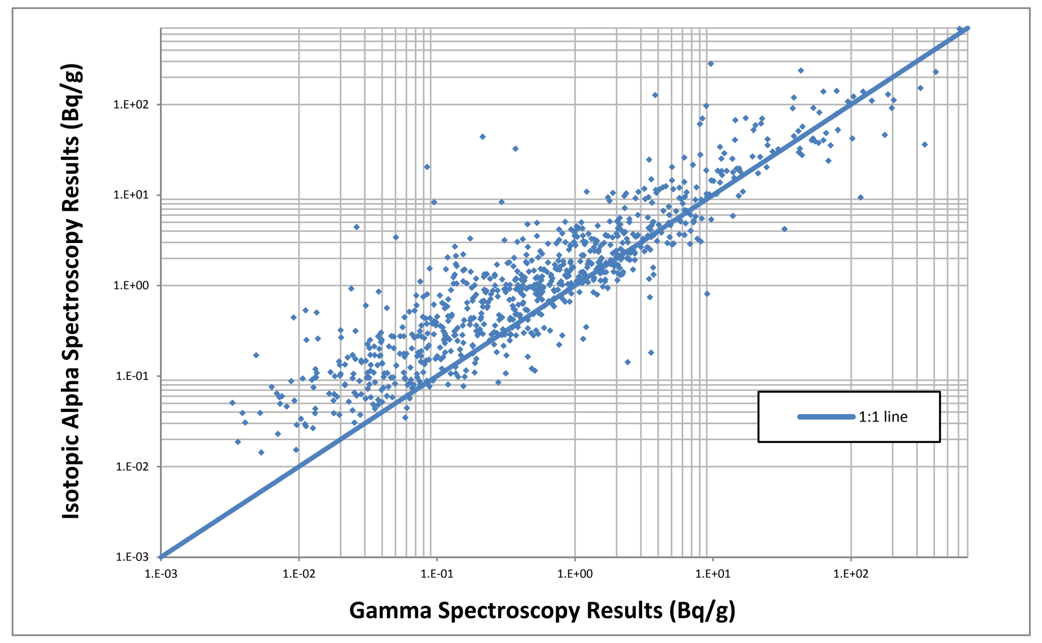
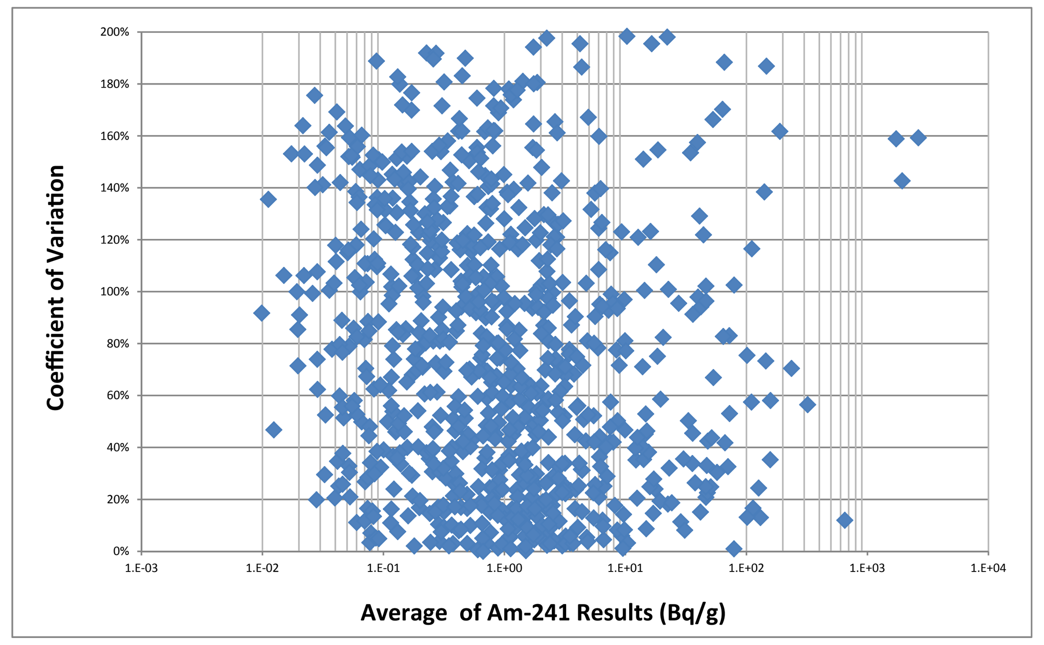
## Isotopic Pu 239/40 Duplicate Comparisons



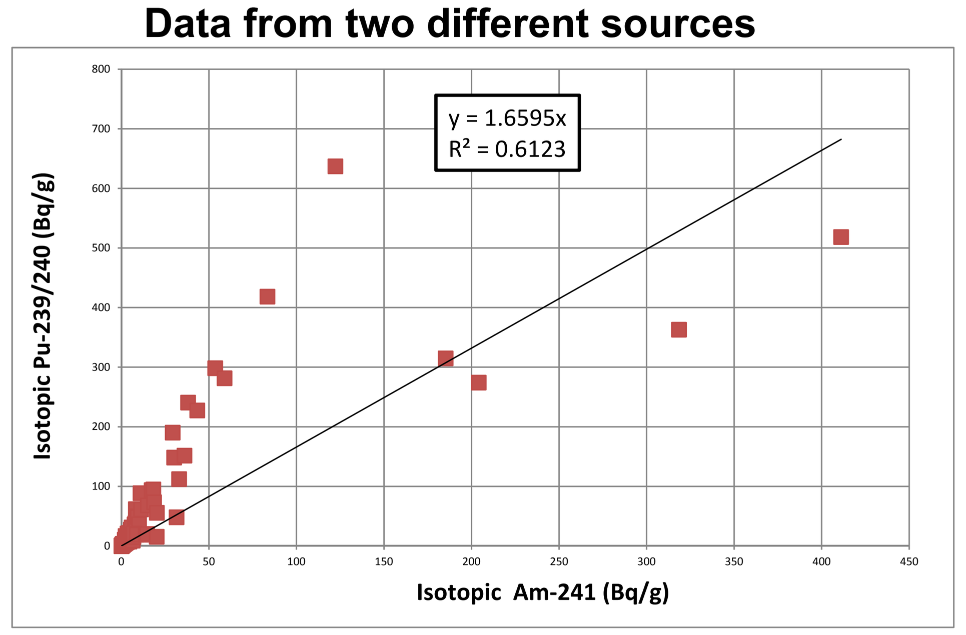

## Isotopic Am-241 versus Gamma Am-241 Comparisons



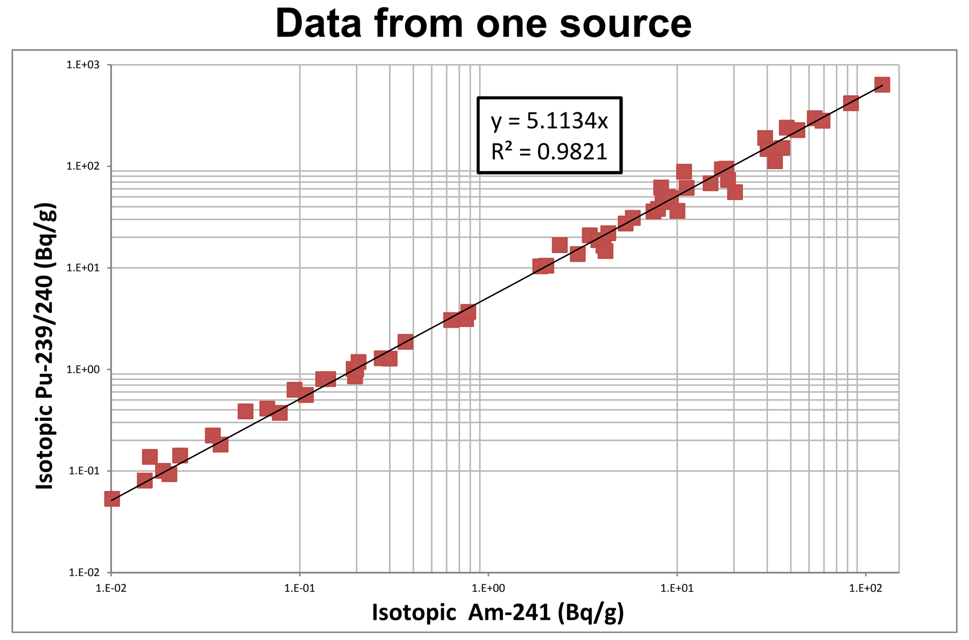




## Pu 239/40 to Am-241 Ratios

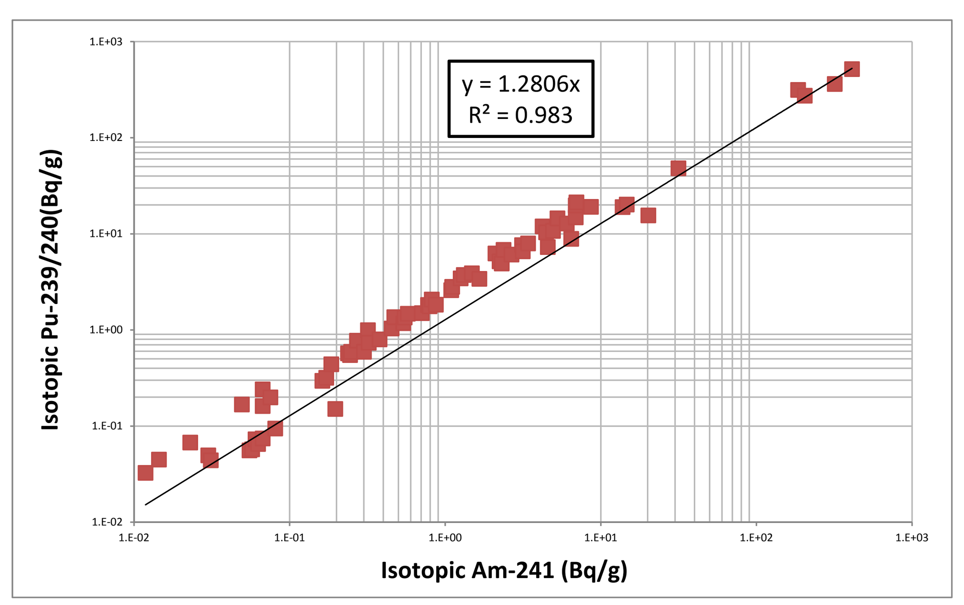
Data from two different sources



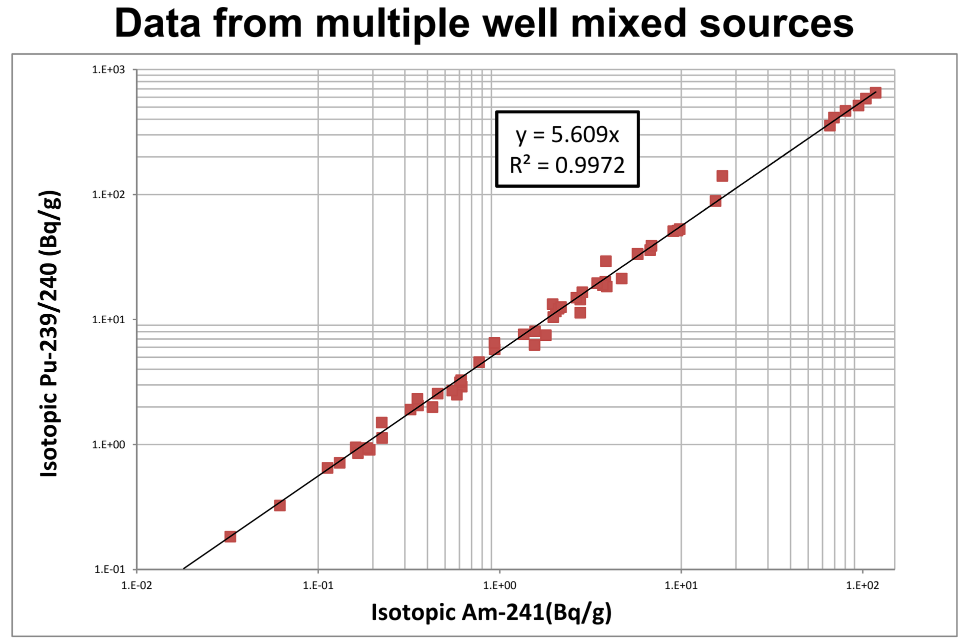

Data from one source




Data from one source




Data from multiple well mixed sources




## Gamma Spectroscopy Replicate Comparisons

**Results (Bq/g)**

| Sample No. | A602 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.01 | 0.34 | 14.5 |
| Replicate 2 | 1.03 | 0.32 | 12.0 |
| Replicate 3 | 1.06 | 0.32 | 13.6 |
| Replicate 4 | 0.99 | 0.33 | 12.7 |
| Replicate 5 | 1.01 | 0.33 | 14.2 |
| Replicate 6 | 1.08 | 0.32 | 12.9 |
| Replicate 7 | 1.05 | 0.31 | 12.4 |
| Replicate 8 | 1.07 | 0.32 | 12.2 |
| Replicate 9 | 1.03 | 0.33 | 14.0 |
| Replicate 10 | 1.02 | 0.30 | 12.3 |
| Average | 1.04 | 0.32 | 13.1 |
| STDev | 0.03 | 0.01 | 0.9 |
| n | 10 | 10 | 10 |
| d.f | 9 | 9 | 9 |
| t | 2.3 | 1.8 | 1.8 |
| 95%LCL | 1.0 | 0.3 | 12.6 |
| 95%UCL | 1.1 | 0.3 | 13.6 |

| Sample No. | A605 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.09 | 2.06 | 108.1 |
| Replicate 2 | 1.07 | 1.94 | 101.9 |
| Replicate 3 | 1.06 | 1.95 | 99.3 |
| Replicate 4 | 1.15 | 1.96 | 104.4 |
| Replicate 5 | 1.10 | 1.93 | 102.2 |
| Replicate 6 | 1.11 | 1.85 | 101.9 |
| Replicate 7 | 1.09 | 1.97 | 103.0 |
| Replicate 8 | 1.10 | 1.93 | 100.7 |
| Replicate 9 | 1.10 | 1.94 | 100.7 |
| Replicate 10 | 1.08 | 1.98 | 102.2 |
| Average | 1.10 | 1.95 | 102.4 |
| STDev | 0.02 | 0.05 | 2.4 |
| n | 10 | 10 | 10 |
| d.f | 9 | 9 | 9 |
| t | 1.8 | 1.8 | 1.8 |
| 95%LCL | 1.1 | 1.9 | 101.0 |
| 95%UCL | 1.1 | 2.0 | 103.9 |

| Sample No. | A658 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.08 | 0.03 | 2.9 |
| Replicate 2 | 1.05 | 0.03 | 4.0 |
| Replicate 3 | 1.01 | 0.03 | 3.1 |
| Replicate 4 | 1.00 | 0.03 | 3.9 |
| Replicate 5 | 1.01 | 0.03 | 3.9 |
| Replicate 6 | 1.04 | 0.03 | 4.0 |
| Replicate 7 | 1.04 | 0.03 | 3.7 |
| Replicate 8 | 1.04 | 0.03 | 3.7 |
| Replicate 9 | 1.04 | 0.03 | 3.0 |
| Replicate 10 | 1.07 | 0.03 | 3.4 |
| Average | 1.04 | 0.03 | 3.6 |
| STDev | 0.03 | 0.00 | 0.4 |
| n | 10 | 10 | 10 |
| d.f | 9 | 9 | 9 |
| t | 2.3 | 1.8 | 1.8 |
| 95%LCL | 1.0 | 0.0 | 3.3 |
| 95%UCL | 1.1 | 0.0 | 3.8 |

| Sample No. | A662 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.09 | 0.05 | 3.9 |
| Replicate 2 | 1.08 | 0.03 | 2.8 |
| Replicate 3 | 1.14 | 0.03 | 2.9 |
| Replicate 4 | 1.11 | 0.03 | 3.2 |
| Replicate 5 | 1.12 | 0.03 | 2.8 |
| Replicate 6 | 1.04 | 0.03 | 2.9 |
| Replicate 7 | 1.03 | 0.03 | 2.7 |
| Replicate 8 | 1.06 | 0.03 | 2.9 |
| Replicate 9 | 0.99 | 0.03 | 2.8 |
| Replicate 10 | 1.13 | 0.03 | 2.8 |
| Average | 1.08 | 0.03 | 3.0 |
| STDev | 0.05 | 0.01 | 0.3 |
| n | 10 | 10 | 10 |
| d.f | 9 | 9 | 9 |
| t | 1.8 | 1.8 | 1.8 |
| 95%LCL | 1.1 | 0.0 | 2.8 |
| 95%UCL | 1.1 | 0.0 | 3.2 |

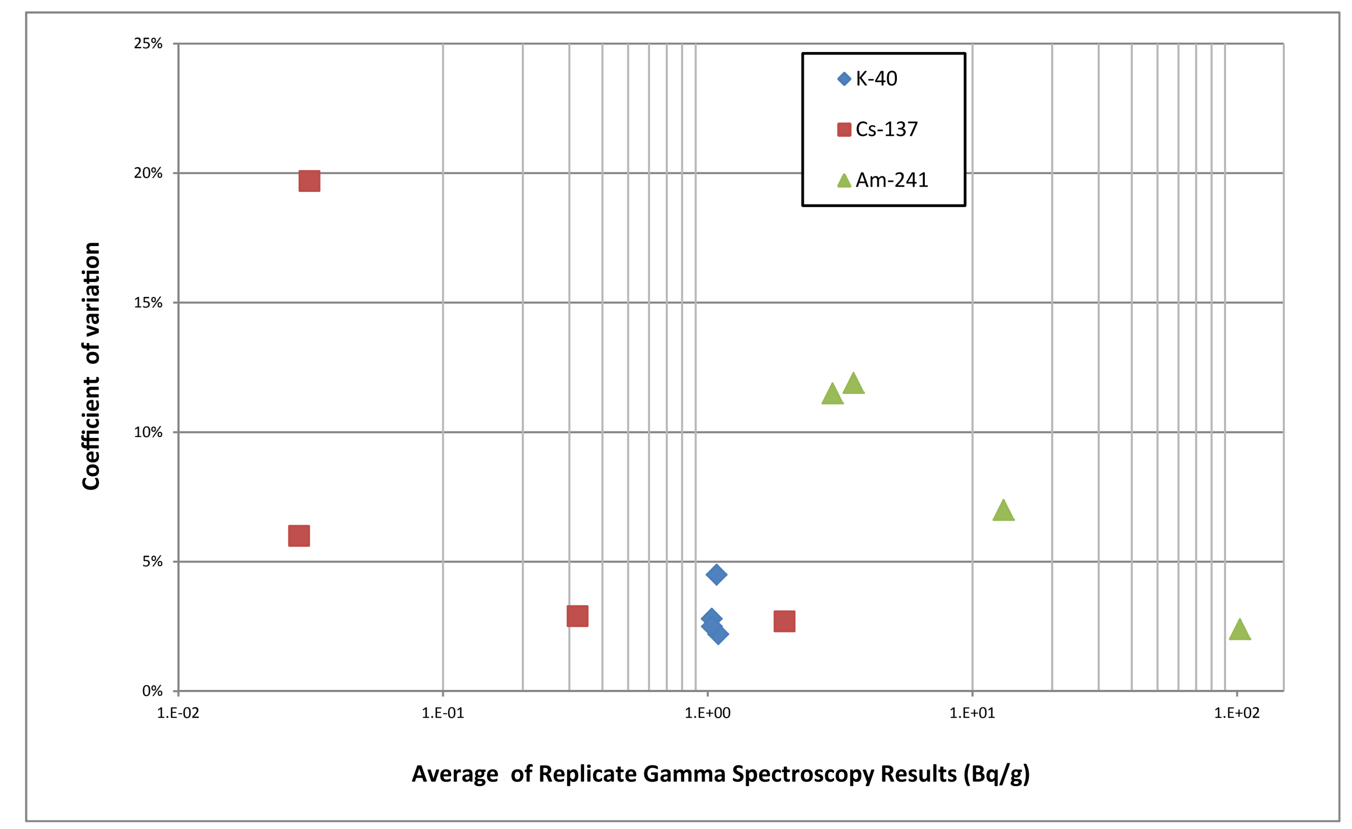
**Normalized Results with Variability**

| Sample No. | A602 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 0.97 | 1.05 | 1.11 |
| Replicate 2 | 0.99 | 0.99 | 0.92 |
| Replicate 3 | 1.02 | 1.00 | 1.04 |
| Replicate 4 | 0.96 | 1.01 | 0.97 |
| Replicate 5 | 0.98 | 1.04 | 1.09 |
| Replicate 6 | 1.04 | 0.99 | 0.98 |
| Replicate 7 | 1.02 | 0.98 | 0.95 |
| Replicate 8 | 1.04 | 0.99 | 0.93 |
| Replicate 9 | 1.00 | 1.01 | 1.07 |
| Replicate 10 | 0.98 | 0.95 | 0.94 |
| CV | 2.8% | 2.9% | 7.0% |
| Unexplained | | 0.1% | 4.2% |

| Sample No. | A605 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.00 | 1.06 | 1.06 |
| Replicate 2 | 0.98 | 0.99 | 0.99 |
| Replicate 3 | 0.97 | 1.00 | 0.97 |
| Replicate 4 | 1.05 | 1.01 | 1.02 |
| Replicate 5 | 1.00 | 0.99 | 1.00 |
| Replicate 6 | 1.02 | 0.95 | 0.99 |
| Replicate 7 | 1.00 | 1.01 | 1.01 |
| Replicate 8 | 1.00 | 0.99 | 0.98 |
| Replicate 9 | 1.01 | 0.99 | 0.98 |
| Replicate 10 | 0.98 | 1.01 | 1.00 |
| CV | 2.2% | 2.7% | 2.4% |
| Unexplained | | 0.5% | 0.2% |

| Sample No. | A658 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.04 | 1.09 | 0.80 |
| Replicate 2 | 1.01 | 1.10 | 1.13 |
| Replicate 3 | 0.97 | 1.01 | 0.89 |
| Replicate 4 | 0.96 | 1.02 | 1.08 |
| Replicate 5 | 0.97 | 1.01 | 1.08 |
| Replicate 6 | 1.00 | 0.93 | 1.13 |
| Replicate 7 | 1.00 | 0.95 | 1.04 |
| Replicate 8 | 1.01 | 0.99 | 1.04 |
| Replicate 9 | 1.01 | 0.95 | 0.85 |
| Replicate 10 | 1.03 | 0.95 | 0.96 |
| CV | 2.5% | 6.0% | 11.9% |
| Unexplained | | 3.5% | 9.3% |

| Sample No. | A662 | | |
|---|---|---|---|
| Isotope | K-40 | Cs-137 | Am-241 |
| Replicate 1 | 1.01 | 1.55 | 1.30 |
| Replicate 2 | 1.00 | 0.95 | 0.96 |
| Replicate 3 | 1.06 | 0.92 | 0.97 |
| Replicate 4 | 1.03 | 0.91 | 1.08 |
| Replicate 5 | 1.04 | 0.91 | 0.94 |
| Replicate 6 | 0.97 | 0.98 | 0.96 |
| Replicate 7 | 0.95 | 0.88 | 0.90 |
| Replicate 8 | 0.98 | 1.00 | 0.98 |
| Replicate 9 | 0.92 | 0.94 | 0.96 |
| Replicate 10 | 1.04 | 0.96 | 0.95 |
| CV | 4.5% | 19.7% | 11.5% |
| Unexplained | | 15.2% | 6.9% |




## Comparison of Variabilities

| Method | Coefficient of Variation |
|---|---|
| Isotopic Pu duplicates | 70% |
| Isotopic Am / Gamma Am | 77% |
| Gamma Am Replicates | 8% |

## CONCLUSIONS

Isotopic analyses results are very accurate in defining the activities of specific isotopes in the digested material, but they may not be representative of isotope activities in soil at a contaminated location when significant heterogeneity in the distribution of soil contaminants is present. However, the isotopic Pu-239/40 to Am-241 to Pu ratios can be determined with confidence using isotopic analyses, and Am-241 activities that are representative of site contamination can be determined with high confidence using gamma spectroscopy analyses. Multiplying the gamma Am-241 result from each sample by the Pu-239/40 to Am-241 ratio will result in higher confidence in the characterization of Pu-239/40 contamination at the release site.