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TRACE ELEMENTS CONTENT IN SOILS OF THE "KRZYWICZYNY" FOREST RESERVE

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A b s t r a c t. The aim of the work was to investigate various soils properties in the partial forest reserve "Krzywiczyny", in the Namysłów Forest Inspectorate (Opole Voivodeship). It was found that upper soil horizons, including organic, humic and illuvial ones, indicated clear accumulation of Mn, Zn, Cu, Pb and Cd. However, a tendency to diminution of these elements content with profile depth was noted. High positive correlation was stated between organic matter content and Mn, Zn, and Cu amounts in the brown leached soils studied.

K e y w o r d s: trace elements, soils, forest reserve.

INTRODUCTION

Papers published so-far on the monitoring of the natural environment in the Voivodeship of Opole, have drawn special attention to the analyses of surface water quality and degree of atmospheric air pollution. Soil environment was investigated only with reference to villages, disregarding forest grounds. Local research and foreign studies give evidence that forest soils have more advantageous properties to evaluate the anthropogenic influence on the natural environment [1,7,10]. Since 1997, research on the reserve soils in the Voivodeship of Opole have been conducted by the Laboratory of Soil Science and Soil Protection at the University of Opole. The programme included local monitoring of the forest area.

The aim of the work was to investigate soils in the partial forest reserve of the "Krzywiczyny", with special regard to the trace elements content (manganese, zinc, copper, lead, nickel and cadmium).

MATERIALS AND METHODS

The "Krzywiczyny" forest reserve is situated in the region of the Namysłów Forest Inspectorate, the premises of Wołczyn, section 96b, in the Voivodeship of Opole. Total area of the reserve is 19.7 ha. The predominant type of the reserve habitat is mixed forest which, according to its species composition, belongs to the plant community close to the Central European wet-ground forest *Galio Silvatici-Carpinetum*. The prevailing species are a beech tree *Fagus silvatica* L. and a hornbeam *Carpinus betulus* L., and additionally, a fir-tree *Abies alba* Miller.

Soils in the reserve belong to proper brown soils and the subtype of leached brown soils [12]. The study soils were formed from boulder clay on unconsolidated glacial sand. Five profiles, typical for the whole area, were chosen for the investigation. Plant communities specific for the predominant type of the forest habitat were taken into account during profile selection. Soil samples were collected according to genetic horizons.

In all the samples, physico-chemical soil properties were determined as follows:
- granulometric composition by the Cassagrande's areometric method modified by Prószyński,
- pH potentiometrically, using a 1:2.5 soil-water ratio and a 1:2.5 1 N KCl ratio,
- organic carbon content by the Tiurin's method,
- total trace elements (Mn, Zn, Cu, Pb, Ni and Cd) content by the absorption spectrometry method after previous dissolution of the soil samples in the acid mixture of HF and $HClO_4$.

RESULTS

Granulometric composition (Table 1) revealed low variability in the illuvial horizon Bbr of the investigated soil. The B horizon was formed from silty light clay in the profiles No. 1 and 3, silty - sandy clay in No. 2, loamy silt in No. 4 and clayey silt in the profile No. 5. The parent rock was formed from loose sand in all the profiles.

A typical distribution of organic matter was observed in the study profiles. Its amount in the organic horizon varied from 66.64% in the profile 4 to 77.83% in the profile 1, and was gradually diminished with depth of the analysed profiles. Consequently, the mineral horizons were characterised by a low amount of organic carbon. The content of C-org. in the illuvial horizon and the parent rock was less than 1%.

Organic horizons showed strongly acidic reaction in the profiles 1, 2, 4 and 5, where the pH in KCl ranged from 3.7 to 4.1, and acidic reaction in the profile 3 -

Table 1. Granulometric composition, reaction and organic carbon content in the leached brown forest soils in the partial reserve "Krzywiczyny"

Profile No.	Genetic horizon	Depth (cm)	Content of fraction in dia (mm)			pH		C-TOC (%)
			1-0.1	0.1-0.2	<0.02	KCl	H_2O	
1	O	0-4	-	-	-	3.9	4.5	45.15
	A	5-7	43	27	30	3.0	3.8	13.57
	ABbr	8-12	42	26	32	3.1	3.6	4.85
	Bbr	13-75	41	31	28	4.0	4.4	0.64
	C	76-110	95	2	3	4.2	4.5	0.39
2	O	0-2	-	-	-	4.1	4.6	42.0
	A	3-4	40	48	12	3.0	3.9	6.50
	ABbr	5-11	42	47	11	3.4	4.0	2.91
	Bbr	12-40	45	31	24	4.2	4.5	0.34
	C	41-110	93	4	3	4.5	5.0	0.12
3	O	0-5	-	-	-	4.8	5.3	42.2
	A	6-9	33	39	28	3.4	4.2	11.70
	Bbr	10-76	34	38	28	3.8	4.7	0.86
	C	77-125	95	3	2	4.4	5.2	0.91
4	O	0-3	-	-	-	3.7	4.2	38.66
	A	4-7	30	47	23	3.0	3.6	2.02
	ABbr	8-11	32	46	22	3.5	4.1	1.87
	Bbr	12-70	29	41	30	4.0	4.3	0.50
	C	71-135	93	4	3	4.8	5.2	0.49
5	O	0-6	-	-	-	3.9	4.1	38.71
	A	7-20	14	48	38	4.7	5.2	9.2
	Bbr	21-65	15	47	38	4.0	4.4	0.76
	C	66-100	89	6	5	4.2	4.7	0.82

pH 4.8. Also the illuvial horizons were characterised by strongly acidic reaction - the pH values varied within the range of 3.8-4.2. The acidity decreased with profile depth to the pH values that ranged from 4.2 to 4.8 in the parent rocks.

The content of trace elements in the investigated profiles is presented in Table 2, in a form of the absolute value (A) and index of distribution (B) calculated as the ratio of the heavy metal concentration in particular genetic horizons to their content in the parent rocks.

Manganese. The highest content of Mn was determined in the organic horizons of all the analysed profiles, and it varied from 1938.5 to 4875.0 mg/kg d.m. Organic horizons had also a very high index of distribution, with the maximum value of 121.0. Whereas humic and illuvial horizons showed lower and uniform

T a b l e 2. Content of trace elements in the leached brown forest soils in the partial reserve "Krzywiczyny" (mg/kg of d.m.)

Profile No.	Genetic horizon	Depth(cm)	Mn		Zn		Cu		Pb		Ni		Cd	
			A	B	A	B	A	B	A	B	A	B	A	B
	O	0-4	4078.1	121.0	63.8	8.7	11.7	2.2	31.4	6.7	6.8	1.1	0.18	1.4
1	A	5-7	345.0	10.2	60.5	8.3	7.4	1.3	56.2	11.9	8.8	1.4	0.30	2.3
	ABbr	8-12	120.0	3.6	20.0	2.7	8.3	1.5	30.0	6.4	6.6	1.1	0.10	0.8
	Bbr	13-75	103.8	3.1	20.0	2.7	6.4	1.2	6.9	1.5	8.0	1.3	0.15	1.2
	C	76-110	33.7	-	7.3	-	5.5	-	4.7	-	6.1	-	0.13	-
	O	0-2	3156.2	44.7	66.2	3.3	15.1	3.4	39.1	3.5	4.8	0.7	1.27	31.7
2	A	3-4	180.0	2.5	35.0	1.7	10.0	2.2	89.7	7.9	11.2	1.7	1.12	28.0
	ABbr	5-11	155.0	2.2	25.0	1.2	6.2	1.4	31.3	2.8	8.8	1.4	0.70	17.5
	Bbr	12-40	160.0	2.3	20.3	1.0	5.8	1.3	11.5	1.0	7.5	1.1	0.97	24.2
	C	41-110	70.6	-	20.0	-	4.5	-	11.3	-	6.5	-	0.04	-
	O	0-5	4875.0	47.3	55.0	5.5	11.2	1.5	24.3	2.8	5.6	0.7	0.80	16.0
3	A	6-9	217.5	2.1	47.5	4.7	5.1	0.7	250.0	28.0	6.8	0.8	0.53	10.6
	Bbr	10-76	230.8	2.2	36.6	3.7	6.5	0.9	16.4	1.9	8.9	1.1	0.07	1.4
	C	77-125	103.1	-	10.0	-	7.3	-	8.8	-	8.0	-	0.05	-
	O	0-3	3406.3	43.5	61.33	3.7	17.7	2.8	576	5.1	5.1	0.4	1.05	3.0
4	A	4-7	175.0	2.2	25.0	1.5	10.0	1.6	33.8	3.0	7.6	0.6	0.44	1.3
	ABbr	8-11	240.0	3.1	30.0	1.8	5.0	0.8	35.0	3.1	9.4	0.8	0.48	1.4
	Bbr	12-70	440.0	5.6	25.0	1.5	5.0	0.8	17.2	1.5	8.6	0.7	0.91	2.6
	C	71-135	78.3	-	16.6	-	6.3	-	11.4	-	11.4	-	0.35	-
	O	0-6	1938.5	13.4	85.0	2.4	17.9	4.0	39.9	3.4	7.8	1.0	1.03	10.0
5	A	7-20	367.5	2.5	51.3	1.5	13.6	3.0	54.9	4.6	16.3	2.1	0.37	3.7
	Bbr	21-65	181.6	1.3	28.3	0.8	6.7	1.5	6.6	0.6	6.3	0.8	0.44	4.4
	C	66-100	145.0	-	35.0	-	4.5	-	11.8	-	7.6	-	0.10	-

A - total content of elements; B - distribution index calculated on the basis of ratio of the element in the given horizon to its content in the parent rock.

accumulation of Mn. For both horizons, the index of distribution was 3.3 on the average.

Zinc. The content of Zn in the organic horizons varied from 55.0 to 85.0 mg/kg d.m. and the index of distribution was 4.7. A decrease of Zn accumulation was observed in the humic and illuvial horizons, where the element content ranged from 25.0 to 51.3 mg/kg d.m. and 20.0-36.6 mg/kg d.m., respectively.

Copper. The highest Cu content was also noted in the organic horizons (11.2-17.9 mg/kg d.m.). These horizons contained 2.8 times more copper, on the average, than the parent rocks. The amount of Cu in the humic horizons of the analysed profiles varied from 1.6 to 5.1 mg/kg d.m., while in illuvial horizons, it was slightly higher and ranged from 5.0 to 6.7 mg/kg d.m.

Lead. The highest Pb accumulation was observed in the humic horizons, where it ranged from 24.3 to 250.0 mg/kg d.m., with the mean value of the index of distribution of 11.0. Organic horizons revealed lower content of lead. The mean index of distribution calculated for the organic horizons was 4.3, and 1.3 for illuvial ones. The amount of lead determined in the illuvial horizons was only slightly higher than in the parent rocks.

Nickel. The nickel content revealed the least quantitative differentiation in the study profiles among all the analysed elements. Regardless of the genetic horizon differentiation, the present investigation showed no Ni accumulation in the soils of the reserve. The mean index of distribution was 1.04.

Cadmium. The highest content of Cd was registered in the organic horizons of the study profiles (mean value 0.87 mg/kg d.m.). The index of distribution calculated for the organic horizons was 12.4, for humic horizons 9.2, and for illuvial ones, it was 8.4 on the average.

DISCUSSION

Basic factors influencing heavy metals content in the soils are: climate and habitat conditions, parent rock abundance, type of soil cultivation and anthropopression [8,9]. The amount of the analysed trace elements in the individual genetic horizons, can be present in the following series:

for the organic horizons (O):

Mn (3490.82) > Zn (66.27) > Pb(38.46) > Cu (11.92) > Ni (6.02) > Cd (0.87)

for the humic horizons (A):

Mn (257.0) > Pb (96.92) > Zn (43.86) > Ni (10.14) > Cu (9.22) > Cd (0.55)

for the illuvial horizons (Bbr):

Mn (223.24) > Zn (26.04) > Pb (11.72) > Ni (7.86) > Cu (6.08) > Cd (0.51)

for the parent rocks (C) :

Mn (86.14) > Zn (17.78) > Pb (9.6) > Ni (7.92) > Cu (5.62) > Cd (0.13).

The results obtained are in agreement with the findings of other authors [4,9]. Taking into consideration a low content of the analysed trace elements in the parent rocks of the study soils, it can be stated that the enrichment of organic and humic horizons in Mn, Zn, Cu, Pb and Cd is a consequence of natural environmental anthropopression. Moreover, many authors [2,4-6,11] are of the opinion that bioaccumulation processes and synthesis of humic-metallic compounds are of great importance. Thus, the enrichment of organic horizons in heavy metals takes place through absorption and accumulation of trace elements by plants, which release them into the soils with falling dead parts.

The statistical analysis showed a significant positive correlation between C-org. content and Mn content ($r = 0.9865$, $p<0.01$) as well as C-org. content and Zn ($r = 0.9423$), Cu ($r = 0.9329$), and Cd content ($r = 0.8389$). Similar relations were also noticed for the amount of some trace elements. The correlation analysis proved a high positive relation between Zn content and Cu ($r = 0.9940$), Cd ($r = 0.9188$), and Mn content ($r = 0.8887$, $p<0.05$). A high positive correlation was also noted between the content of Mn and Cu ($r = 0.8667$, $p<0.05$).

CONCLUSIONS

1. Organic, humic and illuvial horizons of the investigated brown leached soils indicated clear accumulation of Mn, Zn, Cu, Pb and Cd. At the same time, a tendency to diminution of the trace elements content with profile depth was observed. The least quantitative differentiation in the genetic horizons was noted for nickel.

2. High accumulation of Mn, Zn and Pb in the organic and humic horizons could possibly result from anthropogenic changes in the natural environment.

3. Correlation analyses showed high positive relations between the content of organic carbon, and Mn, Zn and Cu, and also between Zn content and Cu, Cd, and Mn contents.

4. Soils of the study forest area constitute a valuable element of the natural environment monitoring.

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