Enriched Uranium Waste Assay at AWE - 9034

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ABSTRACT

Previously published studies have concluded that the Spectral Non-Destructive Assay Platform (SNAP) is the selected option from Best Practical Means (BPM) studies for radioactive waste assay of the majority of waste packages normally encountered at the Atomic Weapons Establishment (AWE) at Aldermaston in the United Kingdom (UK) (1). This paper presents the results from recent studies comparing the performance of SNAP with the Segmented Gamma Scanner (SGS) for the most highly contaminated Enriched Uranium (EU) waste streams generated at AWE, together with standard waste packages containing known amounts of EU.

In all cases the SNAP assay result was either similar to or significantly higher than the SGS result. The majority of the higher SNAP results were due to the need for uranium lump corrections (LC), for some waste streams, which were performed using the SNAP LC routine, but not done by the SGS. In other cases it was found that, where the SGS result was lower and the SNAP result higher, it was related to the EU source moving from high to low-density regions within the prepared waste drum standard.

The general trend observed was for the best agreement between SGS and SNAP for those waste packages where the 143/205 keV peak area ratio was relatively high (around 2/1) and therefore little or no uranium LC was required. In conclusion, the results support the selection of SNAP from the BPM options as the technique for EU waste assay at AWE.

INTRODUCTION

Previously published work has concluded that SNAP is the selected option from BPM studies for the assay of most radioactive waste packages encountered at AWE (1). This paper focuses on recent studies where the most highly contaminated EU waste streams were assayed with SNAP and the results compared to the SGS benchmark.

The SNAP assay system and assay procedure is briefly described, followed by an evaluation of the SNAP and SGS performance against homogeneous and heterogeneous hard and soft waste drum standards containing known amounts of EU and around 100 of the most highly EU contaminated waste drums encountered at AWE. SNAP software was used to investigate the relative insensitivity of the 143/205 keV peak area ratio, that is important for flagging up abnormal shielding effects, to changes in waste matrix composition/density when compared to changes in EU lump size.

SNAP ASSAY SYSTEM

Table I summarises the key hardware and software components of the portable SNAP system. Figure 1 shows the SNAP monitoring a drum of waste situated on a rotating turntable.

Table I HRGS components

Component	Specification
Detector	High Purity Germanium N-type (45 % relative efficiency)
Collimator	20 mm lead (copper lined)
Multichannel analyser	ORTEC digiDART
Computer	Laptop with windows 98
MCA emulator	Maestro 32
Analytical software	SNAP
Trolley	ORTEC ISOCART

Figure 1 SNAP monitoring a waste drum on a turntable

SNAP PROCEDURE

The SNAP analytical software corrects the detector calibration for counting geometry (e.g. drum dimensions and distance from the detector) and gamma ray attenuation (e.g. waste matrix mass and composition). It also has routines for differential peak analysis and uranium and plutonium LC. The reader is referred to the SNAP software user's manual, available from Eberline Services Inc., for a detailed description of SNAP features and analysis procedures since there does not appear to be a published reference that gives the reader this level of detail. Reference 1 shows that the software gave good results when applied to a certified waste drum standard containing a uniform distribution of contamination and simulated waste.

RESULTS FOR WASTE DRUM STANDARDS WITH KNOWN AMOUNTS OF EU

Two standards were prepared by filling 200 l drums with evenly distributed material (i.e. homogeneously distributed waste) and 10 g of EU (93 % U-235) swarf present in 5 randomly distributed polythene bags, each containing 2 g of EU. Drum A contained 20 kg of soft waste (PVC and paper), whilst drum B contained 60 kg of hard waste (steel). The comparative SGS and SNAP results are summarised in table II.

Table II Results (U-235 g) for waste drum standards A and B

Drum	SNAP	SGS	SNAP/SGS	143/205	LC (microns)
A	8	4.2	1.90	1.44	500
B	10.3	3.9	2.64	1.30	500

The above results highlight significant activity underestimation by SGS when the EU was present in the form of swarf rather than fine particulate contamination. The need to apply a LC was signalled by an abnormally low 143/205 keV ratio and significant underestimation at 143 keV compared to 205 keV. Applying a 500 micron LC, using the SNAP uranium LC routine, resulted in consistent activities at all photon energies. Table III summarises the SNAP results with and without a LC.

Table III Effect of lump correction on SNAP results for drum standards A and B

Photon (keV)	Drum	U-235 (g) without LC	U-235 (g) with LC
143	B	3.67	10.7
163	B	4.57	10.7
186	B	5.29	10.2
205	B	5.62	9.57
143	A	2.78	8.1
163	A	3.44	8.02
186	A	4.18	8.06
205	A	4.63	7.89

Applying a 500 micron LC to the SGS results would roughly double them to give around 8g. So when the waste is evenly distributed the major difference between SNAP and SGS is the LC.

In order to investigate the effect of heterogeneous waste distribution a 200 l drum was prepared by filling the bottom third with solid wood roundels (high-density region, approximately 0.4 g/cc), the middle third with empty polythene bottles (low-density region, approximately 0.1 g/cc) and leaving the top third empty. A 5 g EU foil source (93 % U-235) was located radially at 28 cm from the axis, vertically in the centre of the high-density region to generate drum standard 1. The source was relocated radially at 28 cm from the axis, vertically in the centre of the low-density region to create drum standard 2. The drums were counted on a rotating turntable, with the SNAP detector at 60 cm from the centre/middle of the drum wall, as shown in figure 1. The SGS detector was much closer at 15 cm. Table IV summarises the results.

Table IV Results (U-235 g) for waste drum standards 1 and 2

Drum	SNAP	SGS	SNAP/SGS	143/205	LC (microns)
1	3.81	1.71	2.23	1.16	700
2	5.1	1.08	4.72	1.24	700

The above results show that a larger LC of around 2.4 was required for the foil source (700 microns) compared to the LC of 2 applied to the swarf (500 microns). This was signalled by lower 143/205 keV ratios and greater underestimation at 143 keV compared to 205 keV without a LC (table V).

Table V Effect of lump correction on SNAP results for drum standards 1 and 2

Photon (keV)	Drum	U-235 (g) without LC	U-235 (g) with LC
143	1	0.96	3.73
186	1	1.61	3.84

205	1	1.9	3.88
143	2	1.33	5.19
186	2	2.29	5.45
205	2	2.47	5.03

Applying a 700 micron LC (x2.4) to the SGS results would increase them to 4.1 g for the high-density region, but only 2.6 g for the low-density region. This shows that, with heterogeneously distributed wastes, discrepancies between SNAP and SGS are greater than can be accounted for by a uranium LC.

RESULTS FOR HIGH ACTIVITY WASTE DRUMS

Around 100 of the highest activity EU drums have been assayed using SNAP and SGS. Figure 2 shows the SNAP results correlated reasonably well with the SGS, but were about 1.6x higher.

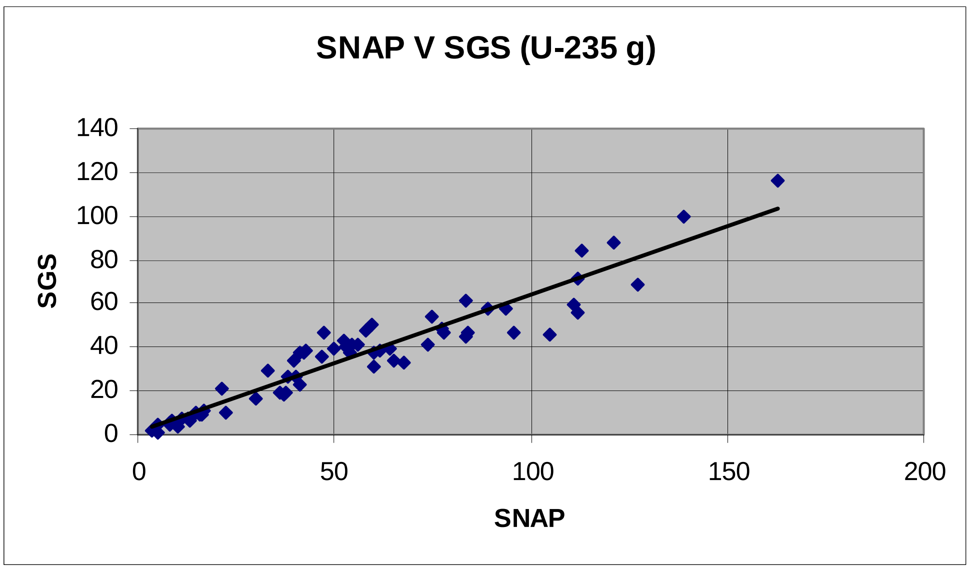

Figure 2 Comparison of SNAP (with LC) and SGS results for high activity EU waste drums

Re-plotting figure 2, but using the SNAP results without LC, improved the correlation with the SNAP results only 1.17x higher than the SGS (figure 3).

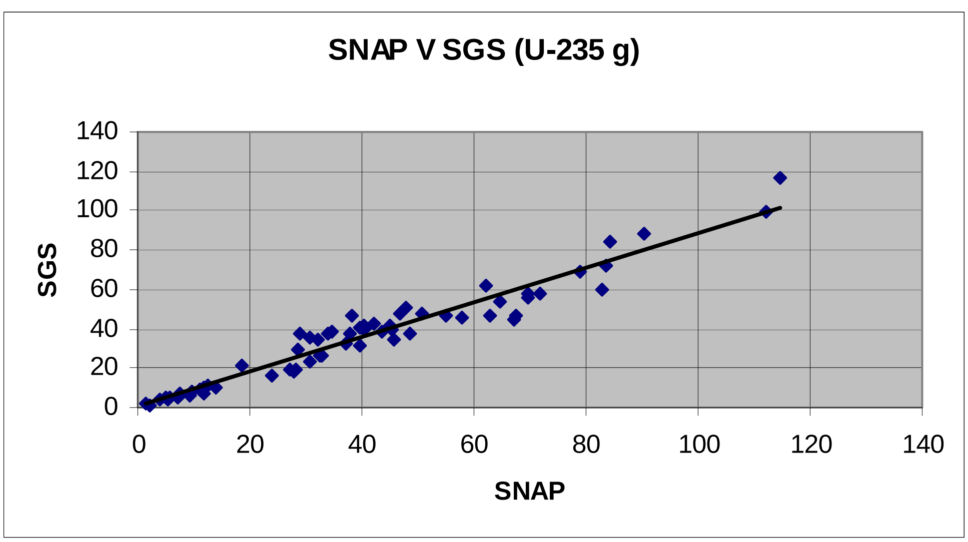

Figure 3 Comparison of SNAP (without LC) and SGS results for high activity EU waste drums

This observation supports the belief that in most cases the main reason for the higher SNAP result was the LC. This size of the LC correlated with the 143/205 keV peak area ratio and ranged from 0 microns (2.8/1 ratio) up to 450 microns (1.5/1 ratio) for drums containing contamination rather than sources.

However, drums having low-density regions, like the heterogeneous drum standards, can give elevated SNAP results and depressed SGS results if EU was concentrated in these regions (table IV).

PEAK RATIO CALCULATIONS

SNAP software was used to investigate the relative insensitivity of the 143/205 keV peak area ratio to changes in waste matrix composition/density compared to changes in EU lump size.

Calibration curves

SNAP calibration curves were generated for the principal photon energies and the results are summarised in table VI. These are cps/g versus gross drum mass for each photo peak, based on uniform EU and matrix distribution within the drum.

Table VI Response factors for drummed waste (cps/g U-235)

Gross mass (kg)	Matrix	143 keV	186 keV	205 keV	143/205 keV
30	Steel	1.22	6.01	0.52	2.35
40	Steel	1.01	5.16	0.45	2.24
50	Steel	0.86	4.49	0.39	2.21
60	Steel	0.74	3.95	0.35	2.11
80	Steel	0.57	3.14	0.28	2.04
100	Steel	0.46	2.60	0.23	2.00
30	Paper	1.30	6.17	0.53	2.45
40	Paper	1.12	5.40	0.46	2.43
50	Paper	0.98	4.76	0.41	2.39
60	Paper	0.87	4.24	0.37	2.35
80	Paper	0.70	3.45	0.30	2.33
100	Paper	0.58	2.90	0.25	2.32

The figures above show that the 143/205 keV ratio is relatively insensitive to drum mass and matrix composition compared to that observed for small changes in uranium lump size. The ratio changed from a maximum of 2.45 for the lightest (30 kg) paper drum to a minimum of 2 for the heaviest (100 kg) steel drum.

Lump corrections

Applying the SNAP LC to uranium metal lumps without any matrix attenuation produced a significant further reduction in 143/205 keV peak area ratio (table VII) than would be expected from normal matrix attenuation (table VI).

Table VII Effect of uranium lump size on LC factor for uranium metal only

Lump size (microns)	143/205 keV ratio	LC factor @ 186 keV

		(multiplier)
0	2.63	1.0
100	2.26	1.16
200	2.00	1.34
500	1.53	1.97
1,000	1.25	3.25
2,000	1.15	6.21
5,000	1.14	15.4
10,000	1.10	31.3

Table VIII shows that similar reductions in the 143/205 peak area were observed in waste packages typically encountered at AWE.

Table VIII Reduction in 143/205 keV ratio with EU lump size

Waste Package	**EU form**	**Lump correction (μ)**	**144/205 keV ratio**
HEPA filter	Contamination	0	2.5
5 l oil container	Contamination	0	2.4
200 l drum (60 kg)	Contamination	0	1.9
200 l drum (40 kg)	Swarf	500	1.4
200 l drum (40 kg)	Foil	800	1.3
200 l drum (60 kg)	Pellet	9000	1.0

DISCUSSION

SNAP and SGS tend to give the best agreement (i.e. SNAP/SGS activity ratio of 1) when the uranium is present as fine particulate contamination and the matrix is evenly distributed throughout the drum. At the other extreme, the worst agreement (SNAP/SGS of 4.72) was noted for a heterogeneous drum standard with a foil source located in a low-density region within the drum. The SNAP result was 114 % of the true activity and the SGS result was 24 %.

Trials with known amounts of EU in drum standards show that, when the waste is evenly distributed, SNAP (without a lump correction) and SGS gave similar results at 186 keV. The same was also true for the most active waste drums (figure 3). However, when the size of the uranium present progressively increased the 143/205 keV peak ratio decreased and an increasingly large uranium LC was required in order to obtain consistent results at all photon energies (e.g. table VIII drums containing increasingly large EU sources).

In the majority of cases the discrepancy between the SNAP and SGS can be accounted for by the uranium LC. However there is some evidence that, when the waste distribution is heterogeneous, the SNAP result can become elevated and the SGS result depressed if the activity is concentrated in a low density region of the drum. The results in table IV show that the SGS result reduced from 1.71 to 1.08 g (60 % lower) by just moving the source from the high density region to the lower density region.

The relative insensitivity of the 143/205 keV ratio to changes in waste matrix composition (e.g. steel or paper) and mass (up to 100 kg), compared to lumps of uranium, makes it a valuable indicator of abnormal shielding effects. However, the uranium LC correction technique soon saturates with increasing lump size (table VIII). Fortunately the need to do lump corrections is relatively rare and (when required) normally limited to just a few hundred microns.

CONCLUSIONS

- Recent inter-comparison studies, between SNAP and SGS, support the continued application of SNAP as the favoured option within BPM studies for EU waste assay at AWE.
- SGS underestimates the activity when lumps of EU are present, since no lump corrections were made by the SGS
- SGS underestimates when activity is present in low density regions within the drum as demonstrated by moving a traceable EU source between low and high density regions in drum standards (table IV).

REFERENCES

(1) T.J.Miller, Applications Where SNAP is BPM for Radioactive Waste Assay, WM2008, Phoenix, Arizona, USA, February 2008..
(2) T.J.Miller Depleted Uranium Waste Assay at AWE, WM 2007, Tucson, Arizona, USA, February 2007.