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Uranium Dispersion Along Roads Paved with Phosphate Slag

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Phosphate ores contain high concentrations of uranium and other trace elements (U.S. GEOLOGICAL SURVEY 1978). During processing, much of the radioactivity is concentrated in the slag by-product, of which about 2.5 million metric tons are produced annually by two plants operating in Pocatello, in Southeastern Idaho (U.S. ENVIRONMENTAL PROTECTION AGENCY 1977). At the site of one of the plants, roadways constructed with slag were found to exhibit a gamma radiation dose rate averaging 50 μR/h , while the slag dump site exhibited rates up to 90 μR/h (U.S. ENVIRONMENTAL PROTECTION AGENCY 1977). Multiplied by the number of hours in a year, these rates result in an annual dose of 2 to 5 times the average received in the U.S. from all sources of ionizing radiation. While concern over radiation exposure has caused the use of slag to be banned by the State of Idaho in the construction of habitable structures, the direct dose from slag used in road construction presents a lesser hazard. This is due to the restricted time people spend on the road and to the partial radiation shielding provided by the understructure of vehicles. The present study was concerned with the possibility of radioactive contamination of soil, air and vegetation when uranium is leached from slag roadbeds by precipitation or abraded by traffic and weathering.

Concentrations of uranium in surface soil have previously been reported to be up to about 3 times natural levels in the immediate vicinity and downwind from the two Pocatello plants (JOHNSON et al. 1980). The concentrations fell off rapidly to background levels with increasing distance from the plants. Only one sampling site along a highway had a uranium concentration in excess of 10 times the background level with elevated concentrations continuing at least to a depth of 10-15 cm below the surface (the maximum depth investigated). This anomaly led to the present, more detailed investigation of the environmental consequences of road construction using phosphate slag. Soil samples were taken at 3 depths (0-5, 5-10, and 10-15 cm) and 5 distances from roadbeds (1, 3, 6, 9, and 12 m) at 13 locations. With few exceptions, 15 soil samples were collected from each location and analyzed for their uranium contents. The samples were oven-dried for 24 hours at 80°C, homogenized by grinding, and sifted through a U.S. No. 80 mesh stainless steel sieve.

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About 0.1 g of the sifted material was used for neutron activation analysis, using the 228.1 and 277.9 keV gamma rays from the decay of ^{239}Np, the radioactive daughter of ^{239}U. The detection limit of ^{238}U using this method is about 0.05 μg. The analysis techniques are described in more detail elsewhere (MELVILLE 1980).

The sampling sites included 3 sites each along 4 road sections in and around Pocatello, and 1 site near Moscow, Idaho. Chubbuck Road (sites 1-3) and Butte Road (sites 4-6) were constructed with gravel and slag aggregate (Intermediate diameters of 5-10 cm). U.S. Highway 91 (sites 7-9) was paved over a non-slag base in 1972 and 1973 with a 3.0 cm layer of 93.5% slag mixed with 6.5% asphalt. Interstate Highway 15 (sites 10-12) was sealed over a base of native materials in 1971 and 1975 with a 15 cm layer of 94% slag mixed with 6% petroleum-based spray. Road #4793 (site 13) in Northern Idaho is a gravel road containing no slag (MELVILLE 1980).

The samples from site 13 showed no dependence of uranium concentration on soil depth or distance from the roadbed. The average concentration in these 15 samples was 1.8 ppm with statistical fluctuations of 0.8 ppm standard deviation. Since the natural uranium concentration in soils of Southeastern and Northern Idaho may well be different, this should not be taken as a background level for the Pocatello sites. Instead, the concentrations at the 10-15 cm depth and at 9 and 12 m from the roadbeds at the latter sites can be used as a background level, since the analysis indicated that elevated concentrations were found mostly in the surface soil and close to the roadbed. An average of 3.6 ppm with 0.8 ppm standard deviation was obtained for 20 deep, remote samples (no samples could be obtained at 12 m along Highway 91, sites 7-9, nor below 5 cm depth at 9 m at site 10, nor at 1 m at site 4).

A number of samples had significantly higher uranium concentrations than the background value. These were collected near the roadbed and primarily at 0-5 cm depth, but occasionally extended down to 10-15 cm depth. The concentrations exhibited considerable fluctuations, and showed no particular correlation with the type of paving. A summary of the results is given in TABLE I. Except for the effect of two unusually high concentrations at site 10, (0-5 cm depth at 9 m and 10-15 cm depth at 6 m), the samples taken more than 3 m from the roadways are consistent with the background level of uranium concentration. The samples taken at distances of 1 m and 3 m show a clear increase in average uranium concentration with proximity to the road and to the surface, with large individual fluctuations, however, ranging from background to 5 times background level.

These results indicate that contamination of the roadside with radioactive slag tends to occur by abrasion of slag particles rather than by leaching, which would probably result in

less fluctuation in the observed concentrations. This conclusion is supported by the results of EADIE & BERNHARDT (U.S. EPA 1977), who found little uranium (1.8 pCi/L of ^{238}U, or about 5.4 µg/L) in the liquid portion of rainwater runoff from a slag pile and a slightly elevated level in the suspended fraction (4.1 pCi/g of ^{238}U or about 12 µg/L).

Concentrations of uranium in plant samples from the same sites as some of the soil samples were also measured. A total of 11 samples were prepared in a manner similar to that for the soil samples, from sagebrush and fescue collected at sites 1, 2, 3, 5, 6 and 7. Their average uranium concentration was 4.2 ppm with a standard deviation of 3.9 ppm, and ranging up to 13 ppm. There was no apparent correlation between the uranium concentrations of the plant samples and the soil samples collected at the same sites.

TABLE I. Average soil uranium concentrations (in ppm) of all 12 sampling sites from Pocatello as a function of soil depth and distance from the roadbed.

Depth (cm)	Distance (m)	Average	Standard Deviation	Minimum	Maximum
0-5	1	9.1	4.7	2.5	18.2
	3	5.3	1.9	2.3	7.7
	6	3.6	1.1	2.3	5.6
	9	4.5	3.9	2.5	16.9
	12	3.5	0.6	3.0	4.9
0-10	1	6.8	3.8	3.7	16.3
	3	4.2	1.1	2.6	6.3
	6	3.3	0.9	1.8	4.9
	9	3.3	0.9	1.9	4.9
	12	3.7	1.1	2.6	6.2
10-15	1	6.5	4.1	3.4	17.5
	3	3.8	1.1	2.4	6.2
	6	4.4	3.9	1.9	16.6
	9	3.6	0.7	2.8	5.0
	12	3.6	0.8	2.9	5.6

A major concern is the possibility of inhalation of radioactive dust particles abraded from the road surface. In order to examine this question, aerosols were collected at sites 1-6 by pumping air through two successive nucleopore filters of 5.0 and 0.4 µm pore size, mounted 1.5 m above ground. The collection times were 2 hours, at a flow rate of 14 liters per minute. The 0.4-5.0 µm fractions collected were too small to analyze, while the > 5.0 µm fractions averaged 6 mg, containing an average of 36 ppm uranium. This corresponds to 0.13 µg of uranium per cubic meter of air (or 0.043 pCi $^{238}U/m^3$), with individual samples reaching twice that value. Those aerosols

with an effective diameter greater than 5 μm are probably not radiologically important because they can be filtered and removed by natural cleansing mechanisms. Only particles in the size range of 0.01-5.0 μm are retained in respiratory system. Based on the detection limit of our analysis, we estimated the amount of uranium in the particle size range of 0.4-5.0 μm to be less than 0.03 μg of ^{238}U per cubic meter of air.

The above results indicate that uranium contamination of the surrounding environment due to the use of phosphate slag in road construction is sufficiently low as not to cause serious concern. However, it does not necessarily imply that the same conclusion can be drawn for the daughter products of uranium. Similar studies on the dispersion of uranium daughter products such as ^{226}Ra, ^{222}Rn, ^{210}Po, and ^{210}Pb are highly desirable in order to evaluate the overall environmental effects associated with the use of phosphate slag for road construction.

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