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Content of Heavy Metals in Plant from Pollution-Free Regions

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Abstract

In this paper the content of Mn, Fe, Zn, Cu, Pb, Ni, Cr and Cd was studied in forest floor plants of Puszcza Biala Forest. Test plants used were lichens, mosses, club-mosses, ferns, convallaria, and bilberries. Puszcza Biala Forest belongs to a region free from pollution by heavy metals. Higher content of manganese, as compared with iron, was found in the following plants: Cladonia clavatum (wolfs claw), Dryopteris filix-mas (shield fern), Convalaria maialis (convallaria), and Vaccinium myrtillus (bilberry). In lichens and mosses the proportion was the opposite: they contained more iron than manganese. The stated concentration of Zn, Cu, Pb, Ni, Cr and Cd was very little differentiated considering particular plant species of forest floor. And those were appreciated at the natural level, typical for the unpolluted area of Poland.

Keywords: forest floor plants, heavy metals, unpolluted area

Introduction

The study was carried out in soil model plots (GPW). The plots had been established in 1975 in Puszcza Biala Forest following the directive of the then Chief Management of State Forests (NZLP, today DGLP). Puszcza Biala Forest is a remnant of huge forested area of the past: the Mazovia Forest. It is nowadays a large, compact forest area situated in the lower part of the Bug and Narew river catchment (Fig. 1). Its total area is estimated to be some 51 thousand ha. It is one of the country's poorest forest regions, considering site quality and species diversity. Three tree species dominate in the Forest stands: Scotch pine, pedunculate oak and black alder. The Puszcza Biala Forest's vicinity is characteristic of lacking heavy traffic highways or industrial plants.

The purpose of the present study was to learn the content of heavy metals in selected forest floor plants collected in Puszcza Biala Forest.

Material and Methods

The soil model plots (GPW) cover little deformed forest ecosystems, typical for the region they are selected in. GPWs supply the permanent basis for comparisons of natural and economic effects of intensive forest management practices [11].

Two Forest Districts of Puszcza Biala were included in the network of GPW: Ostrow Mazowiecka Forest District (325.74ha) and Wyszkow FD (some 470.83ha). In the study area there prevailed rusty soils established/formed from fluvioglacial sands; these soils were accompanied in lower parts of terrain, by degraded black earths or gleyey-podzol soils or peat-mucky soils [6]. Both forest litter and organic horizons of the soils contained larger quantities of heavy metals (Zn, Cu, Pb, and Cr) than the mineral horizons. Noteworthy, despite the insignificantly increased concentration of zinc and cadmium as found in the organic horizons, was that the soils should be considered to contain the natural content of heavy metals.

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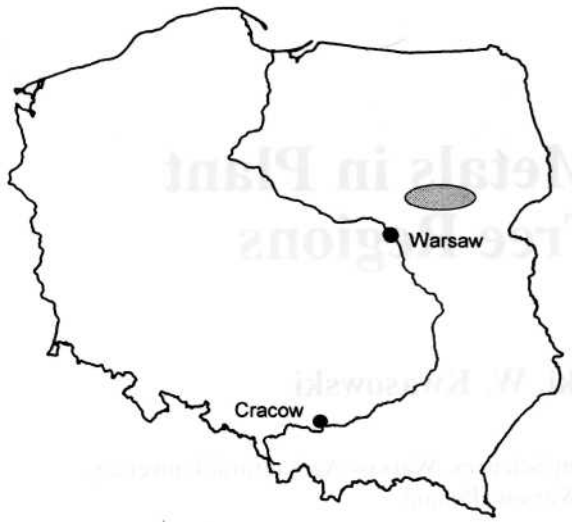

Fig. 1. Location of Puszcza Biała in Poland.

The study area belonged to two forest site types: the moderately humid mixed coniferous forest and moderately humid mixed broad-leaved forest.

The following plant taxa representatives were sampled for analyses: lichens, mosses, club-mosses, ferns, bilberry, and convallaria. The plants were collected from their natural sites, where given taxa occurred frequently. In most cases, whole plants were analyzed. In the case of ferns and bilberry, stems and leaves were analyzed separately. In mosses only the green part of a plant was used for analysis.

The plant material sampled was initially dried at 50-70°C. Then the plants were subjected to dry grinding and dry mineralized at 480-500°C. The ash obtained was subjected to thermal etching in 6 M HCl under hot environment. In solutions obtained following the above-described procedure there was determined the concentration of Zn, Pb, Cu, Cd, Ni, Co, Mn, and Fe with use of the atom absorption spectroscopic technique. The determinations were made using the Perkin-Elmer 2000 apparatus.

Results

The concentration of manganese in sampled forest floor plants showed a very high inter-specific variation: it ranged, depending on the species considered, from 65 to 4672 mg/kg (Table 1). The lowest content of the element was found in lichens: 41 mg/kg, and in fern (shield fern and eagle fern): 65 mg/kg. Relatively highest was the concentration of manganese in bilberries: 4672 mg/kg of dry weight. High-level manganese concentration was also found in Dryopteris and Convallarium. The actual concentration of the element depended on the organ of the plants: considering bilberry and both fern species, the largest concentration of manganese was found in the leaves; the concentration of manganese in stems was 2.0-2.5 lower. Differences in manganese concentration were also stated between similar plant taxons: Dryopteris had higher values of Mn content than Pteridium, regardless of the organ considered.

Iron concentration in plants has been maintained within 27 - 650 mg/kg d.w., and this element's concentration was always below the respective level of manganese, in some cases (bilberry) even 30 times less. In the majority of studied plants, the concentration of iron is inversely proportional to that of manganese. The following plants contained rather low amounts of iron: bilberry, convallaria, both fern species and wolfs claw - they all had between 31 and 131 mg/kg iron. On the contrary, mosses and lichens were found to be plants containing large concentration of iron - between 326 - 650 mg/kg. More iron was found in leaves than in stems of ferns and bilberry. The difference was especially evident in both fern species.

The concentration of Zn, Cu, Pb, Ni, Cr and Cd showed very little inter-specific diversity (Table 1).

The concentration of zinc has been maintained within the range 16 - 48 mg/kg d.w. on average, regardless of the plant organ sampled, in nearly all taxa considered. In one case only - in shield fern - the actual zinc concentration found was 105 mg/kg d.w. Differences were found between particular plant organs, considering the concentration of zinc. In ferns, for instance, the descending order of zinc content was as follows:

whole plant > leaves > stems;

in bilberry:

stems > whole plant > leaves.

The content of copper was little differentiated in the studied plants and it varied on average from 7.2 to 10.8 mg/kg d.w. Only lichens contained lower amounts of the element, 3- 4 times less than the remaining plants. No clear differences were observed in copper content between particular plant organs.

Similarly, the concentration of lead was also insignificantly differentiated between particular taxa. It ranged within 1.4 - 10. 6 mg/kg d.w. Only mosses contained from 2.5 to 3.6 times more lead on average than the other species. The actual concentration of the element in either plant organs: leaves, stems or in the whole of plant was maintained at a similar level, in both ferns and bilberries.

No clear differences were found considering the content of nickel and chromium in studied plants from Puszcza Biala Forest. The mean concentration of nickel varied from 1.60 to 6.5 mg/kg d.w., and that of chromium from 0.2 to 3.3 mg/kg d.w. Only insignificantly increased chromium content was found in lichens and mosses, as compared with the remaining plant taxa.

The accumulation of nickel as observed in leaf blades of eagle fern and mosses was nearly twice as much as that recorded in leaf petioles.

The observed concentration of cadmium varied from 0.30 to 2.2 mg/kg d.w. The lowest content of the element was found in lichens, while the highest one in convallaria (in the latter 1.9 mg/kg d.w.). No substantial differences were found considering cadmium concentration between the stems and leaves of ferns and bilberries.

Table 1. Concentration of heavy metals (ranges and means) in some plants of Puszcza Biala Forest (all date in mg/kg dry wight).

Plant species	n*	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
Lichens Scelond moss Centraria islandica (L)	6	460	65	27	2.5	3.0	4.4	3.3	0.3
Mosses Pleurozium schreberi	6	326-650 485	290-514 383	33-43 37	6.7-12.6 8.6	4.0-10.6 8.4	2,0-4,6 3.4	0.8-5.2 2.5	0.0-0.6 0.4
PTERIDOPHYTES									
Wolf's claw Lycopodium clavatum L	4	84-131 107	140-371 284	26-30 28	5.3-9.6 7.2	1.4-3.5 2.3	1.0-5.8 3.8	0.2-2.0 0.9	0.4-0.6 0.5
Shield fern Dryopters filix – mas (L) Schott.	8	whole plants							
		40-106 78	314-1094 614	22-105 48	5.1-10.6 7.6	1.8-3.6 2.3	1.9-8.8 4.0	0.3-1.8 1.1	0.6-2.2 0.9
		leaves							
		58-104 80	450-1062 749	23-58 43	6.4-10.0 7.7	1.6-2.4 2.0	2.2-2.6 2.5	0.4-1.7 1.5	0.6-0.8 0.7
		stems							
		27-50 33	234-550 392	22-27 24	3.8-9.5 5.7	1.6-2.6 2.1	1.4-1.8 1.6	0.2-0.8 0.5	0.6-0.8 0.7
Eagle fern Pteridium aquilinum (L.) Kuhn.	5	whole plants							
		50-82 75	41-104 71	14-40 22	7.5-13 10.8	1.7-3.0 2.3	2.0-7.5 3.9	0.6-1.8 1.0	0.4-1.8 0.7
		leaves							
		67-115 88	60-104 75	11-23 18	7.7-12.6 10.2	1.8-20.0 1.9	2.6-11.0 5.5	0.8-1.0 0.9	0.3-0.5 0.4
		stems							
		33-42 39	22-38 28	12-20 16	7.4-11.0 9.1	1.6-2.2 2.0	1.4 -4.0 2.5	0.2-0.8 0.5	0.4-0.6 0.5
ANGIOSPERMS									
Convallaria Convallaria L. malalis L.	4	41-76 57	344-1090 710	23-48 33	4.7-11.0 7.2	3.2-3.4 3.3	3.4-6.0 4.5	0.8-2.6 1.6	1.0-1.9 1.4
Bilberry Vacinium myrtillus	6	whole plants							
		55-93 74	1292-4672 2652	17-31 23	7.7-9.8 8.8	2.1-3.6 2.4	3.8-7.4 5.8	0.5-1.8 1.1	0.4-0.8 0.6
		leaves							
		47-97 74	1540-3952 2758	12-27 20	6.4-7.8 7.4	1.6-2.6 1.9	3.8-9.6 6.5	0.4-2.2 1.1	0.4-0.6 0.5
		stems							
		37-73 62	1044-2120 1763	28-34 32	7.7-12.0 9.5	1.6-3.4 2.4	1.4-4.0 3.3	0.4-1.6 0.9	0.4-0.6 0.5

n* – number of samples

Discussion

Based on the above presented data it was stated that out of the set of heavy metals studied it was manganese and iron that occurred in relatively highest concentrations in the plants of Puszcza Biala Forest. Nevertheless, substantial differences were recorded in concentrations between particular plant species. The content of Zn, Cu, Pb, Cr, Ni and Cd was smaller and significantly less differentiated between the species of forest floor subjected to the present analyses.

Considering the concentration of manganese and iron in plants, two plant groups were identified. Lichens and mosses have constituted one group characteristic of lower concentration of manganese than iron. Group two is characteristic of manganese concentration higher than

Table 2. Concentration of heavy metals in studied plants (all data in mg/kg dry weight).

Element	Range	Mean
Zn	14-105	31
Cu	2.5-13	7.5
Pb	1.4-10.6	3.4
Ni	1.0-8.8	4.2
Cr	0.2-5.2	1.6
Cd	t-2.0	0.7

t – trace amounts

iron concentration. To this group belong wolfs claw, shield ferns and representatives of dicotyledonous plants: convallaria and bilberry. Bilberry contained some 30 times more manganese than iron; therefore, bilberry population density is decisive for the biological accumulation of manganese in both forest litter and organic horizons of Puszcza Biala Forest soils.

Considering the actual concentration of manganese in plant tissues, the following ascending order of Puszcza Biala natural sites; plants may be presented: lichens < eagle fern < wolfs claw < mosses < shield fern < conva llaria < bilberry.

Another order may be produced showing the ascending order of iron concentration: convallaria < bilberry < shield fern < club-mosses < lichens < mosses.

Numerous papers suggest a wide range of manganese accumulation rates depending on different species as well as intra-specific variation [4, 8, 9]. Examples can be given from our own research: bilberry from Kampinos National Park contained lower amounts of manganese than bilberries from Puszcza Biala [7]. Mosses collected in the outer parts of Warsaw region forests near industrial area had very much similar concentration of manganese compared with mosses from the unpolluted area of Puszcza Biala [5]. It is shown in the present study that bilberry leaves had nearly twice the content of manganese and iron found in their stems. A similar pattern was stated by Wasilowska and Gworek considering iron accumulation in bilberry leaves [10].

The plant species subjected to the present analyses contained rather similar quantities of the following elements: Zn, Cu, Pb, Ni, Cr, and Cd. Two departures from the generally homogenous patterns were found: lichens had 3-4 times lower copper concentration than the general mean, and mosses had 2.8-3.3 times bigger lead content as compared with the majority of other plants. The following descending order of mean concentration of heavy metals may be presented for the whole set of plant species studied: (all data in mg/kg d.w.)

Zn (31) > Cu (7.5) > Ni (4.2) > Pb (3.4) > Cr (1.6) > Cd (0.7)

The distribution of heavy metals in plant organisms of ferns and bilberies was not identical; it depended, actually, on the species and the element considered. It has been shown in the present study that lead and cadmium had accumulated in equal quantities in both leaves and stems of ferns and bilberries. Considering zinc and copper, however, higher were the concentrations of the elements in stems rather than in bilberry leaves. The distribution of the remaining trace elements depended on plant species. Wasilowska and Gworek [10] proved that in the case of zinc content in bilberry plants the highest concentration occurred in stems; lower amounts of the element were found in leaves and roots. Lead and cadmium, on the contrary, accumulated first of all in roots, and in smaller amounts in leaves and stems.

The concentrations of heavy metals in plants of Puszcza Biala Forest were similar to those characteristic for other forested regions subjected to little impact of industrial pollution and traffic intensity [1, 2, 4, 7].

It should be emphasized that the concentration of heavy metals in forest floor plants from Puszcza Biala was maintained at a similar level as in mosses collected from the Slowinski National Park [3]. Slowinski National Park has been included to the group of forest area with very little impact of industrial and communication (traffic) pollution and, if so, to regions not very polluted with heavy metals. The results obtained for Puszcza Biala Forest plants are also characterized by significantly smaller concentrations of heavy metals and in particular lead and zinc, in mosses and some vascular plants as compared with the heavily polluted regions of Swierklaniec [8], Warsaw environs [5], some parks and other forest complexes [3, 4].

The concentration of Zn, Cu, Pb, Ni, Cr, and Cd as found in forest floor plants (lichens, mosses, club-mosses, ferns, convallaria nad bilberry) of Puszcza Biala should be considered the natural unaltered value typical of plants growing on soils unpolluted with heavy metals. Also, other vascular plants of forest floor, e.g. mosses and lichens, may be good bioindicators in the assessment of natural environment pollution degree.

Conclusion

1. Some plants of forest floor of Puszcza Biala Forest (e.g. lichens, mosses) contain more iron than manganese, while others *(JLycopodium clavatum, Dryopteris fdix-mas, Convallaria maialis, Vaccinium myrtillus)* contain more manganese than iron.

2. The actual concentrations of Zn, Cu, Pb, Ni, Cr, and Cd in plants from the pollution-free forests of Puszcza Biala is rather poorly differentiated between species and the following general pattern (descending order) prevails: Zn (31) > Cu (7.5) > Ni (4.2) > Pb (3.4) > Cr (1.6) > Cd (0.7).

3. The distribution of heavy metals in the organs of plants is not homogenous, it depends on the species and the element. Lead and cadmium accumulate in equal quantities in the leaves and stems of ferns and bilberry; higher concentrations of zinc and copper occurred in bil berry stems than in leaves; in shield fern another pattern was found: more Zn and Cu was accumulated in the leaves than the stems.

4. The concentration of heavy metals in forest floor plants of Puszcza Biala should be recognized as typical, natural values for the unpolluted regions of Poland.

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