APPLICATION OF IN-LINE MONITORING TO WASTE MINIMISATION DURING SOIL REMEDIATION

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ABSTRACT

The Decontamination Group (DG), at the Atomic Weapons Establishment (AWE), in the UK, managed and operated by Hunting-BRAE Ltd., on behalf of the Secretary of State for Defence, has successfully applied in-line radiological monitoring techniques, to minimise the volume of controllable radioactive waste arisings, during the remediation of uranium contaminated land. The approach adopted was to locate "hot spot" contaminated areas, using a sensitive x-ray counter (IS 610) developed at AWE, then excavate the "hot spots", together with the minimum of associated uncontaminated material, for radiological assay (IS 610) at a monitoring station local to the contaminated site, so that only genuinely contaminated waste was packaged for disposal and uncontaminated material was returned to its point of origin. Figures are presented, comparing the improved performance of this approach, with traditional remediation techniques, which involve an iterative process of sample analysis and excavation, until the desired end-point is achieved.

INTRODUCTION

The AWE DG maintains a capability to develop economical, efficient and effective decontamination and monitoring practices, which minimise the volume of controllable radioactive waste arisings from AWEs operations. Traditional land remediation practices, relying on an iterative process of sample analysis and excavation, have proven to be expensive, time consuming and ineffective at meeting the stringent radiological end-points required. However, the development, at AWE, of a sensitive x-ray counter (IS 610), has enabled much cheaper, quicker and more effective in-line monitoring practices to be introduced.

Traditional Remediation Practices

The contaminated site is cordoned off and a grid, usually one metre squares, is superimposed. Small samples, typically a few grammes, of the topsoil are removed at the grid intersections and sent away for laboratory analysis. When the results are known, the entire surface, often the whole area where above background samples were found, is then removed, usually down to a depth of one tenth of a metre, for controlled disposal as contaminated waste. The process of sampling and excavation is then repeated until the samples are uncontaminated or below an agreed end-point which is acceptable to all parties. For depleted uranium (DU) this could be 11.1 Bq/g (1), but AWE normally aims for 2.5 Bq/g, with more stringent end-points for other isotopes. This approach is costly and lengthy, with no guarantee of reaching the desired end-point, since large numbers of samples must be processed and, inevitably, large quantities of uncontaminated material are removed, along with the contamination, for controlled disposal, but some contamination may remain behind.

In-Line Monitoring Practice

A sensitive x-ray counter (IS 610) is employed to rapidly pinpoint "hot spot" contamination areas within the field. The "hot spot" topsoil is then transferred to a local monitoring station, sited in an uncontaminated area which is several metres outside the field, for assay by another x-ray counter (IS 610). If the removed material is below the end-point criterion, then it is returned to its point of origin. Only genuinely contaminated material is packaged for controlled disposal, according to its contamination level. Finally, the field is resurveyed to confirm that it is free of contamination. This approach is rapid and inexpensive because there is constant feedback on the progress of the remediation by direct monitoring, so that excavation stops when the end-point has been achieved and only contaminated waste, with the minimum of associated uncontaminated material, is removed for controlled disposal.

IS 610 X-Ray Counter

The IS 610 was originally developed by AWE (2) for the detection of L x-ray photon and gamma emissions, from low level ground contamination, by the various isotopes of plutonium and uranium and their radioactive decay products, such as americium and thorium. It can be used as a hand held monitor, or mounted on its tripod (figure 1).

Figure 1   IS 610 mounted on its tripod

The IS 610 detector consists of a NaI(Tl) crystal, with a diameter of 75 mm and a thickness of 1 mm. There are three regions of interest: channel 1 (C1), 10-24 keV;
channel 2 (C2), 47-72 keV and channel 3 (C3) 10-72 keV. Typical sensitivity and background counts (C2) are 2 cps/Bq/cm^2 and 8 cps respectively (3). The normal field of view, when mounted on its tripod 30 cm above the ground (optimum working height), is a 4 m diameter circle. Detection limits improve with counting time (figure 2), but the standard, factory set, counting time is 100 s. However, the counter may be used in RUN mode, where the cps display is updated every second.

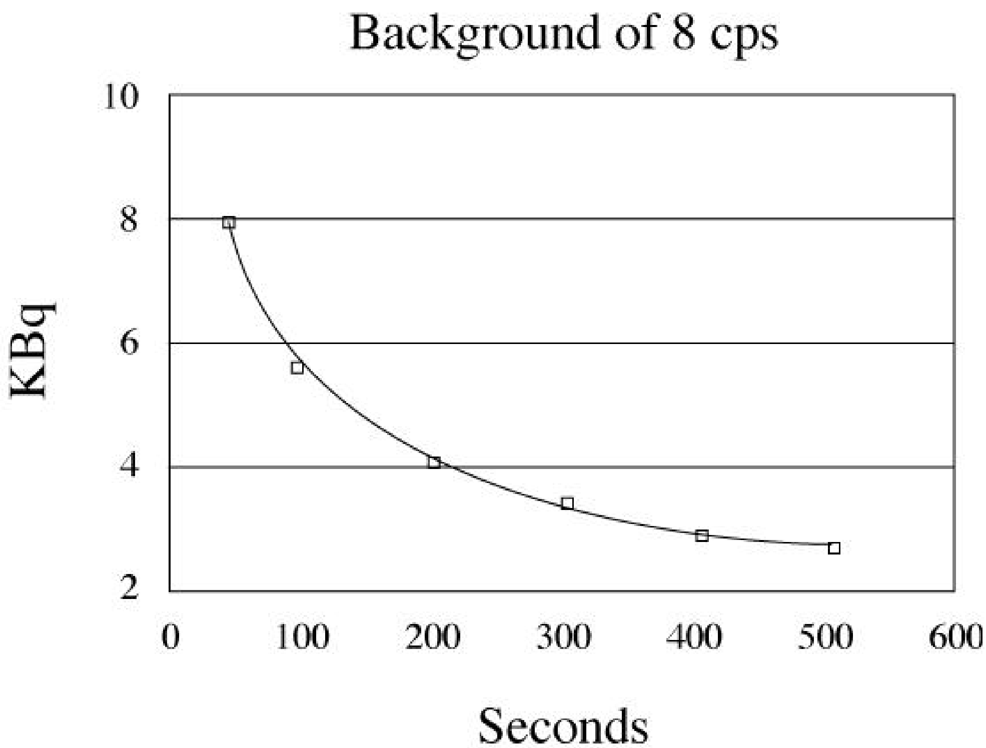

Figure 2 IS 610 detection limits

Detection limits may be reduced by attenuating materials. However, the emissions from DU penetrate several cm of soil (figure 3), so the IS 610 can assay bulk samples, provided they are monitored as thin layers, contained in trays.

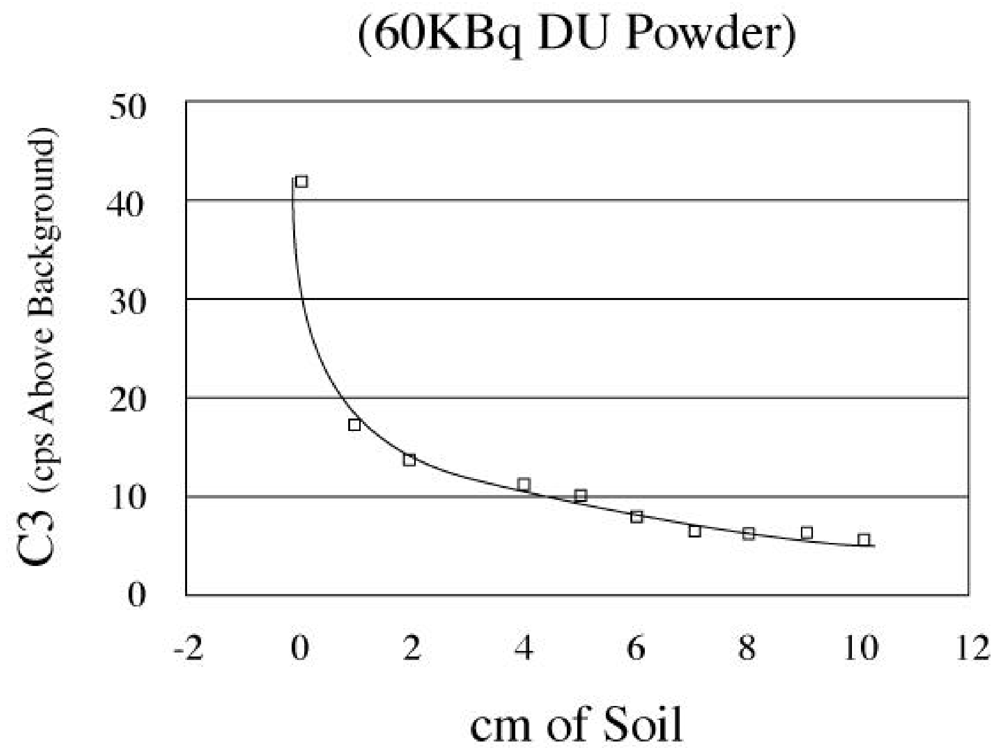

Figure 3 IS 610 response to 60 kBq (4 g) DU powder under soil

CASE STUDY

A small area of DU contaminated ground, approximately 40 m long and 3 m wide, was surveyed conventionally by taking samples of topsoil at the intersections of a m^2 grid and sending them for laboratory analysis. Some samples had approaching 100 Bq/g alpha activity and averaged over 10 Bq/g. A subsequent IS 610 survey quickly identified a number of "hot spots" in areas where the analytical samples were high. The ground was then remediated using the in-line monitoring approach. Confirmation of achieving the desired end-point, of below 2.5 Bq/g, was obtained by resampling in addition to remonitoring the whole area.

IS 610 Calibration

DU powder was mixed with soil to produce trays containing a range of DU/soil standards from 0-6 Bq/g above background levels. The standards were then counted with the IS 610 in various mass and dimension configurations. The counting efficiency, E, (cps/Bq/g), was derived from the slope of the calibration plot (figure 4).

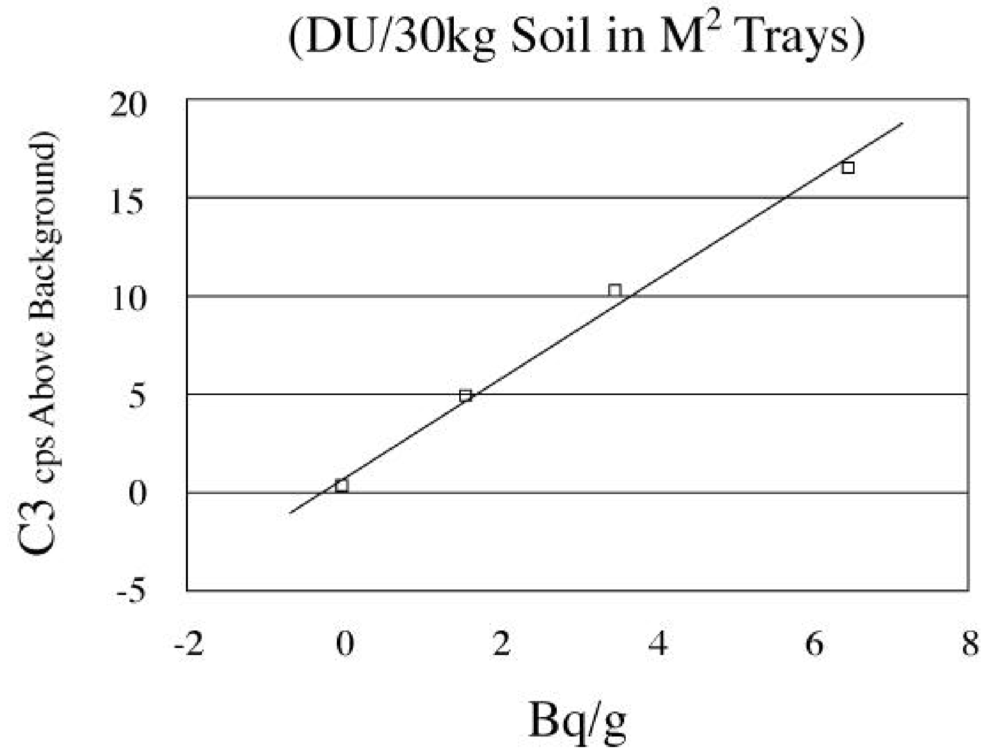

Figure 4 IS 610 calibration for 30 Kg DU/soil standards in m^2 trays

Decision levels (Dcl), detection levels (Dtl), errors (Er) and activities (A), were calculated from the sample counts (S), background counts (B), count times (T) and efficiencies (E), using the following formulae (4):

$Dcl = B + (1.64 \times B^{1/2})$	counts	(Eq. 1)
$Dtl = Dcl + (1.64 \times Dcl^{1/2})$	counts	(Eq. 2)
$Er = 1.96 \times (S + B)^{1/2}$	counts	(Eq. 3)
$A = (S - B / E \times T)$	(Bq/g)	(Eq. 4)

Field Survey

The whole area (40 x 3 m) was surveyed, in RUN mode (cps display updated every second), by walking slowly (2 kph) along the grid and using the hand grip so that the detector faced downward and slightly forward. All m^2 squares having > 5 cps above background (C3) were noted and identified as 'hot spots'. These 'hot spots' were then surveyed in INT mode (100 s count), by setting up the IS 610 on its tripod so that the detector was 30 cm above the centre of the m^2 square containing the 'hot spot', and collecting and recording the cps above background.

"Hot-Spot" treatment

All "hot-spots" were removed (shovel and bucket) for assay at the monitoring station. The IS 610 was used in standard INT mode and the soil was spread out evenly in a m^2 tray to a depth of 2.5

cm. All trayloads below 2.5 Bq/g (above background) were returned to their point of origin. Those above 2.5 Bq/g were packaged for controlled disposal.

RESULTS

IS 610 Performance

Given the standard counting time of 100 s, the standard IS 610 counting geometry and a sample mass of 30 kg, spread to a depth of 2.5 cm in m^2 trays, it was possible to achieve sub Bq/g detection levels for DU in soil. Efficiency factors were improved by using larger masses of sample (Table I).

Table I IS 610 efficiency factors for bulk soil assay

Soil Mass (kg)	Soil Dimensions (cm)	Efficiency (cps/Bq/g)
10	25 Diameter x17 height	1.7
3	48 x 57 x 0.9 height	0.6
10	48 x 57 x 3 height	1.7
30	100 x 100 x 2.5 height	2.7

Field Survey and Assay

A few "hot spot" areas were located in places where samples had also given high results. Removal of the topsoil from the "hot spot" areas and assay at the side of the field showed that only one 30 Kg tray in 17 was contaminated above the end-point criterion of 2.5 Bq/g (Table II). This was disposed of as controlled waste and the other 16 trays were returned to their point of origin. Subsequently, the field was resurveyed with the IS 610 and found to be uncontaminated. This was confirmed by conventional sampling and laboratory analysis.

Table II IS 610 field assay of 30 Kg trays of soil

Tray	cps	Bq/g
1	4.3	1.6+/-0.1
2	4.5	1.7+/-0.1
3	3.6	1.3+/-0.1
4	3.1	1.1+/-0.1
5	4.9	1.8+/-0.1
6	3.3	1.2+/-0.1
7	2.0	0.7+/-0.1
8	1.9	0.7+/-0.1
9	3.4	1.3+/-0.1
10	2.4	0.9+/-0.1
11	3.4	1.3+/-0.1
12	0.7	0.3+/-0.1
13	2.1	0.8+/-0.1
14	1.4	0.5+/-0.1
15	1.3	0.5+/-0.1
16	8.0	3.0+/-0.1
17	3.8	1.4+/-0.1

COMPARISON OF TRADITIONAL AND IN-LINE TECHNIQUES

The costs, timescales and effectiveness of the in-line monitoring approach are all far superior to the traditional approach. Table III gives a simple comparison of costs.

Table III Comparative costs for remediation of a small area of DU contaminated ground

Operation	Traditional procedure (£)	DG procedure (£)
Site characterisation	3,000	100
Excavation of contamination	300	300
Confirmatory monitoring	3,000	50
Waste disposal	6,000	30
Totals	12,300	480

Site Characterisation

A conventional survey for a small area would cost around £3,000 and it would be several months before the results were known (5). Also, grid sampling in the presence of "hot spots" is a hit and miss method of determining the overall contamination distribution and its boundaries. This can lead to the excavation of much clean soil, along with the contamination, or missing contaminated areas altogether and removing no soil. By contrast, the IS 610 is able to rapidly home in on "hot spots" in

RUN mode. The contaminated areas may then be monitored more accurately in INT mode. The whole operation takes only a few hours and would cost only £100.

Excavation of Contamination

On the basis of the conventional survey alone it would have been recommended that an area of 60 m^2 be excavated to a depth of 0.1 m, generating some 6 tonnes of waste. This operation would cost around £300 and may need to be repeated several times until subsequent surveys indicate that radiological end-points have been met. By contrast, the in-line monitoring technique generates only a small quantity of waste, since only contaminated surface soil is excavated. This is then assayed at the side of the field and only removed if it is above the end-point criterion. Clean soil is returned. The net cost for this operation would be around £300 for the small "hot-spot" areas requiring treatment.

Confirmatory Monitoring

A second conventional survey would be required to confirm that radiological end-points had been met and would cost a further £3,000 and have the drawbacks noted for the initial characterisation. If the site were still contaminated, further cycles of excavation and monitoring would lead to rapidly escalating costs. However, a second IS 610 survey would be more rapid than the first, since only the excavated areas, where the "hot spots" were, would need to be examined. This would only cost around £50.

Waste Disposal

The traditional technique would generate around 6 tonnes of waste which would cost £6,000 if sent to Drigg as low level waste. By contrast the in-line monitoring technique ensures that only the contamination is removed with the absolute minimum of associated soil. This was only 30 Kg, with minimal disposal costs.

REFERENCES

1. Radioactive Substances Act 1960 (RSA 1960) in conjunction with Exemption Order SI1002 (1986) (exempts natural uranium isotopes from controlled disposal below 11.1 Bq/g).

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