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Trace elements in arable Cambisols and Luvisols developed from boulder loam and fluvioglacial sands of the Skierniewicka Upland (central Poland)

Abstract: The paper was focused on determining the content soluble in 20% HCl of Fe, Mn, Zn, Cu, B, Co, Pb, and Ni in arable Cambisols and Luvisols, developed from boulder loams and fluvioglacial sands of the Middle-Polish (Riss) glacial period, Wartanian Stadial in the Skierniewicka Upland, and recognizing the relationships between these elements and selected soil properties. The mean content of Mn, Zn, Cu, B, Co, Pb, Ni, and Fe in the soils developed from boulder loam was: 288, 24, 5, 3, 12.4, 4, 9, and 6.8 mg·kg⁻¹ of soil, and 1.24%, respectively. The contents of the above mentioned elements in soils developed from fluvioglacial sands were lower and reached: 235, 16, 2.9, 6.5, 2.5, 7, 3.4 mg·kg⁻¹ of soil, and 0.71%, respectively. Statistical analysis has indicated a correlation between the total amounts of Zn, Cu, B, Co, Ni, and the contents of <0.02 mm and <0.002 mm particles and iron. The Fe content was correlated with the texture of soil, the Mn amount was correlated only with the iron content, whereas that of lead – with the organic carbon content. The soil-forming processes influenced the distribution of total contents of elements. The lessivage process influenced the distribution of Zn, Cu and B, the brunification process influenced the distribution of Fe, Ni, B and Co, the gleying process influenced the distribution of Mn, whereas Pb and Zn were bioaccumulated in most humus horizons of the studied soils. The studied arable soils had natural contents of trace elements.

Key words: trace elements, boulder loam, sand, lessivage, brunification

INTRODUCTION

Factors influencing the occurrence and transformations of trace elements in soils have been the subject of many previous reports (e.g. Kabata-Pendias and Piotrowska 1971, Czarnowska and Gworek 1987), and are still continued (Abgottspon et al. 2014, Jeske 2014, Muñoz et al. 2013, Sosulski et al. 2013). The results of these studies are of high significance because many elements are indispensable for the growth and development of living organisms, which influences food security and safety. Deeper knowledge of some elements, particularly lead, cadmium, and mercury allows to determine the hazards that they pose on the environment, access in the food chain and transportation into surface- and groundwater. It should be noticed that soil is an important element of environment and the basic link of the trophic chain: soil – plant – animal – human being.

The paper was focused on analyzing the content soluble in 20% HCl of Fe, Mn, Zn, Cu, B, Co, Pb, and Ni in arable soils, developed from the boulder loams and fluvioglacial sands of the Middle-Polish

(Riss) Glaciation in the Skierniewicka Upland, and determining the relationship between these elements and selected soil properties. Premise for the conducting these studies was the lack so far studies on the occurrence of trace elements in the soil developed from boulder loams and sands of the area, and the good of their agricultural value.

MATERIAL AND METHODS

Eight profiles of arable soils located in the Experimental Field of the Warsaw University of Life Sciences-SGGW in Miedniewice near Skierniewice (central Poland) were investigated. They included the following soils according to the FAO-WRB classification (IUSS Working Group WRB 2015): Eutric Stagnic Cambisols – two profiles, Dystric Stagnic Cambisols – one profile, Dystric Endogleyic Cambisols – two profiles, and Stagnic Luvisols – three profiles. Field investigations and basic soil analyses have been conducted by methods commonly applied in soil science laboratories (Pansu and Gautheyrou 2006). The Fe, Mn, Zn, Cu, B, Co, Pb and Ni contents were determined

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using the ASA technique in solutions after etching the soil samples with 20% HCl (Gedroń 1955). The soil samples were ground in an agate mortar, and the organic matter was reduced to ashes in a muffle furnace at 450–480°C for 8 h prior to acid etching. The results were subject to statistical analysis by calculating the correlation coefficients between the content of trace elements and selected physical and chemical properties of the soils.

The studies have been conducted in soils developed from boulder loams of the basal moraine from the Middle-Polish (Riss) Glaciation, Wartanian Stadial in the Skierniewicka Upland, central Poland. The upland is situated at the boundary between the Łowicz-Błonie Plain, eastern part of the Łódź Elevation and the western part of the Rawska Upland (Kondracki 2009). The area is dominated by shallow boulder

loams, 1 to 4 m thick, and only locally their thickness exceeds 10 m (Rdzany 2006). The layers are not always continuous, underlain by sand-gravel fluvio-glacial sediments and by mud-clay ice-dammed sediments in some places. Slightly younger fluvio-glacial sands occur in the depressions within the loams. During the Eemian Interglacial period, the loams from the area had undergone aqueous denudation, decalcitization, rinsing, and surface water gleying (Konecka-Betley and Czepińska-Kamińska 1979, 1985). Surficial layers of loams were enriched in sand, impoverished in colloidal clay, iron compounds and nutrients. Their further intense transformations took place during the cool periglacial interval, related to the youngest glaciation (Vistulian).

TABLE 1. Selected physical and chemical properties of soils

Profile No.	Horizon	Depth (cm)	pH (KCl)	% fraction (mm)				CEC (cmol ₍₊₎ ·kg ⁻¹)	BS %	Corg
				1–0.1	0.1–0.02	<0.02	<0.002			
Eutric Stagnic Cambisol										
9	A	0–30	5.5	62	17	21	10	18.46	45.20	0.88
	Bw	30–40	5.9	53	17	30	19	27.22	48.90	0.24
	Bwg	40–60	6.1	55	15	30	20	24.10	55.10	0.12
	Cg	60–80	8.1	58	15	27	18	19.58	74.40	0.07
	2Cg	80–100	6.8	88	4	8	5	7.54	66.00	0.0
11	A	0–25	6.8	60	16	24	11	19.26	62.60	0.88
	Bwg	25–41	7.3	55	17	28	18	15.66	79.00	0.18
	BwCg	41–60	7.4	60	15	25	16	13.38	77.40	0.09
	Cg	<60	7.1	53	15	32	17	21.45	76.10	0.0
Dystric Stagnic Cambisol										
4	A	0–30	4.4	68	15	17	5	14.30	30.60	0.54
	2Bw	30–40	3.7	50	17	33	21	24.72	10.60	0.14
	2BwCg	40–60	3.7	47	15	38	25	32.04	10.70	0.09
	2Cg	<60	3.8	49	16	35	23	28.18	15.10	0.05
Dystric Endogleyic Cambisol										
13	A	0–30	6.6	69	16	15	6	10.22	59.70	0.65
	Bw	30–40	6.4	78	9	13	7	11.04	61.80	0.18
	Cg	40–60	6.5	82	8	10	6	7.91	55.50	0.0
	Gor	60–90	6.5	74	15	11	6	7.94	48.20	0.0
15	A	0–27	5.5	78	13	9	3	9.00	35.40	0.58
	Bw	27–60	4.0	70	24	6	2	7.21	19.40	0.05
	2Gor	60–90	5.1	40	43	17	6	17.73	27.70	0.0
Stagnic Luvisols										
1	A	0–30	6.3	69	15	16	5	8.60	67.20	0.551
	Etg	30–70	5.9	72	12	16	7	7.59	68.20	0.092
	2Btg	70–90	5.8	65	13	22	16	18.95	60.80	0.061
	2Cg	90–150	6.1	59	13	28	19	16.81	67.80	0.025
5	A	0–20	5.6	70	15	15	4	10.91	37.50	0.52
	Etg	20–40	5.3	74	14	12	5	8.00	37.90	0.11
	2Btg	40–60	5.7	63	15	22	18	19.04	48.40	0.06
	2Cg	<60	5.1	49	24	27	20	21.61	31.10	0.0
8	A	0–30	5.0	63	16	21	10	13.09	36.90	0.71
	Et	30–42	5.5	63	16	21	11	11.14	42.00	0.27
	Btg	42–60	6.3	51	17	32	21	23.87	52.90	0.22
	Cg	<60	5.5	53	17	30	20	25.02	39.20	0.04

RESULTS

Eutric Stagnic Cambisols have developed from sandy loam, with sandy topsoil and accompanying a pseudogleying process (profiles 9 and 11, Table 1). The soils were characterized by a significantly lower content of colloidal clay fraction (<0.002 mm) particles in the surficial humus horizons than in the deeper levels. The particle size change is related to the soil reaction and the base saturation (BS) of the sorption complex. With depth, the reaction changes from poorly acidic in profile 9 and neutral in profile 11 to alkaline in both profiles, whereas the BS reaches values exceeding 60% in the subsoil. Dystric Stagnic Cambisol (profile 4) has a similar particle size composition and pseudogleying as in profiles 9 and 11, except for the slightly higher impoverishment of

the surficial humus horizon in colloidal clay. This soil has a strongly acidic reaction in the entire profile and the BS value below 30%. Dystric Endogleyic Cambisols have developed from sands (profile 13 from loamy sand and profile 15 from sand). Despite a similar particle size composition, profile 13 has a poorly acidic reaction in the entire profile and BS in the range of 50-60%, whereas profile 15 has an acidic reaction and BS below 20%. Both profiles have groundwater at the depth of 80 cm. In Stagnic Luvisols (profiles 1, 5, and 8) developed from loams, impoverishment in <0.002 mm fraction is deeper and encompasses the surficial humus horizon (A) and the *luvic* (Etg) horizons. They are accompanying by pseudogleying process, usually with a poorly acidic reaction in the entire profile and BS values in the range of 30-50%, with the exception of profile 1, in

TABLE 2. Content of trace elements soluble in 20% HCl

Profile No.	Horizon	Depth (cm)	Fe %	Mn	Zn	Cu	B mg·kg ⁻¹	Co	Pb	Ni
Eutric Stagnic Cambisol										
9	A	0-30	0.84	267	30	4.6	8.6	3.0	8	3.2
	Bw	30-40	1.86	860	33	4.1	13.8	8.2	15	10.0
	Bwg	40-60	1.83	800	26	6.1	16.6	6.6	7	11.5
	Cg	60-80	1.50	380	23	6.7	16.4	4.8	11	10.6
	2Cg	80-100	0.33	133	7	2.0	3.0	1.2	5	2.4
11	A	0-25	0.97	477	30	4.2	8.6	3.4	11	2.3
	Bwg	25-41	1.43	400	23	2.8	15.0	4.2	4	6.0
	BwCg	41-60	1.23	298	19	3.2	14.6	3.6	9	7.4
	Cg	<60	1.31	223	20	6.6	15.2	3.2	8	6.4
Dystric Stagnic Cambisol										
4	A	0-30	0.59	206	19	3.9	4.8	2.6	15	2.7
	2Bw	30-40	1.73	166	30	5.2	14.8	4.2	8	8.1
	2BwCg	40-60	2.05	108	30	9.6	21.0	4.2	9	8.9
	2Cg	<60	1.87	162	28	10.0	20.2	5.4	6	11.8
Dystric Endogleyic Cambisol										
13	A	0-30	0.56	153	23	3.0	4.0	2.2	9	3.2
	Bw	30-40	0.82	306	16	2.8	6.2	2.6	7	4.3
	Cg	40-60	0.66	258	12	2.4	6.8	2.4	7	4.0
	Gor	60-90	0.62	69	12	3.1	8.6	2.0	3	2.1
15	A	0-27	0.47	154	19	2.6	3.0	1.8	9	1.9
	Bw	27-60	0.83	554	13	2.2	6.4	3.8	8	4.2
	2Gor	60-90	1.01	149	14	4.0	10.4	2.8	5	4.4
Stagnic Luvisols										
1	A	0-30	0.59	190	19	3.4	5.0	2.6	10	2.5
	Etg	30-70	0.36	60	10	1.7	3.8	1.6	4	2.2
	2Btg	70-90	1.33	84	22	9.9	15.0	3.4	3	8.7
	2Cg	90-150	1.50	218	24	9.4	17.2	4.6	5	13.0
5	A	0-20	0.39	108	22	2.8	3.8	1.6	12	1.6
	Etg	20-40	0.50	246	16	1.6	3.6	3.2	3	3.0
	2Btg	40-60	1.30	203	23	3.4	15.0	3.6	10	7.2
	2Cg	<60	1.45	172	24	6.2	17.2	3.8	13	8.0
8	A	0-30	0.73	218	28	5.0	6.6	2.8	13	3.7
	Et	30-42	0.85	249	20	3.0	7.0	3.0	6	3.9
	Btg	42-60	1.83	383	28	4.5	14.6	5.4	7	7.1
	Cg	<60	1.73	433	26	8.9	18.0	6.0	7	11.3

which the BS value is higher and ranges within 60 to 70%.

The cation exchange capacity (CEC) of the studied soils ranges from 7.21 to 32.04 $\text{cmol}_{(+)}\cdot\text{kg}^{-1}$ of soil and depends on the particle size composition, particularly the contribution of <0.002 mm fraction. The humus horizons of most soils have a thickness of 30 cm and an organic carbon content in the range of 0.52 – 0.88%.

The mean contents of trace elements and their range in soils developed from loams (profiles 9, 11, 4, 1, 5, 8) are as follows (in $\text{mg}\cdot\text{kg}^{-1}$): Mn – 288 (60–860), Zn – 24 (10–33), Cu – 5.3 (1.6–9.9), B – 12.4 (3.6–20.2), Co – 4.0 (1.6–8.2), Pb – 9.0 (3–15), Ni – 6.8 (1.6–13.0), and Fe in % – 1.24 (0.36–2.05) (Table 2). In turn, in soils developed from sands (profiles 13 and 15), the content of these elements was lower and were (in $\text{mg}\cdot\text{kg}^{-1}$): Mn – 235 (69–554), Zn – 16 (12–23), Cu – 2.9 (2.8–4.0), B – 6.5 (3–10.4), Co – 2.5 (1.8–3.8), Pb – 7 (3–9), Ni – 6.8 (1.6–13.0), and Fe in % – 0.71 (0.56–1.01). Statistical analysis of the results has indicated that the contents of: Zn, Cu, B, Co, and Ni were highly correlated with the percentage contribution of <0.02 mm and <0.002 mm fraction, and with the iron content (Table 3). The Fe content was correlated with the grain size composition of soils, the Mn amount was correlated only with the iron content, whereas that of lead – with the organic carbon content.

The distribution of the studied elements in the profiles depended on the texture and the pedogenic processes. The highest amounts of Fe, B, Co, and Ni were noted in most *cambic* horizons of both Dystric Stagnic Cambisols and Dystric Endogleyic Cambisols. In turn, the surficial horizons (A and Etg) of Stagnic Luvisols display significant depletion in Fe, Zn, Cu and, B due to the lessivage process.

The contents of Mn do not show a characteristic distribution, with the exception of its significant decrease in the oxidation-reduction horizons (Gor) of profiles 13 and 15, at a simultaneous enrichment of the *cambic* horizons of these soils. Contrary to most studied elements, the content of Mn was not correlated with particle size composition, but with the iron content.

In most humus horizons of the soils, the highest contents of Pb, Zn, and to a lesser degree of Cu, were observed. This is most likely an effect of their bioaccumulation in the topsoil where soil organic matter was accumulated. Lead undergoes particularly distinct accumulation. Its largest amounts occurred in the surficial humus horizons of all studied soils, with the exception of profile 9.

DISCUSSION

The investigations have shown that the mean contents of the elements (in $\text{mg}\cdot\text{kg}^{-1}$ of soil and Fe in %) in the studied soils developed from loams can be arranged according to the following series: Fe (1.24%) > Mn (288) > Zn (24) > B (12.4) > Pb (9) > Ni (6.8) > Cu (5.3) > Co (4). Similar values of trace elements were noted in arable soils developed from boulder loams of the Middle-Polish (Riss) and Baltic (Würm) glaciations in north-eastern Poland (Gworek 1985), and in the area covered by the Middle-Polish glaciation in the Mazowsze-Podlasie Lowland (Czarnowska 1972, 1995; Czarnowska and Gworek 1987, Gworek and Jeske 1996).

It is difficult to explain the lack of significant differences between the content of trace elements in the soils developed from boulder loams of the Middle-Polish Glaciation and the content in soils developed from boulder loams of the Baltic Glaciation (Gworek 1985), despite the fact that many investigations point to a higher sand content, leaching of carbonates, acidification and lower saturation of the sorption complex by alkaline cations in the soils developed from boulder loams of the Middle-Polish Glaciation (Gworek 1984, Konecka-Betley, Czepińska-Kamińska 1979).

The results obtained in this study and in previous reports (Czarnowska 1972, 1996; Czarnowska and Gworek 1987, Gworek 1985, Gworek and Jeske 1996) indicate that the distribution of the studied trace elements and iron in the soil profiles is related to various pedogenic processes and particle-size distribution. Leaching of Cambisols and lessivage processes in Luvisols cause the release of trace

TABLE 3. Coefficients of correlation between the content of trace elements soluble in 20% HCl and selected soil properties

Variable	Fe	Mn	Zn	Cu	B	Co	Pb	Ni
<0.02	0.901**	0.248	0.775**	0.724**	0.876**	0.719**	0.152	0.771**
<0.002	0.947**	0.256	0.688**	0.733**	0.945**	0.751**	0.052	0.870**
C	-0.371	0.026	0.370*	-0.232	-0.466	-0.241	0.472**	-0.495
Fe total	–	0.422*	0.687**	0.722**	0.944**	0.864**	0.069	0.894**

*, ** – significant at the level of $p = 0.05$ and $p = 0.01$, respectively.

elements in weathering processes in the superficial horizons, and then their transportation into deeper *cambic* and *argic* enrichment horizons. Consequently, the lowest contents of trace elements, particularly of Zn, Cu and B, occur in the *luvic* horizons of Stagnic Luvisols and increased contents of iron, nickel, boron and cobalt in the *cambic* horizons of Cambisols. In turn, in the *cambic* horizons of Cambisols developed from sands (profiles 13 and 15), the accumulation of Fe and Mn is probably the result of brunification and groundwater gleying process, caused by shallow groundwater levels.

Statistical analysis has indicated that the content of most of the investigated trace elements depends on particle-size distribution, content of iron, and to a lower degree – organic carbon content. Similar relationships were obtained by other authors (Czarnowska 1972, 1996; Czarnowska and Gworek 1987; Gworek 1985; Gworek and Jeske 1996). An exception is Mn, the content of which is not related to the particle-size distribution (content of <0.02 and <0.002 mm fractions). This may be related to pseudogleying process, as a accompanying process, in all profiles of soils developed from loams and a gleying process, caused by groundwater, in soils developed from sands (profiles 13 and 15). Manganese is easily released and transported, particularly intensive in the gleying process (Chojnicki 2002). Lack of correlation between the content of Mn and the particle size in Cambisols and Luvisols with accompanying pseudogleying process developed from boulder loams of the Middle-Polish Glaciation was also indicated by Czarnowska (1972).

The content of boron, and the factors influencing its occurrence in the studied soils, both developed from loam and from sand, are similar to the results obtained for soils developed from the same rocks in Poland (Boratyński et al. 1971, Kabata-Pendias, Piotrowska 1971). Comparison of the obtained results with the guidelines for the assessment of contents of trace elements in soils, proposed by Kabata-Pendias et al. (1993), shows that the studied soils contain natural contributions of trace elements.

CONCLUSIONS

1. The mean total content of Mn, Zn, Cu, B, Co, Pb, Ni, and Fe in arable soils developed from boulder loams of the Middle-Polish (Riss) Glaciation, Wartanian Stadial, in the Skierniewicka Upland, was as follows: 288, 24, 5, 3, 12.4, 4, 9, and 6.8 mg·kg⁻¹ of soil, and 1.24%, respectively. On the other hand, these values for soils developed from fluvio-glacial sands were as follows: 235, 16, 2.9, 6.5, 2.5, 7, 3.4 mg·kg⁻¹ of soil and 0.71%, respectively.
2. Statistical analysis has shown a correlation between the total content of Zn, Cu, B, Co, and Ni, and the contribution of <0.02 mm and <0.002 mm particles and the iron content. The Fe content was correlated with the texture of soils, the Mn amount was correlated only with the iron content, whereas that of lead – with the organic carbon content.
3. The lessivage process had influence on the distribution of Zn, Cu, and B in the profiles, the brunification process – the distribution of Fe, Ni, B, and Co in the profiles, and the gleying process – the distribution of Mn. Lead and zinc underwent bioaccumulation in humus horizons of majority of the studied soils.
4. The studied arable soils contain a natural concentration of trace elements typical for non contaminated soils in Poland.

REFERENCES

- Abgottsporn F., Bigalke M., Wolfgang Wilcke W., 2014. Fast colloidal and dissolved release of trace elements in a carbonatic soil after experimental flooding. *Geoderma* 259–260: 156–163.
- Boratyński K., Roszyk E., Ziętecka M., 1971. A survey of investigations on trace elements carried out in Poland. Part I. Boron, copper and manganese. *Roczniki Gleboznawcze – Soil Science Annual* 22 (1): 205–264.
- Chojnicki J., 2002. Soil – forming processes in alluvial soils of central Vistula valley and Żuławy. *Wyd. SGGW*: 1–83.
- Czarnowska K., 1996. Total content of heavy metals in parent rocks as the reference background levels of soils. *Roczniki Gleboznawcze – Soil Science Annual* 47(Supl.): 43–50.
- Czarnowska K., Gworek B., 1987. Heavy metals in some soils of the central and northern parts of Poland. *Roczniki Gleboznawcze – Soil Science Annual* 38(3): 41–57.
- Czarnowska K., 1972. Investigations on Mn, Zn, Cu and Mo distribution in soils developed of boulder loams. *Roczniki Gleboznawcze – Soil Science Annual* 23(2): 25–30.
- Gedroń K., 1955. *Chemiczkiej analizy poczw. Moskwa*: 156 ss.
- Gworek B., Jeske K., 1996. The trace elements and iron contents in arable soils formed from glacial materials. *Roczniki Gleboznawcze – Soil Science Annual* 47(Supl.): 51–63.
- Gworek B., 1985. Trace elements (Mn, Zn, Cr, Cu, Ni, Co, Pb and Cd) in arable soils developed from boulder loam and silty formations of the northeastern region of Poland. Part II. The total content of trace elements in soils developed from boulder loams. *Roczniki Gleboznawcze – Soil Science Annual* 36(2): 43–59.
- Gworek B., 1984. Trace elements (Mn, Zn, Cr, Cu, Ni, Co, Pb and Cd) in arable soils developed from boulder loam and silty formations of the northeastern region of Poland. Part I. Physico-chemical properties of the soils investigated. *Roczniki Gleboznawcze – Soil Science Annual* 35(2): 79–100.
- IUSS Working Group WRB, 2015. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. *World Soil Resources Reports No. 106*. FAO, Rome.

- Jeske A., 2014. Use of innovative and advanced computer simulations of chemical speciation of heavy metals in soils and other environmental samples. *Soil Science Annual* 65(2): 65–71.
- Kabata-Pendias A., Motowicka-Terelak T., Piotrowska M., Terelak H., Witek T., 1993. Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. Wyd. IUNG, Puławy: 1–20.
- Kabata-Pendias A., Piotrowska M., 1971. Całkowite zawartości mikroelementów w glebach Polski. Materiały IUNG, Puławy. S8: 7–47.
- Kondracki J., 2009. Geografia regionalna Polski. Wydawnictwo Naukowe PWN.
- Konecka-Betley K., Czępińska-Kamińska D., 1979: Typology of soils developed from shallow silty formations of the Skierniewicka Upland. *Roczniki Gleboznawcze – Soil Science Annual* 30(2): 95–110.
- Konecka-Betley K., Czępińska-Kamińska D., 1985. Fossil organic sediments in Rogów forests as an index of site changes. *Roczniki Gleboznawcze – Soil Science Annual* 36(2): 131–141.
- Muñoz M., Wern H., Johnsson F., Bhattacharya P., 2013. Geogenic arsenic and other trace elements in the shallow hydrogeologic system of Southern Poopó Basin, Bolivian Altiplano. *Journal of Hazardous Materials* 262: 924–940.
- Pansu M., Gautheyrou J., 2006. Handbook of Soil Analysis. Mineralogical, Organic and Inorganic Methods. Springer-Verlag, Berlin Heidelberg, pp. 993.
- Rdzany Z., 2006. Sediments of the Warta ice-sheet deglaciation in the eastern part of the Łódź region. *Przegląd Geologiczny* 54(4): 343–351.
- Sosulski T., Szara E., Korc M., Stępień W., 2013. Leaching of macronutrients, micronutrients and aluminium from the soil under long-term fertilizer experiments in Skierniewice (Central Poland). *Soil Science Annual* 64(3): 106–113.

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Pierwiastki śladowe w uprawnych glebach brunatnych i płowych wytworzonych z gliny zwałowej i piasków fluwiogłacialnych Wysoczyzny Skierniewickiej (centralna Polska)

Streszczenie: Celem pracy było zbadanie ogólnej zawartości Fe, Mn, Zn, Cu, B, Co, Pb i Ni w uprawnych glebach brunatnych (Cambisols) i płowych (Luvisols), wytworzonych z gliny zładowacenia środkowopolskiego stadiału Warty i piasków fluwiogłacialnych na Wysoczyźnie Skierniewickiej oraz określenie zależności między wymienionymi pierwiastkami a niektórymi właściwościami gleb. Średnia ogólna zawartość Mn, Zn, Cu, B, Co, Pb, Ni i Fe w badanych glebach wytworzonych z gliny zwałowej wynosiła odpowiednio: 288, 24, 5, 3, 12,4, 4, 9, 6,8 mg·kg⁻¹ gleby oraz 1,24%. Wartości te w glebach wytworzonych z piasku fluwiogłacialnego były mniejsze i wynosiły odpowiednio: 235, 16, 2,9, 6,5, 2,5, 7, 3,4 mg·kg⁻¹ gleby oraz 0,71%. Analiza statystyczna wykazała korelację pomiędzy ogólną zawartością Zn, Cu, B, Co, Ni a ilością cząstek o średnicy <0,02 mm, <0,002 mm i zawartością żelaza. Zawartość Fe zależała od uziarnienia gleb, Mn była skorelowana tylko z ilością żelaza, natomiast ołowiu z zawartością węgla organicznego. Proces płowienia miał wpływ na profilowe rozmieszczenie: cynku, miedzi i boru, proces brunatnienia: żelaza, niklu, boru i kobaltu, proces glejowy: manganu. Ołów i cynk ulegał bioakumulacji w większości poziomów próchnicznych badanych gleb. Badane gleby uprawne wykazały naturalne zawartości pierwiastków śladowych typowe dla niezanieczyszczonych gleb Polski.

Słowa kluczowe: pierwiastki śladowe, glina zwałowa, piasek, brunatnienie, płowienie