Acta Agrophysica, 2001, 51, 263-274

HEAVY METALS IN THE FOREST SOILS OF THE SOUTH PODLASIE LOWLAND

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A b s t r a c t: Concentration and profile distribution of heavy metals was investigated as contamination indicators of the forest soils formed from glacial deposits of the South Podlasie Lowland. The study was carried out on thirteen soil profiles situated a hundred meters from the road. The highest content of heavy metals was found in the organic horizons of the investigated soils. The mean content of Mn, Zn, Cu, Pb, Ni, Cr in the investigated soils were: 556.7, 72.9, 15.5, 63.5, 13.8, 16.5 mg/kg d.m. of the soil, respectively. In the mineral-organic and mineral horizons of the investigated soils heavy metals were present in quantities which were close to natural. The podzol soils, podzols and rusty soils developed from sands contain less heavy metals than the soils lessivés, black earth and deluvial soil. The Mn, Zn, Cu, Pb distribution in the soil profiles is influenced by the soil forming processes. The distribution index of the examined metals distribution in the genetic horizons testify to it.

K e y w o r d s: heavy metals, forest soils, pedogenesis, lithogenesis, anthropogenesis.

INTRODUCTION

Heavy metal accumulation of anthropogenic origin may influence soil biological properties. It exerts toxic effects on plants, and may contaminate both the food chain and ground waters. The degree of environment pollution can be measured by determining the content and profile distribution of heavy metals in the soil.

In 1998, research was undertaken to determine the content and distribution of heavy metals in the forest soils of the South Podlasie Lowland. The investigated soils were near communication routes.

MATERIAL AND METHODS

The subject of the research were the following types of forest soils: podzol soils, podzols, rusty soils, soils lessivés, black earth and deluvial soil.

All of the analysed soils developed from sands, loams and silts of the Middle-Polish Glaciation. The study was carried out on thirteen soil profiles situated a hundred meters from the road.

The following characteristisc were determined in the sampled soils: granulometric-composition with use of the Bouyoucos method as modified by Casagrande - Prószyński; organic carbon amount - according to the Tiurin's method.

Total concentration of heavy metals was determined by the method of atomic absorption spectrophotometry (AAS) in the solutions obtained by soil digestion with HNO_3 in a microwavable mineraliser.

RESULTS

The content of heavy metals and their distribution indices in the genetic horizons of the analysed soil profiles as well as the content of carbon organic compounds and clay particles (<0.02 mm) are given in Table 1.

Manganese. The content of this element in the examined soil profiles was between 19.9 and 798.7 mg/kg of soil dry matter (Table 1). The highest quantity of the element in question was found in the O organic horizons regardless of the soil kind.

In the analysed podzol, podzols, and rusty soils the content of manganese in the O organic horizons fluctuated between 351.6 and 580.3 mg/kg of dry matter. This quantity was from 9.82 to 16.39 times higher than in the C parent rock (Table 1). The lowest quantities of this element were determined in the Ees eluvial horizons as well as in the C parent rock. Moreover, a clear trend towards manganese accumulation in the Bhfe, BfeBv, and Bv enrichment horizons was noted. The distribution index in these horizons reached the values between 1.37 and 3.00 (Table 1).

In the O organic horizons of soils lessivés, the content of the above element ranged from 393.4 to 484.9, being from 1.63 to 2.05 times higher than in the C parent rock (Table 1). In all the examined soils, the lowest quantity of manganese occurred in the Eet eluvial horizons for the Mn distribution index fluctuated between 0.42 and 0.79. Among the mineral horizons of the soils lessives, the highest quantities of manganese was determined in the C parent rock and in the Bt illuvial horizons.

In the profiles of the black earth and deluvial soil, the highest concentration of manganese was found in the O organic horizons and in the A mineral-organic ones for which the distribution index varied from 1.30 to 5.90 and from 1.21 to 5.41 (Table 1).

Zinc. This element was found in the quantities from 6.7 to 94.9 mg/kg of dry matter (Table 1). The highest quantity of this element was observed in the organic horizons of the examined soils.

Table 1. Total content of heavy metals (mg/kg d.m.) in investigated soils and sme of their physico-chemical properties

Genetic horizons	Depth (cm)	Mn		Zn		Cu		Pb		Ni		Cr		Organic C	<0.02
		Mg/kg d.m.												%	
		A*	B**	A	B	A	B	A	B	A	B	A	B		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Podzol soil															
Gręzów															
O	0-4	563.2	11.40	94.9	8.79	21.1	3.29	76.4	14.15	17.7	7.69	19.9	7.37	40.25	
A	4-11	48.6	0.98	10.2	0.94	4.3	0.67	7.9	1.46	2.2	0.96	2.9	1.07	1.28	3.0
Ees	11-28	33.8	0.68	7.1	0.66	4.1	0.64	6.1	1.13	1.9	0.83	1.5	0.56	0.51	2.0
Bhfe	28-56	86.5	1.75	12.2	1.13	5.6	0.88	7.4	1.37	1.8	0.78	2.9	1.07	0.27	5.0
C	>56	49.4	-	10.8	-	6.6	-	5.4	-	2.3	-	2.7	-	0.07	3.0
Stasin															
O	0-6	519.5	13.89	77.4	8.15	14.7	2.58	53.4	11.60	14.3	7.53	16.2	8.53	38.29	
A	6-12	36.7	0.96	8.4	0.88	5.9	1.04	6.2	1.35	2.5	1.32	2.5	1.32	1.22	4.0
Ees	12-30	27.9	0.73	6.7	0.71	4.7	0.82	5.3	1.15	1.4	0.74	1.7	0.89	0.55	3.0
Bhfe	30-52	66.7	1.74	11.2	1.18	5.1	0.89	5.9	1.28	2.3	1.21	2.2	1.16	0.24	4.0
C	>52	38.4	-	9.5	-	5.7	-	4.6	-	1.9	-	1.9	-	0.06	3.0
Podzols															
Mokobody															
O	0-10	351.6	9.82	41.5	4.51	18.8	2.65	60.7	11.04	11.2	10.18	15.2	5.07	41.28	
AEes	10-20	46.9	1.31	7.3	0.79	4.5	0.63	6.4	1.16	1.8	1.64	2.1	0.70	0.57	6.0
Ees	20-30	31.9	0.89	7.4	0.80	4.9	0.69	4.8	0.87	1.3	1.18	1.9	0.76	0.33	5.0
EesBh	30-40	68.9	1.92	8.3	0.90	7.3	1.03	7.3	1.33	1.4	1.27	2.4	0.80	0.36	3.0
Bh	40-63	65.8	1.84	9.9	1.08	7.5	1.06	8.8	1.60	1.7	1.55	2.7	0.90	0.42	4.0
Bfe	63-90	56.2	1.57	10.9	1.18	6.8	0.96	6.1	1.11	1.1	1.0	2.5	0.83	0.33	5.0
C	>90	35.8	-	9.2	-	7.1	-	5.5	-	1.1	-	3.0	-	0.12	3.0

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 parent rock.

T a b l e 1. Continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lessivés soil															
Stok Lacki															
O	0-2	484.9	2.05	53.4	1.54	18.4	1.14	89.9	3.38	10.1	1.23	11.1	0.61	37.37	
A	2-9	192.9	0.82	30.2	0.87	10.9	0.68	23.2	0.87	4.9	0.60	8.9	0.49	2.39	16.0
Aeet	9-29	181.7	0.72	18.1	0.52	8.6	0.53	19.1	0.72	4.3	0.52	6.8	0.37	0.60	18.0
Eet	29-50	178.7	0.75	17.7	0.51	3.8	0.24	16.2	0.61	4.0	0.49	5.6	0.31	0.24	21.0
Bt	50-92	223.9	0.94	29.5	0.85	15.7	0.98	31.1	1.17	7.5	0.91	14.3	0.78	0.14	31.0
C	>92	236.6	-	34.6	-	16.1	-	26.6	-	8.2	-	18.3	-	0.14	35.0
Wyczołki															
O	0-1	393.4	1.63	68.9	2.88	15.6	1.33	54.5	3.86	11.9	1.47	14.3	0.79	34.89	
A	1-10	187.5	0.78	23.6	0.99	9.8	0.84	13.6	0.96	6.8	0.84	9.8	0.54	2.51	18.0
Eet	10-37	167.8	0.69	17.1	0.72	6.2	0.53	10.1	0.72	6.1	0.75	8.3	0.46	0.37	16.0
Bt	37-85	252.7	1.05	25.4	1.06	12.6	1.08	16.9	1.20	8.9	1.10	18.9	1.04	0.15	29.0
C	>85	241.3	-	23.9	-	11.7	-	14.1	-	8.1	-	18.2	-	0.10	26.0
Niemojki															
O	0-2	433.4	1.17	77.6	3.30	11.4	0.89	43.2	3.22	9.2	0.99	14.7	1.04	35.29	
A	2-15	159.1	0.43	15.3	0.65	7.1	0.56	11.9	0.89	5.7	0.61	7.1	0.50	0.96	16.0
Aeet	15-31	157.1	0.42	13.7	0.58	6.6	0.52	5.2	0.39	5.3	0.57	8.1	0.57	0.55	16.0
Eet	31-56	155.4	0.42	11.9	0.50	6.3	0.50	2.9	0.22	4.9	0.53	8.7	0.62	0.24	17.0
IIBtg	56-101	382.5	1.03	28.3	1.20	14.5	1.14	14.9	1.11	9.9	1.03	15.6	1.10	0.11	23.0
IICg	>101	370.4	-	23.6	-	12.7	-	13.4	-	9.3	-	14.1	-	0.11	33.0
Wyrąb															
O	0-2	470.8	2.61	84.8	2.91	13.1	0.74	62.6	7.20	8.2	1.34	11.4	0.63	34.12	
A	1-11	152.9	0.85	14.5	0.50	12.8	0.73	11.3	1.30	2.5	0.41	7.3	0.40	2.34	14.0
Eet	11-39	142.7	0.79	13.9	0.48	7.1	0.40	7.4	0.85	2.9	0.48	7.6	0.42	0.29	14.0
EetBt	39-54	154.9	0.86	28.5	0.98	13.6	0.77	8.3	0.95	5.3	0.79	14.7	0.80	0.21	28.0
Btg	54-92	185.9	1.3	33.1	1.14	18.2	1.03	9.1	1.05	6.7	1.10	20.1	1.10	0.13	29.0
Cg	>92	180.1	-	29.1	-	17.6	-	8.7	-	6.1	-	18.3	-	0.10	35.0

Table 1. Continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
						Rusty soils									
Gostchorza						2									
O	0-6	460.8	23.10	55.1	9.5	12.1	3.78	66.4	11.64	9.4	6.27	8.5	4.05	39.12	
AEes	6-18	45.3	2.27	14.7	2.5	10.4	3.25	17.8	3.12	2.9	1.93	3.3	1.57	1.14	8.0
BfeBv	18-48	59.8	3.00	11.7	2.0	5.6	1.75	8.3	1.46	2.6	1.73	2.4	1.14	0.31	8.0
BvC	48-56	39.8	2.00	9.1	1.6	4.3	1.34	7.3	1.28	1.9	1.27	2.2	1.05	0.06	4.0
C1	56-86	19.9	-	5.8	-	3.2	-	5.7	-	1.5	-	2.1	-	0.03	4.0
C2	>86	64.4	-	15.2	-	2.7	-	10.8	-	2.4	-	2.6	-	0.08	4.0
Kisielany															
O	0-6	580.3	16.39	70.3	6.06	10.5	1.52	53.2	10.86	10.2	7.28	13.4	3.94	38.35	
A	6-15	57.8	1.63	18.3	1.58	9.7	1.40	11.6	2.37	3.1	2.21	4.1	1.21	0.93	6.0
AEes	15-26	44.5	1.26	16.7	1.44	8.1	1.17	7.8	1.56	2.5	1.79	3.6	1.06	0.31	5.0
BfeBv	26-58	48.5	1.37	15.1	1.30	7.5	1.09	6.5	1.33	3.1	2.21	3.8	1.12	0.22	5.0
C	>58	35.4	-	11.6	-	6.9	-	4.9	-	1.4	-	3.4	-	0.09	3.0
Czachy															
O	0-4	432.1	9.93	68.9	4.72	9.5	3.52	48.9	11.64	7.9	3.04	12.4	2.21	38.99	
A	4-12	79.5	1.83	19.2	1.32	7.3	2.70	8.9	2.12	3.8	1.46	5.2	0.93	0.99	7.0
Bv	12-35	62.3	1.43	16.3	1.12	6.9	2.56	7.4	1.76	3.2	1.23	5.9	1.05	0.37	7.0
BvC	35-64	46.7	1.07	15.8	1.08	6.1	2.26	6.5	1.55	2.9	1.16	5.8	1.04	0.12	6.0
C	>64	43.5	-	14.6	-	2.7	-	4.2	-	2.6	-	5.6	-	0.08	6.0
Sabnie															
O	0-3	489.7	5.02	57.4	3.40	11.2	3.29	41.2	12.87	5.9	3.93	9.7	1.80	37.79	
A	3-10	102.6	1.05	23.7	1.40	5.7	1.68	12.2	3.81	2.5	1.67	6.7	1.24	0.81	5.0
Bv	10-38	144.7	1.48	18.6	1.10	5.4	1.59	8.4	2.63	2.1	1.40	6.3	1.17	0.28	5.0
BvC	38-67	127.1	1.30	17.2	1.02	4.8	1.41	3.6	1.13	1.8	1.20	5.9	1.09	0.09	4.0
C	>67	97.5	-	16.9	-	3.4	-	3.2	-	1.5	-	5.4	-	0.05	4.0

Table 1. Continuation

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
						Black earth									
Czabaje															
O	0-2	679.5	1.30	1.30	4.72	18.7	2.25	79.4	6.01	22.3	3.14	25.1	2.02	32.84	
A	2-32	631.6	1.21	1.21	2.22	15.4	1.86	34.2	2.59	9.2	1.29	15.9	1.28	4.73	24.0
AG	32-85	583.4	1.12	1.12	1.59	12.7	1.53	21.1	1.60	8.5	1.20	13.6	1.10	1.27	27.0
G	>85	521.2	-	-	-	8.3	-	13.2	-	7.1	-	12.4	-	0.29	36.0
						Deluvial soil									
Konstantynów															
O	0-1	798.7	5.90	84.6	4.31	16.9	2.77	62.5	5.58	18.6	4.00	20.8	2.28	31.12	
A	1-9	731.5	5.41	54.5	2.78	14.6	2.39	30.1	2.69	7.8	1.70	13.1	1.44	5.46	49.0
A	9-39	639.5	4.73	46.9	2.39	13.4	2.20	26.6	2.38	7.6	1.65	12.1	1.33	4.08	45.0
AC	39-118	314.1	2.32	29.1	1.48	8.4	1.38	15.5	1.38	4.8	1.00	10.8	1.20	1.15	29.0
C1	118-139	135.2	-	16.9	-	6.1	-	11.2	-	4.6	-	9.1	-	0.54	18.0
C2	>139	260.2	-	28.4	-	10.4	-	13.7	-	6.4	-	13.4	-	0.33	21.0

In the organic horizons of the podzol soils, podzols, and rusty soils, the content of zinc fluctuated between 41.5 and 94.9 mg/kg of dry matter (Table 1). This the quantity was 4.51 to 8.79 times higher than in the C parent rock. Among the mineral horizons, the highest quantities of Zn were found in the following enrichment horizons BfeBv, Bhfe, and Bv, for which the distribution index of this element fluctuated between 1.08 and 2.00. As far as the podzols and podzol soils are concerned, the soils were characterised by a visible reduction in zinc quantity in their Ees eluvial horizon. The Zn distribution index in the Ees horizon was between 0.66 and 0.80 (Table 1).

In the O organic horizons of the soils lessivés, the content of zinc was in the range of 53.4 to 84.8 mg/kg of dry matter (Table 1), i.e. from 1.54 to 2.91 times higher than in the parent rock. In the analysed soils lessives, most of zinc was accumulated in the Bt illuvial horizons and in the C parent rock. The zinc distribution index in the Bt horizons varied from 0.85 to 1.20. The Eet eluvial horizons showed a clear reduction in zinc quantity, which was proved by the zinc distribution index fluctuating between 0.48 and 0.72.

In the black earth and deluvial soil, the content of the element in question was decreasing with an increasing depth of the soil profiles and had values ranging form 77.4 to 84.6 mg/kg of dry matter in the O organic horizons, while in the C parent rock from 19.6 to 16.4 mg/kg of dry matter.

Copper. The content of copper in the analysed soils was in the range of 2.7-21.1 mg/kg of dry matter (Table 1).

In the O organic horizon of the podzol soils, podzols, and rusty soils, the highest quantity of this element was found, i.e. 9.5-21.1 mg/kg of dry matter. For these soils, the Cu distribution index as compared to the parent rock fluctuated between 1.52 and 3.80. In the podzol soils and podzols the lowest quantities of Cu occurred in the A accumulation horizon of humus and in the Ees eluvial, for which the distribution indices were 0.63-1.04 and 0.64-0.82, respectively (Table 1). No clear accumulation of copper was found in the B enrichment horizons. After analysing the rusty soils, it was noted that the content of Cu was decreasing with an increasing depth of the soil horizons, reaching the lowest value in the C parent rock.

In the examined genetic horizons of the soils lessivés, the highest quantities of this element were identified in the C parent rock and in the Bt illuvial horizons. The Cu distribution index fluctuated between 0.98 and 1.03. The Eet eluvial horizons were found to have the lowest content of Cu and the distribution index was 0.24-0.53 (Table 1).

After analysing the black earth and deluvial soil, it was determined that the highest concentration of Cu was in the O and A accumulation horizons as well as in the C parent rock, reaching values from 16.9 to 18.7; from 14.6 to 15.4; from 6.1 to 8.3 mg/kg of dry matter, respectively (Table 1).

Lead. The content of Pb in the analysed soils had values between 41.2 and 89.9 mg/kg of dry matter (Table 1). The highest content of this element was found in the O organic horizons irrespective of the kind of soil. These quantities were from 3.22 to 14.15 times higher than those in the C parent rock.

Generally, the content of lead in the rusty and podzol soils was getting lower as one went deeper into the soil profiles, reaching the values between 3.2 and 5.7 mg/kg of dry matter in the C parent soil (Table 1). Only in the podzols profile there was a slight reduction in the content observed in the Ees eluvial horizon, while the Bh horizon was enriched in Pb. The lead distribution indices were 0.87 for Ees and 1.60 for Bh (Table 1).

In the Eet eluvial horizons of the analysed soils lessivés, the lowest quantity of lead was found, i.e. 2.9-16.2 mg/kg of dry matter. The lead distribution indices reached values from 1.05 to 1.20.

Next, in the black earth and deluvial soil, the most of lead, i.e. in the quantity of 30.1-79.4 mg/kg of dry matter were accumulated in the O and A accumulation horizons. For these the lead distribution indices were 5.58-6.01 and 2.59-2.69, respectively (Table 1).

Nickel. The content of this element in the analysed soil profiles fluctuated between 1.1 and 22.3 mg/kg of dry matter (Table 1). The most of this element was found in the O organic horizons irrespective of the soil kind.

On examination, the content of nickel in the O organic horizons of the podzols, podzol soils, and rusty soils reached values from 5.9 to 17.7 mg/kg of dry matter (Table 1). On the basis of the calculated distribution indices it was hard to judge decrease in the Ni content in the Ees eluvial horizons or of Ni enrichment in the illuvial horizons of these soils.

In the soils lessivés, the content of nickel in the O organic horizons fluctuated between 8.2 and 11.9 mg/kg of dry matter. So, it was 1.34-1.47 times higher than in the C parent rock (Table 1). After examining all the mineral horizons of the soils lessives, most of nickel was accumulated in the C parent rock and in the Bt illuvial horizons, whereas the lowest content of this element was observed in the Eet eluvial and A humus horizons. The Ni distribution index in the soils lessivés varied from 0.41 to 1.47 regardless of the kind of soil examined.

On the analysis of the black earth and deluvial soil, it was found out that the content of Ni was falling down according to the depth of the soil profile and it was in the range of 18.6-22.3 in the O organic horizons, while in the parent rocks it was from 4.6 to 7.1 (Table 1).

Chromium. The content of this element in the examined soils was from 1.5 to 25.1 mg/kg of dry matter. The highest content of chromium, i.e., 9.7-19.9 mg/kg of dry matter was found in the O organic horizons of the podzols, podzol soils, and in the rusty soils. There, this element occurred in the quantities from 1.80 to 7.37 times higher than the content of this element in the C parent rock (Table 1). Next, the Eet eluvial horizons were found as having least of chromium. For these horizons the distribution indices fluctuated between 0.56 and 0.76 (Table 1).

In the soils lessivés, the content of chromium varied from 5.6 to 18.9 (Table 1). The C parent rock and the Bt illuvial horizons had the highest quantities of chromium, whereas the A humus horizons and the Eet eluvial horizons were found to have the lowest content of this element. Distribution indices for these last horizons were 0.40-0.54 and 0.31-0.62, respectively.

Cr content in the black earth and deluvial soil was from 20.8 to 25.1 mg/ kg of dry matter in the O organic horizons, and in the C parent rock from 9.1 to 12.4 mg kg of dry matter (Table 1).

DISCUSSION

It can be concluded from the present results that the mean content of heavy metals in the analysed soils showed the following sequence patterns of content level:

- podzols, podzol soils, rusty soils: Mn (137.0)>Zn (22.5)>Pb (16.4)>Cu (7.3)>Cr (5.3)>Ni (3.8);
- soils lessivés: Mn (247.2)>Zn>(31.2)>Pb>(22.4)>Cu (11.8)>Cr>(12.3)>Ni (6.8);
- black earth and deluvial soils: Mn (529.5)>Zn>(41.9)>Pb>(30.8)>Cr>(14.6) >Cu>(14.6)>Cu>(123.5)>Ni (9.7).

The above patterns show that the first three soil groups, i.e. podzols, podzol soils, rusty soils, originating from sands, had, on average, lower quantities of heavy metals than the soils lessivés, black earth and deluvial soil, that developed from loam and silt. This was also confirmed by the results by Czarnowska [2].

Statistical analysis showed a highly significant influence of carbon organic compounds on the heavy metal distribution in the analysed soils (Tables 2 and 3). Only chromium did not show such a relation in the soils lessivés and in the black earth and deluvial soil. Additionally, clay particles had a highly significant influence on the Mn, Cu, Pb, Ni, and Cr distribution in the soils developed from loam and silt (Table 3). In the soils developed from sands, clay particles (<0.02 mm) had a highly significant influence on the distribution of Ni, Pb, Zn and Cr. The influence of soil forming processes on the heavy metal distribution was also quite noticeable. The Ees eluvial horizons in the podzol soils, podzols and the AEes horizons of the rusty soils and the Eet eluvial horizons of the soils lessivés showed some signs of impoverishment in Mn, Zn, Cu, Pb, which was visible in their distribution indices, calculated against the parent rock.

Similar dependence was determined for the soils created from glacial formations by Czarnowska [1], Gworek and Jeske [4], Gworek and Degórski [3].

Taking into account a low content of heavy metals in the parent rock of the podzol soils, it can be said that the enrichment of the organic horizons in these elements is the result of biological accumulation and the influence of anthropogenic factors. Malczyk and Kędzia [7] also came this conclusion when examining heavy metals in the forest soils located along communication routs.

In the soils lessivés, black earth and deluvial soil, organic horizons were enriched only with Pb, Mn, Zn.

Biological accumulation applied mainly to such elements as Mn, Zn, Cu. These elements occurred in plant ashes in quantities a few times higher than in the soil. Therefore, it is possible for them to accumulate in the horizons of the forest litters and in the organic horizons [1,6,8-10].

The present results prove that apart from biological accumulation also anthropogenic factors, i.e. in this study, automotive pollutants, can be the reason for heavy metal accumulation in the top horizons of the forest soils. Pb accumulation in the O organic horizons of the examined soils was observed. According to Kabata-Pendias [5], lead concentration in the individual soil horizons is linked to a considerable influence of anthropogenic factors. Generally, lead concentration was higher than its normal content. In our investigation, it was proved that only lead in the organic horizons occurred in the quantities higher than the most frequent levels in this type of forest soils, while the remaining heavy metals were in natural quantities [2,5].

The results show clear interdependence between occurrence of individual elements. The calculated correlation coefficients indicate a highly significant and significant correlation among the content of the examined metals. The lowest correlation coefficients, lower than 0.50, were determined for Cr and Mn, Cr and Pb, Cu and Mn in the soils lessivés, the black earth and the deluvial soil (Table 3).

CONCLUSIONS

1. The highest content of heavy metals was found in the organic horizons of the forest soils of the South Podlasie Lowland situated near communication routs.

T a b l e 2. Coefficient of correlation between heavy metals, clay particles and organic carbon contents in podzol soils, podzols and rusty soils

	<0.02	Corg.	Mn	Zn	Cu	Pb	Cr	Ni
<0.02	1.000							
Corg.		1.000						
Mn	0.1475	0.9675**	1.000					
Zn	0.4554**	0.9331**	0.9698**	1.000				
Cu	0.3461	0.8097**	0.7657**	0.7963	1.000			
Pb	0.4670**	0.9703**	0.9432**	0.9353**	0.8706**	1.000		
Cr	0.6307**	0.8886**	0.9068**	0.9415**	0.8344**	0.8981**	1.000	
Ni	0.3992*	0.9017**	0.9017**	0.9400**	0.8872**	0.9471**	0.9435**	1.000

*P=0.05; **P=0.01.

T a b l e 3. Coefficient of correlation between heavy metals, clay particles and organic carbon contents in the soils lessivés, black earth and the deluvial soil

	<0.02	Corg.	Mn	Zn	Cu	Pb	Cr	Ni
<0.02	1.000							
Corg.		1.000						
Mn	0.6848**	0.5420**	1.000					
Zn	0.0769	0.8914**	0.7000**	1.000				
Cu	0.5820**	0.4423**	0.4946**	0.5954**	1.000			
Pb	0.4943**	0.9088**	0.6694**	0.8489**	0.5822**	1.000		
Cr	0.5835**	0.2828**	0.4581**	0.5020**	0.7796**	0.3708**	1.000	
Ni	0.6088*	0.6333**	0.6694**	0.7296**	0.6876**	0.6977**	0.8204**	1.000

The mean content of Mn, Zn, Cu, Pb, Ni, Cr in the investigated soils was: 446.7, 72.9, 15.5, 63.5, 13.8, 16.5 mg/kg soil dry matter, respectively.

2. In mineral-organic and mineral horizons of the investigated soils heavy metals were present in the quantities close to natural.

3. The podzol soils, podzols and rusty soils developed from sands contain less heavy metals, than the soils lessivés, black earth and the deluvial soil developed from loams and silts of the Middle Polish Glaciation.

4. Statistical analysis indicated a positive correlation between clay particles (<0.02 mm) and the total content of Zn, Pb, Ni, Cr and between the quantity of organic carbon and the contents of Zn, Cu, Mn, Pb, Ni, Cr in podzol soils, podzols, rusty soils.

5. It was observed that clay particles (<0.02 mm) had significant influence on the distribution of Mn, Cu, Pb, Ni, Cr, organic carbon had significant influence on the distribution of Mn, Zn, Cu, Pb, Ni in the soils lessivés, black earth and the deluvial soil.

6. The Mn, Zn, Cu, Pb distribution in the soil profiles is influenced by the soil forming processes which is proved by the distribution index of the examined metals in the genetic horizons.

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