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PROFILE DIFFERENCES OF FE, AL AND MN IN THE PEAT-MUCK SOILS IN THE UPPER LIWIEC RIVER VALLEY

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Summary. In peat-muck soils of the upper Liwiec River valley (from the locality of Sobicze 52°06'N and 22°38'E to the locality of Żytnia 52°12'N and 22°13'E), total contents of iron, aluminium and manganese showed a great spatial and profile variation. Chemical analyses revealed that mean contents of these elements can be arranged in the following decreasing series for muck layers (Mt) and peat layers (Otni): Fe > Al > Mn; for mineral subsoil (D): Al > Fe > Mn. The enrichment of muck layers of the peat-muck soils in the elements analysed resulted from organic matter becoming muck and from the precipitation of iron, aluminium and manganese compounds in the aeration zone as a result of capillary rise of soil moisture of the groundwater. Due to the agricultural character of the research area, the degree of anthropopressure should be considered low.

Key words: aluminium, iron, Liwiec River valley, manganese, peat-muck soils

INTRODUCTION

The river valley and post-melt-out hollows enhance the accumulation of soil-producing material which can be affected by the swamp soil-forming process. Hydrogenic soils of the Liwiec River valley are mainly represented by post-swamp peat-muck soils [Dembek et al. 2000]. The river is a left tributary of the lower Bug River and one of the bigger rivers of the Southern Podlasie Lowland. The physiographic and hydrologic area variation, different methods of use and land reclamation treatments result in a high soil variation in the Liwiec River valley. The environmental changes, especially a decreased ground water level, intensify the mineralization rate of the organic soil substance and qualitative and quantitative changes of organic and mineral compounds in the organic soils profile [Piaścik and Bieniek 2001, Piaścik and Gotkiewicz 2004, Mocek et al. 2007].

Changes in the content of elements in respective peat-muck soil layers can provide information on the progress of the processes of peat-forming and transforming-into-

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muck as a result of dynamically changing water relations and oxidation-reduction conditions as well as different forms of economic activity in the river valley.

The aim of the present paper was to investigate the profile variation of the content of iron, aluminium and manganese in peat-muck soils (12 profiles), located on permanent grasslands of the first flood terrace of the upper Liwiec River and to evaluate the effect of pedogenic processes and the degree of anthropopressure on the content and distribution of these elements in the soil profile.

MATERIAL AND METHODS

Over 2006-2007 twelve soil pits were made on permanent grasslands of the first flood terrace of the Liwiec River, found within the following localities: Sobicze, Klimy, Kośmidry, Izdebki-Kosny, Szydłówka, Radzików Wielki, Pruszyn, Golice Kolonia, Strzała and Żytnia, in the eastern part of the Mazowsze Province. Based on the total thickness of organic layers, the soils researched have been considered organic shallow and mid deep soils. The mineral subsoil of organic formations was made up of sandy water accumulation formations.

In the organic soil material sampled basic physicochemical properties were determined [Sapek and Sapek 1997]: ash content, pH in 1 mol $KCl \cdot dm^{-3}$, exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) in 1M CH_3COONH_4, total exchangeable acidity (Hwc) in $BaCl_2$–TEA and the following were calculated: the sum of base exchangeable cations (BEC), cation exchange capacity of soil (CEC) and the index of soil saturation with base cations (V). The content of carbonates was determined with the Scheibler method. Based on the content of carbonates, the amount of carbon of mineral compounds (C_{min}) was calculated. The total content of carbon (C_t) and nitrogen (N_t) was determined with the use of autoanalyzer using the thermal conductivity detector (TCD). Carbon of organic compounds (C_{org}) was calculated as follows: $C_{org} = C_t - C_{min}$. The total content of Fe_t, Al_t and Mn_t was defined using the ICP–AES method, following the 'dry' sample mineralization (at the temperature of 450°C) and following the preparation of elements extracts in 20% HCl. Similarly, basic properties of underlying mineral materials of the organic soils researched were analysed with the use of methods commonly applied in soil science laboratories for mineral soils.

The analyses were made in three reps and the results were calculated in relation to the absolutely dry soil matter. As for the content of iron, aluminium and manganese, the following were calculated: mean values, standard deviations, coefficients of variation and coefficients of enrichment of muck layers in relation to peat layers (as an organic parent formation).

RESULTS AND DISCUSSION

In the peat-muck soils investigated there was observed a variation in the selected physicochemical and chemical properties (Table 1), which suggests their considerable profile and spatial variation. In the muck layers (Mt), in relation to parent peak formations (Otni), the ash content increased, content of organic matter and the value of cation exchange capacity decreased and the C : N ratio narrowed. These changes are typical for peak-muck soils [Okołowicz and Sowa 1997, Okołowicz 1999, Piaścik and Gotkiewicz 2004, Kalembasa et al. 2006].

Table 1. Some properties of the peat-muck soils investigated
Tabela 1. Wybrane właściwości badanych gleb torfowo-murszowych

Parameter Parametr	Layer – Warstwa					
	Mt		Otni		D	
	Mean Średnia	Range Zakres	Mean Średnia	Range Zakres	Mean Średnia	Range Zakres
Ash – Popielność, $g \cdot kg^{-1}$	372	202-632	299	73.4-701	964	856-996
C_{org}, $g \cdot kg^{-1}$	302	163-414	376	170-562	17.6	0.8-80.5
$C_{org} : N_t$	11.0	7.21-12.8	14.5	8.48-19.8	10.2	6.43-17.2
$CaCO_3$, $g \cdot kg^{-1}$	20.6	3.10-127	15.1	3.40-123	9.68	0.60-43.5
pH_{KCl}	–	4.74-7.05	–	4.81-7.20	–	5.46-7.95
CEC, mmol(+)$\cdot kg^{-1}$	1207	715-1934	1305	418-1889	210	65.0-412
V, %	76.0	58.0-92.0	74.0	54.0-93.0	90.0	69.0-99.0

Mt – muck layer – warstwa murszu
Otni – peat layer – warstwa torfu
D – mineral subsoil – podłoże mineralne
CEC – cation exchange capacity – kationowa pojemność sorpcyjna
V – the index of soil saturation with base cations – stopień wysycenia kationami zasadowymi

In the layers of muck (Mt), peat (Otni) and mineral subsoil (D) of the soils researched, there was observed a varied total content of iron, aluminium and manganese (Table 2), which is seen from high values of the coefficient of variation. Mean contents of these elements ($mg \cdot kg^{-1}$) can be arranged in the following series of decreasing values for muck layers: (Mt): Fe (24300) > Al (3380) > Mn (547); peat (Otni): Fe (13400) > Al (2710) > Mn (182); for mineral subsoil (D): Al (1500) > Fe (1330) > Mn (30.7). The differences in the content of respective elements, between the separated horizons in the profiles of the peat-muck soils researched, are a result of a different origin and degree of intensity of pedogenic processes (peat-forming process, transformation into muck and into mud) as well as a varied water accumulation, water relations and the kind of subsoil [Piaścik and Gotkiewicz 2004, Smólczyński et al. 2006, Mocek et al. 2007].

The layers of muck (Mt) in relation to the layer of underlying parent peat (Otni) contained more iron (2-times), aluminium (1.2-times) and manganese (3-times). The coefficients of enrichment for these elements varied: 1.88 for Fe, 1.25 for Al and 3.01 for Mn. In mineral subsoil (D) there were observed considerably lower amounts of the metals analyzed than in the higher-located organic horizons, which is due to a low richness of sandy mineral material. Similar relations in the profile distribution of the elements researched are reported in literature [Okołowicz and Sowa 1997, Kalembasa et al. 2001, Turbiak and Matkowski 2004, Kalembasa et al. 2006, Mocek et al. 2007]. Piaścik and Bieniek [2001] observed 1.5-3-fold more iron in muck layers than in the peats they originated from.

The accumulation of elements in roof muck layers suggests quantitative and qualitative transformations of the soil matter as affected by the process of organic matter getting transformed into muck and is a result of agricultural use of peat-muck soils being the main factor of their anthropopressure [Piaścik and Bieniek 2001, Turbiak and Matkowski 2004]. The reason for enrichment of surface hydrogenic soil layers in the elements analyzed can be their precipitation in the aeration zone or on the border of changes in the oxidation-reduction potential, which in the soils of intensive capillary water rise of soil moisture was reported by other authors [Okołowicz 1999, Piaścik and Bieniek 2001, Kalembasa et al. 2001, Smólczyński et al. 2006]. The content of aluminium and manganese and their distribution in organic soils depend on the degree of the layer developed from peat getting transformed into mud [Smólczyński et al. 2006, Mocek et al. 2007].

Table 2. Content of iron, aluminum and manganese in the peat-muck soils investigated, $mg \cdot kg^{-1}$
Tabela 2. Zawartość żelaza, glinu i manganu w badanych glebach torfowo-murszowych, $mg \cdot kg^{-1}$

Layer Warstwa	Parameter Parametr	Element – Pierwiastek		
		Fe	Al	Mn
Muck – Mursz (Mt)	Mean – Średnia	25200	3380	547
	Min.	7970	610	120
	Max – Maks.	61300	8240	1380
	SD	15.6	2.30	481
	CV, %	61.9	68.0	88.0
	WW	1.88	1.25	3.01
Peat – Torf (Otni)	Mean – Średnia	13400	2710	182
	Min.	3640	360	83.2
	Max – Maks.	41600	8990	730
	SD	11.9	2.42	136
	CV, %	88.5	89.5	74.9
Mineral subsoil Podłoże mineralne (D)	Mean – Średnia	1330	1500	30.7
	Min.	550	170	7.37
	Max – Maks.	2100	3850	44.2
	SD	0.98	1.03	22.1
	CV, %	73.8	68.4	71.8

SD – standard deviation – odchylenie standardowe
CV – coefficient of variation – współczynnik zmienności
WW – coefficient of enrichment in relation to the peat layer – wskaźnik wzbogacenia w stosunku do warstwy torfu

As compared with earlier reports [Kalembasa et al. 2006], there was observed a slight increase in the content of iron and aluminium in organic horizons, which could have been due to a greater intensification of organic substance mineralization (as a result of a human economic activity), intensification of oxidation processes and quite low requirements for these elements in plants [Mocek et al. 2007]. A higher content of manganese in Mt horizons can be due to an intensified biological accumulation of this element [Okołowicz and Sowa 1997].

In the soils researched, irrespective of the morphologically diversified genetic layer, there were identified highly significant and significant relationships between the content of iron, aluminium and manganese (Table 3). In muck horizons (Mt), as compared with the peat horizons (Otni), there were found stronger correlations between the content of Fe, Al and Mn and ash content (respectively, $r = 0.45 - 0.52$ and $r = 0.30 - 0.38$). In organic horizons (Mt and Otni) there was recorded a highly significant effect of iron compounds on the value of cation exchange capacity (CEC). No impact of pH and the content of C org was found on the accumulation of the metals analysed. In the mineral subsoil (D) of the soils researched there were identified no significant relationships between the content of Fe, Al, Mn and selected properties of the soils. Similar relations between the metals, ash content and the content of carbon of organic compounds were reported by Okołowicz and Sowa [1997] and Mocek et al. [2007].

Table 3. Coefficient values of the correlation between the total content of iron, aluminum, manganese and some properties of the soils investigated
Tabela 3. Wartości współczynnika korelacji między zawartością żelaza, glinu, manganu i wybranymi właściwościami badanych gleb

	Fe	Al	Mn	Ash – Popielność	pH	C_{org}	CEC
Mt – muck layer – warstwa murszu							
Fe	x	0.68**	0.51*	0.52*	-0.15	-0.10	0.64**
Al		x	0.44*	0.47*	-0.04	0.10	0.06
Mn			x	0.45*	-0.42	0.23	0.23
Otni – peat layer – warstwa torfu							
Fe	x	0.39**	0.40**	0.38*	-0.15	0.25	0.58**
Al		x	0.50**	0.33*	-0.14	0.22	0.24
Mn			x	0.30*	-0.29	-0.08	0.06
D – mineral subsoil – podłoże mineralne							
Fe	x	0.96**	0.43*	-0.07	-0.28	-0.16	-0.09
Al		x	0.44*	-0.13	-0.23	-0.09	-0.05
Mn			x	0.13	-0.08	-0.17	0.17

significant at: *α = 0,05 and **α = 0,01 – istotne przy *α = 0,05 i **α = 0,01
CEC – cation exchange capacity – kationowa pojemność sorpcyjna

CONCLUSIONS

1. In the peat-muck soils of the upper Liwiec River valley, the total content of iron, aluminium and manganese demonstrated a high spatial and profile variation. Mean contents of these elements can be arranged in the following series of decreasing values for muck horizons (Mt) and peat (Otni): Fe > Al > Mn; for mineral subsoil (D): Al > Fe > Mn.

2. The enrichment of muck layers of the peat-muck soils of the elements analyzed was a result of the process of organic matter getting transformed into muck and precipitation of the compounds of iron, aluminium and manganese in the aeration zone, due to the capillary rise of soil moisture of the groundwater. Due to an agricultural character of the research area and no pollution emitters, the degree of anthropopressure must be considered inconsiderable.

3. In respective horizons of the soils researched there were observed highly significant and significant relationship between the content of iron, aluminium and manganese (in Mt, Otni, D) and a significant effect of the metals on ash (in Mt, Otni). In these soils there were found no significant effects of pH, content of carbon of organic compounds and soil exchange capacity (except for Fe in organic layers) on the accumulation of the metals analysed.

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ZMIENNOŚĆ PROFILOWA FE, AL I MN W GLEBACH TORFOWO-MURSZOWYCH DOLINY GÓRNEGO LIWCA

Abstract. W glebach torfowo-murszowych doliny górnego biegu rzeki Liwiec (od miejscowości Sobicze 52°06'N i 22°38'E do miejscowości Żytnia 52°12'N i 22°13'E) zawartość żelaza, glinu i manganu charakteryzowała się dużą zmiennością przestrzenną i profilową. Średnie zawartości tych pierwiastków można ułożyć w następujące szeregi malejących wartości dla warstw murszu (Mt) i torfu (Otni): Fe > Al > Mn; dla podłoży mineralnych (D): Al > Fe > Mn. Wzbogacenie warstw murszu badanych gleb torfowo--murszowych w analizowane pierwiastki było wynikiem procesu murszenia materii organicznej i wytrącania związków żelaza, glinu i manganu w strefie aeracji w wyniku podsiąku kapilarnego wody gruntowej. Ze względu na rolniczy charakter terenu badań stopień antropopresji należy uznać za niewielki.

Słowa kluczowe: dolina rzeki Liwiec, gleby torfowo-murszowe, glin, mangan, żelazo

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