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Lichens and mosses as biomonitors

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Abstract

A national survey was performed in 2001 in Slovenia in which two different biomonitors, namely an epiphytic lichen *Hypogymnia physodes* and the terrestrial mosses *Hypnum cupressiforme* and/or *Pleurozium schreberi* were collected at the same sampling locations all over the country and analysed for trace elements. The main aim was to find out if the both kinds of biomonitors give similar estimates of trace element air pollution.
The preliminary results for some selected elements As, Cd, Cr, Hg, La, Sb, Sc, U and Zn showed significantly higher mean value of anthropogenic or atmophile elements (As, Cd, Hg and Zn) in lichens and only slightly higher lithophile or soil derived elements (Cr, La, Sc and U) in mosses.

1. INTRODUCTION

For more than 30 years terrestrial mosses and epiphytic lichens have been used to monitor trace element air pollution, not only around known pollution sources but also because of their relatively low cost, on a larger regional or national scale [1-9]. These organisms, although neither evolutionarily nor taxonomically related, have some common characteristics, which enable them to be used as monitors for trace element atmospheric pollution. Both have a high accumulation ability for dissolved substances based mainly on their ion-exchange properties and the fact that they have no protective organs such as cuticle or waxy surface. They also lack roots. Furthermore, since lichens and mosses have a high surface to mass ratio they are highly effective as air filters for airborne particulates carrying atmospheric pollutants, as well as soil or rock dust particles carried by wind. However, the ecophysiology of the two species differs as well as the mechanisms of bioaccumulation. Although there is a huge literature on the use of each of these organisms for monitoring purposes, there are only a few dealing with direct comparison of the two kinds of organisms as biomonitors for trace element contamination [10,11] .

In 1992 the first survey throughout the territory of Slovenia, in total comprising 86 locations for an area of 20256 km^2, was performed using epiphytic foliose lichens to monitor trace element air pollution [8]; and three years later Slovenia joined the European moss monitoring project employing sampling and analysis of mosses (*Hypnum cupressiforme* and/or *Pleurozium schreberi*) at 33 locations out of the total 86 [12].

A new national survey was performed in 2001 in which the same biomonitors, namely an epiphytic lichen *Hypogymnia physodes* and the terrestrial mosses *Hypnum cupressiforme* and/or *Pleurozium schreberi* were collected at 86 sampling locations all over the country and analysed for trace elements.

The main aim was to determine if both kinds of biomonitors give similar estimates of trace element air pollution.

2. MATERIALS AND METHODS

2.1 Sample collection and preparation

In the period between June and August 2001 the epiphytic lichen *Hypogymnia physodes* (L.) Nyl. and the epigeic mosses *Hypnum cupressiforme* or/and *Pleurozium schreberi* were collected at 86 locations of the national 16 x 16 km bionidication grid. All sampling locations from the bioindication grid were distant from known pollution sources and samples at the sampling sites were taken according to procedures (at least 300 m away from main roads and at least 100 m from any road or dwellings) used in similar surveys elsewhere[5,6,8].

Samples were not washed before analysis; only in the case of lichens adhering bark particles were carefully cleaned from the thallus, but in the case of mosses all dead material and attached litter was removed and only green and green-brown shoots of the last three years were used for analysis. Samples were then lyophilized (Freeze drier ALPHA 1-4) and homogenized in an agate planar micro mill (Fritsch, Pulverisette 7) after immersion of the samples in liquid nitrogen.

2.2 Determination of trace elements

About 150-200 mg of dry lichen or moss material was used to make tablets for instrumental neutron activation analysis (INAA). For determination of As, Ba, Br, Ca, Cd, Ce, Co, Cr, Cs, Fe, Ga, Hf, Hg, K, La, Mo, Na, Rb, Sb, Sc, Se, Sm, Sr, Th, U, W and Zn standardized k_0-INAA was used as described in detail elsewhere [12].

For routine quality control of the determination of trace elements two standard reference materials (IAEA Lichen 336 and NAT-6 Moss sample) were analysed according to the same procedure as the other samples.

3. RESULTS AND DISCUSSION

Table 1 summarize analytical results for some selected number of elements determined in epiphytic lichen *H. physodes* and epigeic moss *H. cupressiforme* which were collected in summer 2001 at the same sampling locations over the whole country. Only at 69 sampling points could both species be found and these results are included in Table 1. At the rest of the sampling locations either of the species was missing and was replaced with an other one; usually *Parmelia caperata* instead of *H. physodes*, and *Pleurozium schreberi* instead of *H. cupressiforme*. The mean elemental levels of all elements in *H. physodes* and *H. cupressiforme* (Table 1) are in agreement with the results of similar investigations [2,6], but lower than was found in the first survey in Slovenia performed in 1992 (lichens) and 1995 (mosses) [8,12].

Direct comparison of elemental levels in lichens and mosses collected at the same locations showed that the mean values of the so-called soil derived or lithophilic elements Cr, Fe, La and Sc were only about 9 % higher in *H. cupressiforme*; however, the mean value of U was the same in both organisms. On the other hand, significantly higher mean values of the so-called anthropogenic or atmophilic elements As, Br, Cd and Zn were found in *H. physodes*. These last elements are regarded as pollutants subject to long-range transport. It was further found that, except for Br, Cd, Hg and Zn, a strong correlation existed ($P < 0.05$) between these elements and Sc which is a tracer usually used to assess the soil contribution [13]. However, this last survey did not exhibit such a high difference in the accumulation or trapping ability of the two organisms for lithophilic elements as found earlier [12] when the results of two different surveys were compared, or as reported in other investigations [11,14]. It seems that local variation in elemental levels, as well as differences in the morphology and ecophysiology of mosses and lichens, as was also reported by Bargagli et al.[11], were the reasons that there was no intraspecies correlation for these elements on a national scale.

Table 1: Mean, standard deviation (SD) range (Min, Max) and coefficient of variation (CV) of element concentrations ($\mu g.g^{-1}$ dry wt.) in *H.physodes* and *H. cupressiforme* collected at the same 69 sampling locations of the national survey and the concentration ratio of moss and lichen mean values.

	H. physodes						*H. cupressiforme*						Ratio moss/lichen
	N	Mean	SD	Min	Max	CV	N	Mean	SD	Min	Max	CV	
As	69	0,53	0,18	0,18	1,39	33	69	0,35	0,15	0,09	0,94	42	0,65
Br	69	11,1	3,36	6,35	22,4	30	69	3,22	1,15	0,46	6,35	36	0,29
Cd	66	0,78	0,50	0,00	2,45	64	66	0,51	0,28	0,17	2,03	56	0,65
Cr	69	3,79	4,21	1,11	35,9	111	69	3,44	3,41	0,63	26,2	99	0,91
Fe	69	777	309	310	1899	40	69	798	348	210	1944	44	1,02
Hg	69	0,05	0,02	0,01	0,13	41	67	0,04	0,01	0,02	0,08	33	0,77
La	69	0,78	0,32	0,28	2,07	42	69	0,84	0,37	0,20	1,97	44	1,08
Mo	69	0,27	0,22	0,09	1,87	81	69	0,36	0,23	0,13	1,90	64	1,33
Sb	69	0,23	0,10	0,08	0,81	44	69	0,21	0,06	0,08	0,40	30	0,94
Sc	69	0,23	0,10	0,08	0,64	42	69	0,25	0,13	0,06	0,67	50	1,09
U	69	0,07	0,03	0,02	0,17	38	69	0,07	0,04	0,02	0,18	49	1,09
Zn	69	97,0	26,15	47,1	183	27	69	39,0	15,1	18,7	101	39	0,40

Even though both organisms, for example, recognized extremely high levels of Cr in the northern part of the county, for the remaining lithophilic elements they gave different and sometimes quite complementary information for a certain location. However, in the contrast, a statistically significant relationship ($P< 0.05$) between values in mosses and lichens on the national scale was found for Zn (Fig.1) and to a lesser extent for Sb.

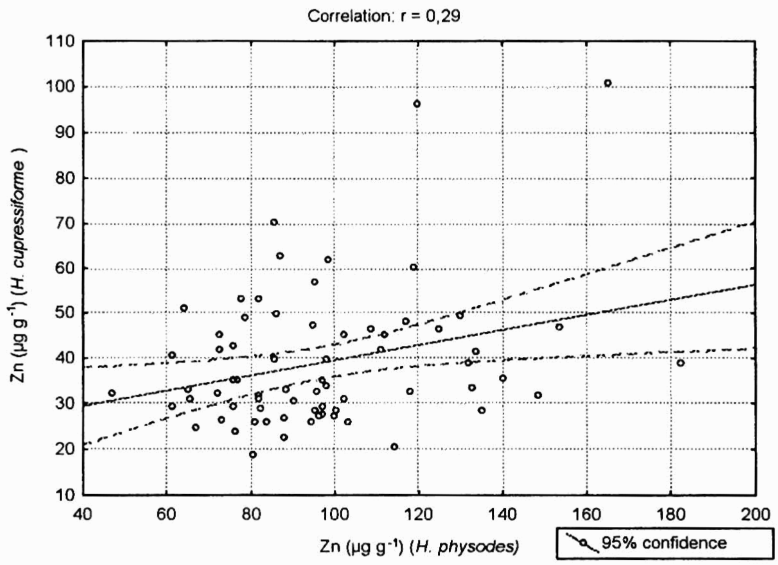

Fig. 1: Scatterplot of concentrations of Zn in *H. physodes and H. cupressiforme* from 69 sampling sites of Slovenian territory.

Since it is known that elemental levels as obtained by analysis of monitoring organisms reflect the exposure to different natural and anthropogenic sources at a particular location, by further application of multivariate statistical methods it would be possible to compare how both organisms reflect the pollution of the country.

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