RADIOBIOLOGY

Biogeochemical Enrichment of Fission Products

Prospecting for radioactive minerals has gone on for some years in southern Sweden, and areas of higher radioactivity have been subjected to a closer examination. During the course of this survey, samples of different plants were also analyzed with the view of discovering whether biogeochemical prospecting methods could be used or not. It was found that the ash of most plant samples possessed a considerably higher radioactivity than the soils upon which they were growing. This observation led to a closer examination of the distribution of plant radioactivity within some districts in southern Sweden. The districts were chosen to cover not only different rock and soil types but also different topographic sites. The plants collected included the following species: *Picea abies*, *Pinus silvatica Juniperus communis*, *Fagus silvatica*, *Quercus robur*, *Calluna vulgaris*, *Vaccinium myrtillus*, *V. vitis-idœa*, *Polytrichum*, and *Athyrium*.

Both Geiger counters and scintillometers were used during the initial stage of the survey; but it was soon found convenient to concentrate mainly on β-activity measurements, since the γ-activity of the mineral soil often varies considerably.

The preliminary results of this survey of plant radioactivity demonstrate that, within each separate area, the ash of most of the plants examined showed about the same β-activity. Some plant samples gave, however, higher values than others. The highest values were obtained for needles, leaves, and for the twigs, whereas the wood of the trunks and the roots gave values corresponding to those of the mineral soil. In some cases the dead parts of the plants showed about the same radioactivity as the living parts, but in other cases a marked decrease in radioactivity was observed.

Table 1 gives the values hitherto obtained. The apparatus used was a Geiger counter type *DG*-2 (Detectron Co.). The most common rocks and soils of the region gave readings under field conditions from 0·025 to 0·050 mr./hr., marked differences being noted between metamorphic rocks of different origin. The ash samples were measured under laboratory conditions with a background of 0·025 mr./hr. In order to facilitate a comparison between the different samples, only the analyses of the ash of spruce twigs have been included in Table 1.

Additional measurements indicated that the plant radioactivity decreased with time more rapidly than could be expected if it were caused by natural radioactive elements only. Some samples were therefore subjected to γ-spectrometric analysis at the Swedish Research Institute for National Defense. It was found that the main part of the γ-activity is due to the presence of more long-lived fission products (zirconium + neobium)-95, cerium-141, and ruthenium-103. There is reason to believe that yttrium-91 and strontium-89 are present in about the same quantities as (zirconium plus neobium)-95, and that cæsium-137 and strontium-90 equal about 1/100 of the amount of (zirconium plus neobium)-95. The amount of natural radioactive elements is negligible compared with that of fall-out products. A comparison between the results of these γ-spectrometric analyses and the conclusion which can be drawn from the geological sites of the different samples is also consistent with low natural radioactivity as compared with that resulting from fall-out.

Table 1. Measurements of the Radioactivity of the Ash of Spruce Twigs from Hills (*A*) and Lowlands (*B*) in Southern and Western Sweden, Collected and Analysed in March and April 1959.

A.	3.	Uncovered mineral soil	0·030	mr./hr.	Ash	0·080	mr./hr.
	8.	,, ,, ,,	0·025	,,	,,	0·150	,,
	17.	,, ,, ,,	0·035	,,	,,	0·080	,,
	19.	,, ,, ,,	0·040	,,	,,	0·150	,,
	24.	,, ,, ,,	0·030	,,	,,	0·105	,,
	25.	,, ,, ,,	0·030	,,	,,	0·115	,,
	30.	,, ,, ,,	0·050	,,	,,	0·150	,,
	31.	,, ,, ,,	0·030	,,	,,	0·060	,,
	32.	,, ,, ,,	0·030	,,	,,	0·110	,,
	33.	,, ,, ,,	0·030	,,	,,	0·110	,,
	36.	,, ,, ,,	0·030	,,	,,	0·120	,,
	39.	,, ,, ,,	0·025	,,	,,	0·060	,,
	40.	,, ,, ,,	0·040	,,	,,	0·060	,,
	45.	,, ,, ,,	0·035	,,	,,	0·075	,,
	48.	,, ,, ,	0·035	,,	,,	0·075	,,
B.	5.	,, ,, ,,	0·025	,,	,,	0·050	,,
	35.	,, ,, ,,	0·025	,,	,,	0·045	,,
	37.	,, ,, ,,	0·030	,,	,,	0·060	,,
	49.	,, ,, ,,	0·030	,,	,,	0·085	,,
	50.	,, ,, ,,	0·035	,,	,,	0·055	,,
	51.	,, ,, ,,	0·035	,,	,,	0·090	,,

K. Löw and K. Edvarson report[1] that the main γ-activity of top-soil layer samples collected in some Swedish localities during the summer of 1958 is due to the presence of (zirconium plus neobium)-95 from fall-out during the first half of 1958. My measurements of the β-activity indicate no special enrichment in the top layer of the mineral soil, in the root, nor in the wood of the trunks of trees examined. On the contrary, there is a high increase of β-activity in the twigs, and especially in needles and leaves, as also in the *F*-layer of the soil profile. The figures upon which this report is based indicate furthermore that there is a higher concentration of fission products in the ash of plants grown closer to the coast; the same is the case for plants grown upon sides and summits of marked hills and mountains. The lowest values are obtained for flat terrains at larger distances from the sea. It is evident that this depends, to a great extent, on the amount and frequency of precipitation, both directly in the form of rain and snow and indirectly through the 'filtering' action of the vegetation upon low-striking clouds and mist. Detailed surveys are, however, necessary in order to discover the distribution pattern of these new elements in the biogeochemical cycles.

The ash of plant samples hitherto examined by me shows a 2–6 times greater β-activity than the top layer of the mineral soil, with an observed maximum of 16 times. One conclusion to be drawn from these figures is that it is not primarily the presence of fission products in the air, in the soils, or in the waters that constitutes the most direct danger for radioactive damage but rather the sometimes very high biogeochemical enrichment in plants and/or animals. This biogeochemical enrichment may give rise to a successive concentration along the plant generations of some of the long-lived fission products through a combination of the continuous supply from the air and the successive supply from decaying, radioactive plants or plant parts in the *F*-layer.

Prospecting for radioactive mineralized zones may be considerably disturbed by the presence of fission products enriched in plants or in the *F*-layer of the soil profile. Due consideration has therefore to be given to the distribution pattern of this fall-out radioactivity, especially if nuclear bomb tests are to proceed.

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[1] Löw, K., and Edvarson, K., *Nature*, **183**, 1104 (1959).