ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 17, No. 2–3 2010

Sławomir SMÓLCZYŃSKI and Mirosław ORZECHOWSKI[1]

CONTENT OF SOME MACRO- AND MICROELEMENTS IN A SOIL TOPOSEQUENCE IN THE LANDSCAPE OF ICE-DAMMED LAKES IN SEPOPOL LOWLAND

ZAWARTOŚĆ WYBRANYCH MAKRO- I MIKROELEMENTÓW W TOPOSEKWENCJI GLEB KRAJOBRAZU RÓWNIN ZASTOISKOWYCH NIZINY SĘPOPOLSKIEJ

Abstract: The study was carried out using soil catena method in Sepopol Lowland, representing the zone of ice-dammed lakes of young glacial landscape. The sequence of soils in the catena was as follows: black earth, proper deluvial soil, humous deluvial soil, mucky soil, strongly and slightly silted peat-muck soils. Soil texture, soil reaction, total content of carbon and nitrogen as well as total amounts of Ca, Mg, K, P, Na, Fe, Mn, Zn and Cu were analysed in the mentioned soils.

The reaction of investigated soils ranged from slightly acid in deluvial soils to neutral in peat-muck soils. In the studied toposequence of soils, the amounts of total carbon and nitrogen increased towards the depression.

Variation of the amounts of analysed elements in the catena depended on the location of soil in a relief. Quantitatively, the content of elements in eroded black earths was in the following sequence: Fe > Ca > Mg > K > P > Na > Mn > Zn > Cu. Deluvial soils contained more potassium than magnesium, and peat-muck soils contained more calcium than iron.

Arable horizons of proper deluvial soils, which were located in the middle of the slope, contained the lowest amounts of macro- and microelements in relation to both deeper layers of the soil profile and parent material of eroded soils. The highest accumulation of macro- and microelements was reported in the soils located at the bottom of the slope. Humous deluvial soils were distinguished by the highest content of K and Fe, mucky soils by the highest content of Mg, Cu, Zn, Mn, and the peat-muck – Ca, P and Na. Humous deluvial soils and upper-silted organic soils are the barriers which prevent the expansion of biogens from agricultural areas to wetlands.

Keywords: landscape of ice-dammed lakes, macro- and microelements, toposeqence, black earths, deluvial soils, mucky soils, strongly and slightly silted peat-muck soils

In young glacial area of north-eastern Poland, three zones of landscape, with different morphogenesis of the land, types of soil formations and character of soil cover,

[1] Departament of Soil Science and Soil Protection, Faculty of Environmental Managemant and Agriculture, University of Warmia and Mazury in Olsztyn 10–719 Olsztyn, Poland, phone 089 523 48 46, email: slawomir.smolczynski@uwm.edu.pl

were distinguished: northern – of ice-dammed lake origin, middle – of morainic hills and southern – of outwash plains [1]. The zone of ice-dammed lake plains includes Sepopol Lowland, formed as a result of deglaciation phase of Pomeranian Vistula Glaciation, during which clay and loam of clay facies were accumulated [2, 3]. Brown soils and black earths were formed from these formations. They have high quality and are intensively used for agricultural purposes [4]. In meltwater basins, which had been supplied with waters flowing on impermeable soil formations (flowing type of hydrological supply), hydrogenic soils were formed [4]. Human activity led to the diversification of soil cover and the formation of soil toposequences comprising eroded and deluvial soils along the slope as well as upper-silted organic soils (mucky soils and peat-muck soils with various degree of silting) in land depressions. The soils in the catenas are interrelated by leaching, translocation and accumulation of soil material. These processes affect the carbon cycle and the cycles of mineral elements in young glacial landscape [5–7]. Owing to high organic matter content and location in a relief, hydrogenic soils play a significant role in the circulation of elements [8, 9].

The distribution of elements in the zone of morainic hills of Mazurian Lakeland was presented in a previous work [10]. In this zone, pro-ecological management is promoted [4].

The aim of the study was to investigate the distribution of some selected macro- and microelemnts in a catena and within the profiles of soils used as agricultural lands in the zone of ice-dammed lakes landscape of north-eastern Poland. Such studied are very important as excessive accumulation of elements may occur locally, which was noted in organic soils of midmoraine depressions in the zone of morainic hills [11–13].

Materials and methods

For the research, Reszel site with coordinates 54°03′16.4″ N, 21°04′22.0″ E was chosen. It is located in southern part of Sepopol Lowland. The transect was made from the top of the slope towards the depression and 12 soil profiles were described. The slope gradient was up to 7.1 % and the soil sequence was as follows: black earths on the top, proper deluvial soils in the middle of the slope, humous deluvial soils in lower parts and at the bottom of the slope, and mucky soils as well as slightly and strongly silted peat-muck soils in the depression.

Deluvial soils occupied the section of approximately 120 m and the thickness of deluvial deposits amounted to 118 cm. In the middle and lower parts of the slope, deluvial deposits were lying on mineral materials, whereas in the depression on organic formations. In mucky soils, under deluvial mineral-organic deposit of thickness of 27–28 cm, a 17–19 cm layer of muck occurred. Beneath, moderately decomposed reed peats underlain by the detritus-calcareous gyttja lying on clay gyttja occurred. In the studied transect, the investigated soils occupied a 35-meter section and turned into strongly silted peat-muck soils formed from reed peats underlain by clay-calcareous gyttja at a depth of 93 cm. Underneath, at a depth of 180 cm, clay gyttja occurred. Muck was strongly silted (50.2–54.0 % of ash) (Table 5) and had thickness of 32 cm. Slightly silted peat-muck soils were formed from deep (200 cm) reed peats lying on detritus-calcareous gyttja which was underlain by clay gyttja at a depth of 580 cm.

The soils samples were collected from selected genetic horizons and the following laboratory analyses were carried out: soil reaction in H_2O and KCl potentiometrically, organic carbon by Tiurin method, total nitrogen by Kjeldahl method, ash content after heating the soil at a temperature of 550 ^{o}C.

Total content of Ca, Mg, K, P, Na, Fe, Mn, Zn and Cu was analysed after mineralization of soil samples in the mixture of $HClO_4$ and HNO_3. Calcium, potassium and sodium was measured photometrically using Jenway flame photometer, phosphorous was measured calorimetrically using Specol EK 1 spectrocolorimeter and magnesium was measured using AAS 1 Zeiss Jena analyzer. Total content of Fe, Mn, Zn and Cu was measured by applying AAS techniques using 30 Zeiss Jena analyser.

Statistical analyses (mean, standard deviation, correlation coefficients) were conducted using Statistica 8.0.

Results and discussion

Black earths were formed from loam, which was lying on heavy clay (Table 1). The amounts of silt fraction in Ap horizon ranged from 46 % to 47 %, and the amounts of clay from 20 % to 25 %. The content of silt and clay in deluvial soils increased down the slope (Table 1). Shallow humous deluvial soils located in the depression contained 4–5 % more silt fraction and 8–16 % more clay than proper deluvial soils located in the middle part of the slope. Humus horizons of proper deluvial soils had loam texture whereas of humous deluvial soils at the bottom of the slope – clay loam texture.

The reaction of examined soils ranged from slightly acidic to neutral (Table 2). The lowest values of pH were noted in proper and humous deluvial soils (pH_{KCl} 5.9–6.6) and the highest in peat-muck soils (pH_{KCl} 6.8–7.1). In the studied soil toposequence, the amounts of carbon and nitrogen increased towards the centre of depression (Table 2). Humous deluvial soils contained on average 2.5-fold more carbon in relation to eroded black earths. Black earths, deluvial and mucky soils had narrow C:N ratio (9.97–11.65) (Table 2). In peat-muck soils this ratio was wider and amounted to 17.6 in slightly silted mucks.

Quantitatively, the content of studied elements in eroded black earths (Ae horizon), can be ordered as follows: Fe > Ca > Mg > K > P > Na > Mn > Zn > Cu (Table 3). In proper deluvial soils (Adw horizon) and in humous deluvial soils (Adp horizon) potassium prevailed over the magnesium, whereas in peat-muck soils (Mtsz and Mtz horizons) there was more calcium than iron.

Mean amounts of calcium were lower in proper deluvial soils (8.40 $g \cdot kg^{-1}$) and eroded black earths (11.10 $g \cdot kg^{-1}$), and increased towards the centre of depression simultaneously with organic matter content, which was proved by positive statistically significant correlation coefficients between the amount of Ca and organic matter (Table 4). Similar relationships were found by Bieniek [11] as well as by Smolczynski and Orzechowski [10] in the catenas in the zone of morainic hills of young glacial

Table 1

Particle-size analysis of soils at Reszel catena

Profile No. and location	Genetic horizon*	Depth [cm]	Percentage of mineral particles [mm]									Soil formation
			> 2.0	2.0–1.0	1.0–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.002	< 0.002	PTG 2008 [23]
Proper black earth*												
1. Top of the slope	Ap	0–25	0	0	6	9	5	14	14	32	20	loam
	Aa	25–38	0	0	3	10	6	13	15	32	21	loam
	C	38–150	0	0	0	3	5	4	2	25	61	heavy clay
Shallow proper deluvial soil												
2. Middle part of the slope	Ap	0–24	0	0	3	14	4	13	14	32	20	loam
	Aa	24-48	0	0	2	11	6	13	14	29	25	loam
	C	48–150	0	0	2	5	2	12	17	37	25	silt loam
Medium deep proper deluvial soil												
3. Middle part of the slope	Ap	0–26	0	1	6	13	6	15	13	34	12	loam
	A2	26–48	0	0	5	10	4	16	10	31	24	loam
	A3	48–85	0	0	6	13	7	11	10	26	27	loam

Table 1 contd.

Profile No. and location	Genetic horizon*	Depth [cm]	Percentage of mineral particles [mm]									Soil formation
			> 2.0	2.0–1.0	1.0–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.002	< 0.002	PTG 2008 [23]
Deep humous deluvial soil												
4. Lower part of the slope	Ap	0–25	0	0	3	9	7	11	19	27	25	loam
	A2a	25–65	0	0	4	9	7	14	14	32	20	loam
	A3a	65–100	0	0	2	8	6	13	13	27	31	clay loam
	A4a	100–118	0	0	2	6	6	12	14	29	31	clay loam
	C	118–150	0	0	3	5	7	19	25	23	18	loam
Medium deep humous deluvial soil, on peat												
5. Lower part of the slope	Ap	0–26	0	0	3	5	7	14	16	33	22	loam
	Aa	26–64	0	0	3	6	4	8	19	20	40	clay loam
Shallow humous deluvial soil, on peat												
6. Bottom of the slope	Ap	0–26	0	0	2	3	5	11	18	33	28	clay loam
	A2	26–48	0	0	2	4	6	10	16	30	32	clay loam

* – according to the Systematics of Polish soils [22].

Table 2

Soil reaction, content of carbon and nitrogen in the soils studied

Horizon	pH			Humus	N	C:N
	in H_2O	in KCl	[$g \cdot kg^{-1}$]			
Ae	7.2–7.3	6.5–6.7	20.1* 16.2–24.0**	34.65 27.9–41.4	1.72 1.69–1.75	11.65 9.6–13.7
Adw	6.7–7.4	6.0–6.6	23.03 19.8–28.4	39.65 34.1–41.5	2.30 2.04–2.74	10.15 7.2–12.9
Adp	6.8–7.1	5.9–6.6	51.42 30.8–86.2	88.65 53.1–148.6	4.67 2.75–7.65	11.15 10.1–13.5
AO	7.0–7.9	6.4–6.9	90.57 76.4–104.1	8.13 15.4–19.6	9.15 7.2–10.54	9.97 9.1–10.6
Mtsz	7.1–7.2	6.8–6.9	215.2 199.4–231.0	47.90 46.0–49.8	17.17 16.93–17.4	12.55 11.5–13.6
Mtz	7.4–7.4	7.0–7.1	263.4 261.2–265.6	51.55 51.0–52.1	14.99 14.96–15.02	17.6 17.4–17.8

Explanations: Ae – humus horizon of eroded black earths, Adw – humus horizon of proper deluvial soils; Adp – humus horizon of humous deluvial soils, AO – humus horizon of mucky soils, Mtsz – strongly silted muck, Mtz – slightly silted muck.
* – mean; ** – oscillation range.

Table 3

Mean total amounts of elements in surface horizons of the soils studied

Horizon	Feature	Ca	Mg	K	Na	P	Fe	Cu	Zn	Mn
		$[g \cdot kg^{-1}]$						$[mg \cdot kg^{-1}]$		
I Ae*	X	11.1	6.3	0.95	0.15	0.50	28.15	15.20	45.30	508.20
	S	2.19	0.00	0.07	0.07	0.14	0.78	0.85	2.55	27.44
	CV	19.73	0.0	7.37	46.67	28.00	2.77	5.59	5.63	5.40
II Adw	X	8.40	5.50	7.00	0.15	1.12	23.98	21.74	56.36	380.22
	S	3.70	1.16	1.62	0.04	0.35	3.51	6.22	15.07	151.0
	CV	44.05	21.09	23.14	26.67	31.25	14.64	28.61	26.74	39.71
III Adp	X	12.69	6.18	8.71	0.20	1.15	29.46	22.25	56.33	441.48
	S	6.51	0.67	2.72	0.02	1.01	3.02	4.30	10.34	65.56
	CV	51.30	10.84	31.23	10.00	87.82	10.25	19.33	18.36	14.85
IV AO	X	13.83	6.56	6.01	0.37	1.60	26.78	25.97	68.71	578.83
	S	2.54	0.65	1.76	0.08	0.28	1.39	3.19	7.66	86.58
	CV	18.36	9.91	29.28	21.62	17.50	5.19	12.28	11.15	14.96
V Mtsz	X	63.60	4.55	2.65	0.41	2.40	12.75	16.50	34.30	508.00
	S	34.22	0.78	2.05	0.05	0.84	1.63	2.83	9.48	39.60
	CV	53.81	17.14	77.36	12.20	35.00	12.78	17.15	27.64	7.80
VI Mtz	X	75.90	4.40	2.85	0.38	2.50	14.60	18.35	32.15	577.50
	S	39.74	0.00	2.05	0.16	0.42	1.56	3.46	0.49	10.61
	CV	52.36	0.00	71.93	42.11	16.80	10.68	18.86	1.52	1.84
Statistically significant differences $\alpha = 0.05$		IV < V	IV > V	I < II I < III III > IV	II < III III < IV	IV < V	II < III IV > V	IV > V	III < IV IV > V	III < IV

* Explanations as below Table 2, X – mean, S – standard deviation, CV – coefficient of variance.

landscape. During erosion, calcium is transformed into soluble forms and it is translocated with erosional waters. Chudecki and Niedzwiecki [14] described this process as chemical erosion. In the examined catena, the content of iron was inversely related to calcium and reached the highest amounts in humous deluvial soils and black earths, and the lowest in peat-muck soils (Table 3). The amount of this element was positively correlated with the amount of mineral fraction with diameter of 0.05–0.002 mm and < 0.002 mm (Table 4). Mean amounts of phosphorous increased from 0.50 $g \cdot kg^{-1}$ in eroded black earths to 2.50 $g \cdot kg^{-1}$ in slightly silted peat muck soils simultaneously with organic matter content (Table 3). This relationship was confirmed by the positive statistically significant value of correlation coefficient (Table 4).

Humous deluvial soils had the highest content of magnesium (Table 3). In mucky soils the content of this element was statistically significantly lower. Humus horizons (AO) of mucky soils had the highest amount of potassium. However, the differences in relation to surface horizons in humous deluvial soils (Adp), proper deluvial soils (Adw) and black earths (Ae) were insignificant. Potassium and magnesium were positively correlated with mineral fraction of diameter of 0.05–0.002 mm as well as clay fraction (< 0.002 mm) (Table 4). According to the study carried out by Chodak et al [15], magnesium is translocated with the soil particles during erosion, whereas potassium and phosphorus are translocated also in a form of solution.

The content of zinc, copper and manganese in the soils of studied catena reached the highest value in AO horizons of mucky soils (Table 3). In humous deluvial soils the contents of zinc and manganese were statistically significantly lower. The contents of copper did not show significant differences between Adw and Adp horizons of deluvial soils as well as Ae horizons of black earths (Table 3). In the light of threshold limit values [16] the contents of copper and zinc did not exceed their natural level.

The soils of the studied toposequence, in comparison with similar soil units in the catenas in the zone of morainic hills of young glacial landscape [10] had higher amounts of Ca, Mg, K and Cu. The contents of other elements in the soils of both landscape zones were similar.

Taking into consideration bulk density of studied soil formation, the contents of analysed elements were calculated in relation to the volume of dry soil and the results are presented in Table 5. Excluding calcium and phosphorous, the lowest contents of studied elements were found in peat-muck soils. The contents of Mg, K, Fe, Cu and Zn increased successively in mucky soils and humous deluvial soils, but the differences were statistically insignificant. The variations of the contents of these elements among humous deluvial soils, proper deluvial soils and black earths were small and generally insignificant.

In order to present the profile distribution of the studied elements, the ratio of the amounts of elements in surface layer (5–10 cm) to the amount at a depth of 30–40 cm was calculated. According to the data presented in Table 6, the highest values of enrichment coefficients, excluding calcium, were found in slightly and strongly silted peat-muck soils and mucky soils. It indicates considerable accumulation of the examined elements in surface horizons of the soil profiles. It may be a result of simultaneous sedimentation of deluvial deposits and macro- and microelements on soil

Table 4

Correlation coefficients between the content of organic matter, mineral particles and total amounts of elements in the soils studied

Properties	Ca	Mg	K	P	Na	Fe	Mn	Zn	Cu
	[g · kg^{-1}]						[g · kg^{-1}]		
< 0.002 m	0.567*	0.895*	0.800*	0.206	0.295	0.780*	0.613*	0.235	0.230
0.05–0.002 mm	0.469*	0.872*	0.666*	0.248	0.338	0.632*	0.839*	0.108	0.031
Organic matter	0.669*	0.260	0.230	0.588*	–0.206	0.286	–0.185	0.109	0.659*

* – significance level at $\alpha = 0.05$.

Table 5

Mean total amounts of elements in surface horizons of soils in relation to dm^3 of dry soil

Genetic horizon	Feature	Ca	Mg	K	Na	P	Fe	Cu	Zn	Mn
		$[g \cdot kg^{-1}]$						$[g \cdot kg^{-1}]$		
I Ae	X	16.39	9.32	1.41	0.22	0.74	41.65	22.46	66.94	752.21
	S	3.71	0.27	0.14	0.10	0.23	2.34	0.61	1.84	62.14
	CV	22.64	2.90	9.92	45.45	31.08	5.62	2.72	2.75	8.26
II Adw	X	9.64	6.79	8.69	0.20	1.31	30.57	25.93	66.97	523.86
	S	2.42	2.31	3.25	0.10	0.21	11.82	6.68	14.41	291.47
	CV	25.10	34.02	37.40	50.00	16.03	38.67	25.76	21.52	55.64
III Adp	X	15.77	7.76	11.06	0.25	1.35	37.08	27.50	71.15	555.23
	S	8.23	1.17	3.79	0.04	0.94	5.78	2.52	15.80	103.73
	CV	52.19	15.08	34.27	16.00	69.63	15.59	9.16	22.21	18.68
IV AO	X	10.72	5.14	4.71	0.29	1.21	20.85	19.91	52.71	450.98
	S	2.53	1.37	1.66	0.09	0.14	4.34	2.21	5.82	115.96
	CV	23.60	26.65	35.24	31.03	11.57	20.82	11.10	11.04	25.71
V Mtsz	X	33.15	2.41	1.42	0.21	1.26	6.74	8.66	18.18	267.30
	S	16.69	0.51	1.14	0.03	0.40	1.13	1.14	5.72	10.09
	CV	50.35	21.16	80.28	14.29	31.75	16.77	13.16	31.46	3.77
VI Mtz	X	38.48	2.30	1.56	0.20	1.30	7.69	9.50	16.82	301.99
	S	16.03	0.28	1.25	0.11	0.06	1.73	0.66	1.76	30.79
	CV	41.66	12.17	80.13	55.00	4.62	22.50	6.95	10.46	10.20
Statistically significant differences $\alpha = 0.05$		I > II IV<V	III > IV IV>V	I < II I < III III > IV IV>V		I < II	III > IV IV > V	I < III III > IV IV > V	III > IV IV > V	I > III

Explanations as below Table 1 and 2.

Table 6

Enrichment or impoverishment coefficients of total amounts of elements in surface horizons (5–10 cm) in relation to the layer at a depth of 30–40 cm

Soil unit*	Ca	Mg	K	Na	P	Fe	Cu	Zn	Mn
Black earths (eroded)	0.75^{-}	1.00	0.90	2.00^{+}	0.67^{--}	0.96	1.08	1.08	0.93
Proper deluvial soils	$\underline{0.82}^{-}$ 0.74–0.91	$\underline{0.83}^{-}$ 0.69–0.98	$\underline{0.81}^{-}$ 0.61–1.01	$\underline{0.92}$ 0.85–1.0	$\underline{1.17}$ 1.00–1.33	$\underline{0.87}$ 0.78–0.96	$\underline{0.89}$ 0.69–1.10	$\underline{0.94}$ 0.79–1.09	$\underline{1.07}$ 1.02–1.11
Humous deluvial soils	$\underline{1.30}^{+}$ 1.09–1.40	$\underline{1.12}$ 1.05–1.18	$\underline{1.16}$ 1.08–1.22	$\underline{1.00}$ 1.00–1.00	$\underline{1.56}^{+}$ 0.80–2.20	$\underline{0.89}$ 0.83–0.94	$\underline{0.90}$ 0.85–0.96	$\underline{0.93}$ 0.83–1.09	$\underline{1.25}^{+}$ 1.07–1.44
Mucky soils	$\underline{0.88}$ 0.51–1.07	$\underline{1.33}^{+}$ 1.04–1.66	$\underline{1.81}^{+}$ 1.10–2.44	$\underline{1.37}^{+}$ 1.00–1.96	$\underline{0.75}^{--}$ 0.45–1.00	$\underline{1.28}^{+}$ 0.92–1.75	$\underline{1.46}^{+}$ 1.09–2.15	$\underline{1.94}^{+}$ 1.36–3.10	$\underline{1.49}^{+}$ 1.31–1.67
Strongly silted peat-muck soils	1.10	3.00^{++}	4.10^{++}	1.47^{+}	2.25^{++}	4.66^{++}	6.04^{+++}	7.19^{+++}	3.47^{++}
Slightly silted peat-muck soils	0.71^{-}	2.32^{+}	4.30^{++}	1.53^{+}	1.38^{+}	4.59^{++}	4.18^{++}	3.61^{++}	2.45^{++}

Explanations: 1.20–2.00 – evident enrichment (+); 2.01–5.00 – strong enrichment (++); > 5.00 very strong enrichment (+++); 0.85–0.71 – evident impoverishment (–); 0.70–0.51 – strong impoverishment (– –); < 0.50 very strong impoverishment (– – –).

* – according to the Systematics of Polish soils [22].

Table 7

Enrichment or impoverishment coefficients of total amounts of elements in surface Ap horizons (5–10 cm) in relation to the parent material of eroded black earth

Profile No.	Soil unit*	Ca	Mg	K	Na	P	Fe	Cu	Zn	Mn
1	Black earths (eroded)	0.44^{---}	0.39^{---}	0.08^{---}	1.00	0.67^{--}	0.66^{--}	0.70^{--}	0.62^{--}	0.99
2	Proper deluvial soils	0.34^{---}	0.35^{---}	0.72^{-}	1.00	1.50^{+}	0.62^{--}	0.94	0.66^{--}	1.12
3	Proper deluvial soils	0.23^{---}	0.23^{---}	0.41^{---}	0.55^{--}	2.00^{+}	0.43^{---}	0.66^{--}	0.61^{--}	0.70^{--}
4	Humous deluvial soils	0.22^{---}	0.37^{---}	0.62^{--}	1.05	1.33^{+}	0.63^{--}	0.85^{-}	0.69^{--}	0.96
5	Humous deluvial soils	0.95	0.42^{---}	1.04	1.00	1.67^{+}	0.68^{--}	0.88	0.77^{-}	1.12
6	Humous deluvial soils	0.99	0.44^{---}	1.06	1.00	1.83^{+}	0.69^{--}	0.90	0.79^{-}	1.03

Explanations: 1.20–2.00 – evident enrichment (+); 2.01–5.00 – strong enrichment (++); > 5.00 very strong enrichment (+++); 0.85–0.71 – evident impoverishment (–); 0.70–0.51 – strong impoverishment (– –); < 0.50 very strong impoverishment (– – –).
* – according to the Systematics of Polish soils [22].

surface. Bieniek and Piascik [17] stressed, that the chemical composition of organic soils in land depressions depends largely on the geomorphological form of the surrounding area. Moreover, fluctuations of groundwater level as well as oxidation and reduction processes play important roles in these soils. Iron, manganese and phosphorous in hydrogenic soils is precipitated from rising groundwaters in the aeration zone of the soil profile [18]. When the soil moisture content is high, increased solubility of some elements, for example manganese, may take place [19]. The lowest values (less than unity) of calculated coefficients for Mg, K, Na, Fe, Cu and Zn were noted in proper deluvial soils, and for P and Mn in black earths (Table 6). Impoverishment of arable horizons of these soils, due to its location on the slope, is a result of both surface flowing processes and migration of colloidal clay together with macro- and microelements deeper into the soil profile. Bieniek [11] stressed, that the eluviation of clay fraction contributes to loosening of humus horizons of deluvial soils, which facilitates infiltration of rainwaters.

During translocation and accumulation deluvial deposits are re-sorted and the granular size of deluvial soils is the derivative of the texture of eroded soils. Therefore the content of studied elements in humus horizons (5–10 cm) were also related to the amounts in the parent material of eroded black earths (Table 7). The highest values of these coefficients were found in humous deluvial soils. However, only for Ca, K, P, Mn and Na these values were approximate or higher than unity. In relation to parent material of eroded soils, proper deluvial soils (profile 3) were most impoverished in macro- and microelements (excluding phosphorous) (Table 7). Uggla et al [20] described these soils as 'washed deluvium' and declerd they contained less nutrients than eroded soils on the top of the slope. Lower content of studied elements (excluding phosphorous) in arable horizons as compared with parent material of eroded soil indicates that agricultural activity did not contribute to excessive accumulation of elements in the environment.

The described distribution of elements in the studied catena revealed that the location of soils in a relief is an important factor which differentiates the content of macro- and microelements. Relief, next to the soil type and soil texture, considerably influences the concentration of biogens in groundwaters [21]. The research proved that humous deluvial soils and mucky soils located at the bottom of the slope and containing substantial amounts of organic matter are a place of accumulation of majority of macro- and microelements in the landscape of ice-dammed lakes. They are the first barrier protecting hydrogenic sites in land depressions against the infiltration of biogens from surrounding slopes, on which the soils in this zone of young glacial landscape are intensively used for agricultural purposes.

Conclusions

1. In the studied toposequence of black earths, proper and humous deluvial soils, mucky soils as well as strongly and slightly silted peat-muck soils, the content of examined elements depended on the location of soils in a relief.

2. Most abundant in macro- and microelements were the soils at the bottom of the slope. Humous deluvial soils had the highest contents of K and Fe, mucky soils – Mg, Cu, Zn, Mn, and peat-muck soils – Ca, P and Na.

3. Arable horizons of proper deluvial soils located on the slope were impoverished in macro- and microelements as compared with deeper horizons of the soil profile and parent material of eroded soils. Considerable enrichment of surface layers in the studied elements (excluding calcium) was noted in mucky soils and silted peat-muck soils.

4. In the zone of ice-dammed lakes of young glacial landscape, humous deluvial soils and mucky soils surrounding wetlands protect them against the infiltration of biogens from agricultural areas.

Acknowledgement

This paper was financed from the financial resources of the years 2007–2009 as a research project No. N N305 2776 33

References

[1] Gotkiewicz J. and Smołucha J.: Zesz. Probl. Post. Nauk Roln. 1996, **431**, 119–136.
[2] Piaścik H.: Zesz. Probl. Post Nauk Roln. 1996, **431**, 31–45.
[3] Roszko L.: *Recesja ostatniego lądolodu z terenu Polski*, [in:] Ostatnie zlodowacenie w Polsce. Instytut Geografii PAN. Pr. Geogr. 1968, **74**, 65–100.
[4] PiaścikH. and Gotkiewicz J.: Zesz. Probl. Post. Nauk Roln. 2001, **478**, 511–518.
[5] Gotkiewicz J., Hutorowicz H., Lossow K., Mosiej J., Pawłat H., Szymczak T. and Traczyk T.: *Czynniki kształtujące obieg wody i biogenów w krajobrazie młodoglacjalnym*, [in:] Obieg wody i bariery biogeochemiczne w krajobrazie rolniczym. UAM, Poznań 1990, 105–126.
[6] Stepa T.: Zesz. Nauk. Komitetu "Człowiek i Środowisko" 1996, **13**, 451–461.
[7] Wocławek T.:. Zesz. Nauk. ART. Olsztyn 1973, **101**, Roln. 1, 49–56.
[8] Kruk M.: Polish J. Ecol. 2000, **48,** 103–161.
[9] Sowiński P., Smólczyński S. and Orzechowski M.: Rocz. Glebozn. 2004, **55**(2), 365–372.
[10] Smólczyński S. and Orzechowski M.: J. Elementol. 2010, **15**(1), 177–188.
[11] Bieniek B.: *Właściwości i rozwój gleb deluwialnych Pojezierza Mazurskiego*. Acta Acad. Tech. Agricul. Tech. Olst. Agricultura, Suppl. 1997, B, **64**, 80–82.
[12] Smólczyński S., Sowiński P. and Orzechowski M.: Polish J. Soil Sci. 2004, **37**(2), 149–158.
[13] Terelak H., Tujak A. and Motowicka-Terelak T.: Zesz. Probl. Post. Nauk Roln. 2001, **476**, 327–334.
[14] Chudecki Z. and Niedźwiecki E.: Zesz. Probl. Post. Nauk Roln. 1983, **272**, 7–18.
[15] Chodak T., Kaszubkiewicz J. and Tasz W.: Acta Agrophys. 2005, **5**(3), 577–587.
[16] Kabata-Pendias A., Piotrowska M. and Witek T.: Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. IUNG, Puławy 1993, 5–14.
[17] Bieniek B. and Piaścik H.: J. Elementol. 2005, **10**(3), 461–468.
[18] Sapek A., Sapek B. and Gotkiewicz J.: Wiad. IMUZ 1991, **16**(3), 109–131.
[19] Diatta J.B.: *Mutual Cu, Fe and Mn solubility control under differentiated soil moisture status*. J. Elementol. 2008, **13**(4), 473–489.
[20] Uggla H., Mirowski Z., Grabarczyk S., Nożyński A., Rytlewski J. and Solarski H.: Rocz. Glebozn. 1968, **18**(2), 415–447.
[21] Szymczyk S. and Cymes I.: J. Elementol. 2005, **10**(2), 403–410.
[22] Systematyka gleb Polski: Rocz. Glebozn. 1989, **40**(3/4), 150 pp.
[23] PTG: Rocz. Glebozn. 2009, **60**(2), 5–16.

ZAWARTOŚĆ WYBRANYCH MAKRO- I MIKROELEMENTÓW W TOPOSEKWENCJI GLEB KRAJOBRAZU RÓWNIN ZASTOISKOWYCH NIZINY SĘPOPOLSKIEJ

Katedra Gleboznawstwa i Ochrony Gleb
Uniwersytet Warmińsko-Mazurski w Olsztynie

Abstrakt: Badania przeprowadzono metodą katen glebowych na Nizinie Sępopolskiej reprezentującej strefę zastoiskową krajobrazu młodoglacjalnego. Sekwencja gleb w katenie przedstawiała się następująco: czarne ziemie, gleby deluwialne właściwe, gleby deluwialne próchniczne, gleby namurszowe, gleby torfowo-murszowe silnie i słabo zamulone. W badanych glebach oznaczono: uziarnienie, odczyn pH, zawartość węgla i azotu ogólnego oraz całkowitą zawartość Ca, Mg, K, P i Na, Fe, Mn, Zn i Cu.

Odczyn badanych gleb kształtował się od lekko kwaśnego w glebach deluwialnych do obojętnego w glebach torfowo-murszowych. W analizowanej toposekwencji gleb w kierunku centrum zagłębienia zwiększała się zawartość węgla i azotu.

Zróżnicowanie zawartości oznaczonych pierwiastków w glebach badanej toposekwencji było uzależnione od ich położenia w reliefie. Szereg ilościowy oznaczonych pierwiastków w czarnych ziemiach erodowanych przedstawiał następująco: Fe > Ca > Mg > K > P > Na > Mn > Zn > Cu. W glebach deluwialnych więcej było potasu niż magnezu, a w glebach torfowo-murszowych więcej jest wapnia niż żelaza.

Poziomy uprawne, zlokalizowanych w środkowej części stoku, gleb deluwialnych właściwych wykazywały największe zubożenie makro- i mikroelementów w odniesieniu zarówno do głębszych warstw profilu, jak i do skały macierzystej gleb erodowanych. Największą kumulację makro- i mikroelementów wykazywały gleby usytuowane u podnóża stoku. Gleby deluwialne próchniczne wyróżniały się największą zawartością K i Fe, gleby namurszowe – Mg, Cu, Zn i Mn, a gleby torfowo-murszowe – Ca, P i Na. Gleby deluwialne próchniczne oraz odgórnie namulone gleby organiczne stanowią bariery, zapobiegające rozprzestrzenianiu się pierwiastków biogennych z terenów rolniczych do siedlisk mokradłowych.

Słowa kluczowe: krajobraz zastoiskowy, makro- i mikroelementy, toposekwencja gleb, czarne ziemie, gleby deluwialne, gleby namurszowe, silnie i słabo zamulone gleby torfowo-murszowe