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THE USE OF BIOMONITORS TO MONITOR ATMOSHERIC DEPOSITION OF ^{210}Pb

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INTRODUCTION

The main source of ^{210}Pb in the environment is the exhalation of ^{222}Rn gas from the ground to the atmosphere during the radioactive decay of natural uranium – radium chain. In the atmosphere this radionuclide is rapidly attached to small particles – aerosols, predominantly on those particles below 0.3 µm. The half-life of ^{210}Pb is longer than the atmospheric residence time of the aerosols on which it resides (1). By sedimentation and washout of aerosols this nuclide is then transferred to the soil or vegetation. The other main sources include burning of fossil fuels and phosphate fertilizers.

The usual way to determine the levels of ^{210}Pb and other radionuclides in the atmosphere is the use of a high volume filter system, which should operate for a long time to collect enough material for analysis. An other approach to determining the outdoor levels of radionuclides is the use of suitable biomonitors such as lichens or mosses. These organisms, although neither evolutionarie nor taxonomically related, have some common characteristics which enable them to be used as monitors for atmosheric pollution. They lack roots and protective organs against the substances derived from the atmosphere (stomata and cuticle) and are very efficient accumulators of atmospheric particulate material and chemical substances such as radionuclides or heavy metals (2). The levels of these substances in lichens and mosses are usually much higher than in air particulates or precipitation and for these reason the analysis is much easier. Another advantage of biomonitors over conventional sampling of air particulates or precipitation is that the collection of lichens or mosses is very cheap therefore allows a very large number of sites to be included in the same survey and permits detailed geographical deposition patterns to be drawn (3). It must be emphasised that concentration data on elements or radionuclides in lichens or mosses represent the relative deposition patterns over a certain time period (3).

The objective of the present paper is to present some results of our biomonitoring programme using the epiphytic lichen *Hypogymnia physodes* and mosses (*Pleurozium schreberi, Hypnum cupressiforme)* to monitor the deposition of ^{210}Pb in Slovenia in order to obtain information about the distribution patterns of natural radioactivity.

MATERIALS AND METHODS

Sampling

Two national surveys using biomonitors to monitor atmospheric radionuclide and heavy metal deposition have been performed in Slovenia. In 1992 the epiphytic lichen *Hypogymnia physodes* was collected at 86 sampling points of the regular 16 x 16 km biondication grid and analysed for heavy metals (4) and natural and artificial radionuclides (5). As a part of the international project Atmospheric Heavy Metal Deposition in Europe, 33 sampling locations out of 86 were selected in 1995 for collection of moss samples *(Pleurozium schreberi, Hypnum cupressiforme)* for determination of metals (6) and radionuclides. The sampling sites were located at least 100-200 m away from roads or dwellings, mainly in forest glades or open habitats. The lichen thalli were taken from 3-5 nearby trees 1.5-2m above the ground, but moss samples were taken from the ground over a 50 x 50 m area at each location.

Sample preparation

In the laboratory lichens and mosses were cleaned manually (but not washed) to remove adhering particles and then crushed and ground after immersion in liquid nitrogen in a zirconia mortar with a ZrO_2 ball in a Fritch vibration micro-pulveriser. The last 3 years' growth of moss was taken for analysis.

Sample analysis

Direct gamma spectrometry using an HP Ge-well type detector with an active volume of 230 cm^3 was used for determination of ^{210}Pb. About 2-5 grams of dry, powdered material was weighed into a 10 ml plastic container and counted for 12-30 hours to achieve a statistical counting error of below 10 %. The ^{210}Pb activity was measured at 46.5 keV. For efficiency calibration of the Ge well-type detector a ^{210}Pb standard prepared from normal grade Whatman cellulose powder as a matrix and spiked as a slurry with a known amount of solution of 5 Bq ^{210}Pb g^{-1} was used.

RESULTS AND DISCUSSION

Table 1 summarises the results of the activity levels of ^{210}Pb in lichens and mosses collected in 1992 and 1995, respectivelly. The results for lichens are divided in 2 columns; the first column presents the results for all 86 sampling locations and the second for the 33 sampling sites at which mosses were also collected in 1995. As can be observed from Table 1, the average value for lichens is around 600 Bq/kg and for mosses around 500, which is a rather good agreement, considering the species differences (epiphytic lichens, epigeic mosses), habitat differences and that the samples were collected in two different sampling campaigns. These results are also in accordance with estimated values for the average natural background of ^{210}Pb in the atmosphere (0.75 mBq/m^3) in Slovenia

(7). Namely, Jeran (8) in an investigation around the Žirovski vrh uranium mine area found that roughly about 1 mBq/m^3 in air corresponds to about 1 kBq ^{210}Pb kg^{-1} dry weight in lichens.

Table 1. Activity concentration of ^{210}Pb in Bq kg^{-1} dry weight in lichens and mosses collected at sampling locations of the 16 × 16 km bioindication grid.

	Lichens		Mosses
Collection (year)	**1992**		**1995**
Number of samples	86	33	33
Minimum	57	119	165
Maximum	1898	1555	1013
Average	594	565	466

The results for lichens and mosses are also within the reported range of some literature values for lichens and mosses collected in different forested regions (9-11).

Graphical presentation of results (Fig.1a,b) showed that except for four sampling sites both surveys give practically the same geographical distribution of ^{210}Pb in Slovenia. Of course since lichens were collected on a denser sampling grid, a much better distribution is achieved. The highest activity levels (over 600 for lichens and over 500 Bq/kg for mosses) were found in the southern Dinaric region and in the north-western parts of Slovenia. The higher activity levels in the southern part coincides on the one hand with naturally elevated levels of uranium in soil (12) and on the other hand with the morphological structure of the terrain (caves, other karst formations). The south - east direction is also the direction of the main tectonic fault. These factors enable easier emanation of ^{222}Rn and thus formation of ^{210}Pb in the atmosphere. ^{210}Pb reaches the surface of lichens and mosses through dry, and mainly, wet deposition. Further, the measurements of indoor ^{222}Rn also support the fact that the southern part of Slovenia has elevated levels of these radionuclides (13). At 3 locations from this region a large discrepancy between lichen and moss results were found, since in mosses much lower activity levels were obtained in comparison to the lichen data. Most probably the reason for this is not the species difference but rather the different environmental conditions since samples were not taken in the same year and also the microlocation was most probably not the same for lichens and mosses.

The high activity concentrations of ^{210}Pb in lichens and mosses in the north-western part coincides with the regions of Slovenia receiving the highest amounts of precipitation. Therefore the explanation for elevated levels of this radinuclide in the NW parts could be that its patterns in this region reflect the movement of global air masses and increased washout or rainout of this radionuclide from the atmosphere.

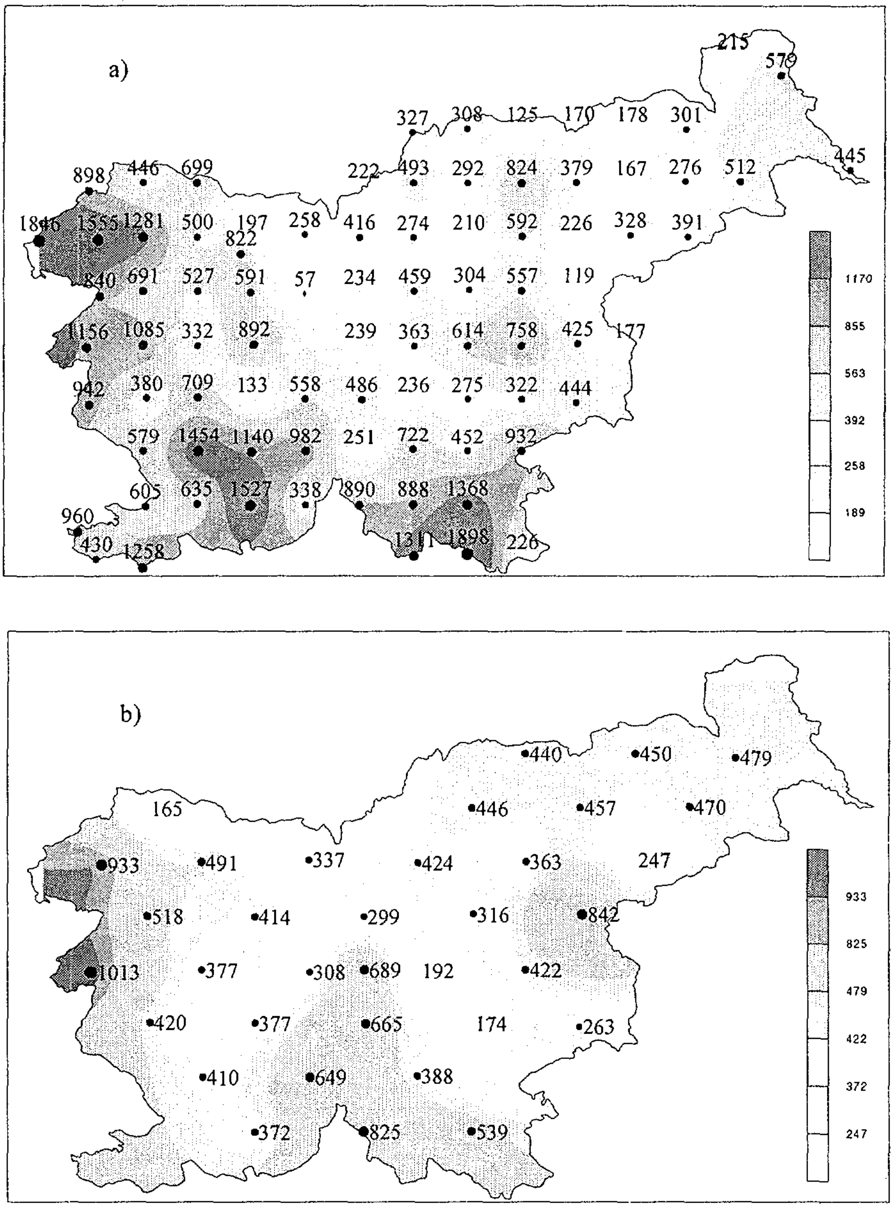

Fig.1. The geographical activity patterns of ^{210}Pb obtained from a) lichen and b) moss data, divided into 7 classes according to percentile values (10, 30, 50, 70, 90, 95%) and mapped using the Surfer programme.

On the basis of our results it is evident that both biomonitors reflect the status of natural radioactivity in the country and give an overall picture of the distribution of ^{210}Pb. However, a more dense network of sampling locations is needed, especially in the southern part of the country to obtain a more detailed distribution pattern of ^{210}Pb, and some further work in the field of intracalibration between lichen and mosses is also needed.

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