THE UPTAKE OF PLUTONIUM-239,240, AMERICIUM-241, STRONTIUM-90 INTO PLANTS

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INTRODUCTION

This report describes the results of measurements on the uptake of plutonium, americium, strontium-90 and caesium-137 into peas, beet, oats, sweet corn, tomatoes and vegetable marrow grown in tubs containing radioactively-contaminated silts. The silts had been taken from an area of west Cumbria commonly referred to as the Ravenglass estuary. The work was carried out in parallel with studies on the uptake of these radionuclides from silts into potatoes (1,2). Like the potato experiments, the experiments described here used non-standard conditions in the sense used by the International Union of Radioecologists (3). Our experiments are categorised as being carried out under non-standard conditions because of the manner in which the radioactivity came to be incorporated into the growth medium. Nevertheless the growth medium was representative of conditions which could arise when the estuarine silt moves inland under the influence of wind and tide and mixes with the adjacent farm land. The silt had been contaminated by radioactive effluents from the nuclear fuels reprocessing plant at Sellafield and this contamination had been brought about by natural means. Because non-standard conditions were used for the experiment the results cannot be related to results from other workers' experiments where standard conditions were used. However, the value of the work is in its application to a real situation. The loss of the facility of relating the results with data from other experiments is of secondary importance.

EXPERIMENTAL

Several blends were prepared from approximately equal volumes of sediment and soil from farmland adjacent to the Ravenglass estuary. The sediment had been exposed to rain over several months so as to reduce the salinity of the material. The soil and sediment were mixed by passing a tilling machine to and fro over a bed of the materials for several hours.

The blends of soil were not subjected to a particle size analysis, but the size distributions of the blends were likely to be closely similar to those of the blend used in the potato experiments (1), 50% sand, 34% silt and 16% clay. Other physical properties of the blends were likely to be similar to the corresponding properties of the blends used in the potato experiments. However, the overall classification of the blend may be of little consequence, the important factor being the nature of the affinity between the radionuclides and the particles on which they were first deposited; the

nature of the soil subsequently mixed with the silt may have little bearing on the movement of radionuclides from silt to plant.

The plants were grown in cisterns measuring 26 x 29 x 40 cm and provided with suitable drainage holes. The volume of the growing medium in each cistern was about 28 l. The crops were harvested periodically (peas, tomatoes, marrows, beet) or when ripe (oats, sweet corn). Peas were shelled and the seed and pods analysed separately. Neither peas nor pods were washed. Tomatoes and marrows were washed and analysed without peeling. Beet was thoroughly washed and lightly brushed under the tap. The roots were peeled and the peel and flesh analysed separately. The oat grain was stripped from the stem by hand, and the whole husk analysed, as was the remaining stem and foliage.

RESULTS AND DISCUSSION

Table 1 shows the results of the radiochemical analyses of the various crops, and Table 2 shows the corresponding transfer factors derived on the basis:-

$$\text{transfer factor} = \frac{\text{conc of radionuclide in the crop, wet wt.}}{\text{conc of radionuclide in the soil, dry wt.}}$$

During the course of this work the results of the potato experiments (1,2) became available, showing that as far as the actinides were concerned, these radionuclides became less available for uptake season-by-season. Consequently work involving growing experiments in the Ravenglass silts was terminated. Current work has switched to growing crops by rotation in different soil types, the radionuclides being added by artificial means.

REFERENCES

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2. D S Popplewell, G J Ham, T E Johnson, J W Stather and S A Summer, The uptake of ^{238}, ^{239}, ^{240}Pu, ^{241}Am, ^{90}Sr and ^{137}Cs into potatoes, The Science of the Total Environment, in the press.

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TABLE 1

CONCENTRATIONS OF RADIONUCLIDES IN CROPS, Bq kg^{-1} WET WEIGHT, AND ASSOCIATED SOILS, Bq kg^{-1} DRY WEIGHT

Description	^{239}Pu + ^{240}Pu	^{241}Am	^{90}Sr	^{137}Cs	% Water
Pea, seed ,1981-82	0.0007,	0.0013, 0.0016	3.3, 4.6	6.9, 18	79, 75
pod ,1981-82	0.0016, 0.0019	0.005 , 0.012	33, 26	11 , 19	87, 87
soils,1981-82 (a)	2790 , 1870	1780 , 1410	1330, 1160	7900, 6470	
Oat, grain,1981-82	0.013 , 0.008	0.008 , 0.008	28,	6.4, 15	42, 27
straw,1981-82	0.01 , 0.075	0.005 , 0.07	43,	6 , 13	74, 69
soil ,1981-82 (b)	2200 , 2120	1550 , 1520	1410, 1370	8390, 7120	
Sweet corn, cob, 1981	0.003 ± 0.001		11 ± 2	10 ± 3	63
leaves, stem	0.088 ± 0.005		38 ± 3	8 ± 1	82
soil	2700 ± 100	1900	1750	13200	
Beet, root flesh 1981	0.033 ± 0.003	0.009 ± 0.002	8.7 ± 1.3	2.8 ± 0.8	89
peel	0.20 ± 0.03	0.25 ± 0.02	11 ± 2	8.0 ± 1.6	84
leaves, stem	0.067 ± 0.004	0.09 ± 0.01	20 ± 2	5.0 ± 0.4	92
soil	2420 ± 80	1600 ± 100	1300 ± 80	7800 ± 100	
Tomato, fruit 1981	0.0009± 0.0003	0.0022± 0.0006	3.0 ± 0.3		95
leaves, stem	0.06 ± 0.01	0.07 ± 0.01	250 ± 20		85
soil	2700 ± 150	2000 ± 40	1800 ± 100	9300 ± 100	
Greenhouse grown marrow, 1981	0.0029± 0.0004	0.0054± 0.0006	7 ± 1	2.8 ± 0.3	94
soil	2520 ± 200	1500 ± 50	1400 ± 100	7800 ± 100	
Outdoor grown marrow, 1981	0.0018± 0.0003	0.0025± 0.0003	5.4 ± 0.8	2.1 ± 0.7	95
soil	2350 ± 70	1600 ± 150	1570 ± 70	8100 ± 120	

(a) Peas grown in 1981 and 1982 in different batches of silt/soil mixture

(b) Oats grown in 1981 and 1982 in the same tubs of silt/soil mixture.

Table 2. Transfer Factors (= Conc. in Plant, Wet Wt. ÷ Conc. in Soil, Dry Wt.)

Description	$^{239}Pu + {}^{240}Pu$	^{241}Am	^{90}Sr	^{137}Cs
Pea[(a)], seed 1981, 1982 respectively	2.5×10^{-7}	7.3×10^{-7}, 11×10^{-7}	2.5×10^{-3}, 4.0×10^{-3}	8.7×10^{-4}, 28×10^{-4}
pod 1981, 1982 respectively	5.7×10^{-7}, 10×10^{-7}	28×10^{-7}, 85×10^{-7}	25×10^{-3}, 22×10^{-3}	14×10^{-4} 29×10^{-4}
Oat[(b)], grain, 1981, 1982 respectively	5.9×10^{-6}, 3.8×10^{-6}	5×10^{-6}, 5×10^{-6}	2×10^{-2}, -	7.6×10^{-4}, 21×10^{-4}
straw, 1981, 1982 respectively	4.5×10^{-6}, 35×10^{-6}	3×10^{-6}, 46×10^{-6}	3×10^{-2}, -	7×10^{-4}, 18×10^{-4}
Sweet corn, cob 1981	1×10^{-6}	-	6.3×10^{-3}	7.5×10^{-4}
leaves, stem 1981	33×10^{-6}	-	22×10^{-3}	6×10^{-4}
Beet, flesh 1981	1.4×10^{-5}	0.6×10^{-5}	6.7×10^{-3}	3.6×10^{-4}
peel 1981	8.3×10^{-5}	16×10^{-5}	8.5×10^{-3}	10×10^{-4}
leaves 1981	2.8×10^{-5}	6×10^{-5}	15×10^{-3}	6×10^{-4}
Tomato, fruit 1981	3×10^{-7}	11×10^{-7}	1.7×10^{-3}	-
leaves, stem 1981	220×10^{-7}	350×10^{-7}		-
Greenhouse grown marrow, 1981	1.2×10^{-6}	3.6×10^{-6}	5×10^{-3}	3.6×10^{-4}
Outdoor grown marrow, 1981	0.77×10^{-6}	1.6×10^{-6}	3.4×10^{-3}	2.6×10^{-4}

(a) Peas grown in 1981 and 1982 in different batches of silt/soil mixture

(b) Oats grown in 1981 and 1982 successively in the same batch of silt/soil mixture