Determining the Extent of Depleted Uranium Contamination in Soils at a Weapons Test Site: An Isotopic Investigation

I.W. OLIVER[1], A.B. MACKENZIE[1], R.M. ELLAM[1], M.C. GRAHAM[2], J.G. FARMER[2]

[1]Scottish Universities Environmental Research Centre (SUERC); i.oliver@suerc.gla.ac.uk

[2]School of GeoSciences, University of Edinburgh

Uranium (U) has three naturally occurring isotopes (^{234}U, ^{235}U, ^{238}U), with ^{238}U being the most abundant (Table 1). The process of uranium enrichment, for nuclear power or weapons, preferentially concentrates the fissile isotope ^{235}U. The process also concentrates ^{234}U in the enriched product, leaving a waste material depleted in both ^{234}U and ^{235}U. Consequently, this depleted uranium, or DU, has an isotopic signature distinct from naturally occurring uranium (Table 1). A variety of civilian and military applications have been found for DU due to its high density (19.05 g/cm^3), penetrating power and pyrophoric properties. In the UK, a DU ammunition research and development programme was conducted at a firing range in Kirkcudbright, southwest Scotland. At one test-firing location, Raebury Gun, experimentation with prototype designs resulted in approximately 70 misfirings, potentially leading to wide-spread DU contamination.

Table 1: Isotope abundances and activity ratios in U and DU

	Mass %			Activity Ratio	
	^{238}U	^{235}U	^{234}U	^{235}U/^{238}U	^{234}U/^{238} U
U	99.27	0.72	0.0055	0.04663	~ 1.000
DU	99.80	0.20	0.0009	0.01299	0.168

We collected surface soils (~ 0-10cm) from the immediate vicinity of the firing point and along the firing line. These were dried, ground and sieved to 2 mm prior to analysis for U isotope distribution and total U concentration. For isotopic analysis 2 g samples (n = 3) were ashed at 600°C, digested in mineral acids and passed through anion-exchange columns to isolate U, which was then electroplated onto stainless steel planchettes for counting by alpha spectrometry (silicon surface barrier detector, Octête plus, Ortec). The presence of any DU contamination was identified from the U isotope signatures observed. In addition to the surface soils, a soil core (cut into 1 cm slices) was also collected immediately in front of the firing point so that the depth penetration pattern of DU could be examined.

The results revealed extensive DU contamination around the firing position (Table 2). Numerous sites had U isotope signatures consistent with that of DU, indicating that >95% of the U present in those samples was sourced from DU contamination. Data for the soil core revealed almost consistent DU contamination down to the depth examined (~ 10cm).

Table 2: U isotopic activity ratios in soils along the firing line

soil	*A*	*D*	*G*	*Bunker*
^{235}U/^{238}U	0.012	0.012	0.021	0.045
^{234}U/^{238} U	0.168	0.171	0.405	0.901
~ distance (m)	15	18	35	150