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Physical properties of organic soil in Stołowe Mountains National Park (Poland)

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The aim of this work was to determine physical properties of organic soils developed in different sites of the mountain area of Stołowe Mountains National Park, Poland. The profiles with different botanical composition of peat were analysed and classified by types and species of peat. Peat, muck and peat-mud were identified (9 profiles) at chosen locations. Investigation showed that top plateau organic soils were developed on a sandy-loam or sand weathered sandstone base. Organic soils in valleys and slopes were developed on a loamy-silt or clay basement. Peat horizons developed according to different types of sites (mesotrophic and eutrophic, sometimes oligotrophic). Generally, these soils are ombrotrophic, i.e. fed by atmospheric water only. These soils were classified as Fibric Histosols and Terric Histosols. Organic soils within the main regions of the park were over-desiccated, with advancing muck-forming processes being noted.

Key words: Stołowe Mountains, organic soils, peat deposit, physical properties, muck process.

INTRODUCTION

The territory of Stołowe Mountains National Park (6 340 ha) is located in Southwest Poland, in the central part of the Sudety Mountains. The total area of organic soils in the Park is about 100 ha. The biggest peatland in the Park is the Great Batorowskie Peatbog (60.55 ha). Organic soils of the Stołowe Mountains National Park are found at altitudes from 500 to 900 a.s.l. (Kaszubkiewicz et al. 1996), where total annual rainfall is at least 700 mm yr^{-1}. The development of organic soils has been largely influenced by various hydrological conditions on the top plateau, at slopes, foothills and in the river valley (Woronko 1998). A muck-forming process was detected in many organic soil areas of the National Park, in particular in top plateau areas where organic soil was developed on sandy-loam weathered sandstone ground and border areas of the Great Batorowskie Peatbog. The mineral base of this soil consists of sandstone and siltstone deposits. Thickness of organic deposits varies but usually does not exceed 1.5 m, with the exception of the Great Batorowskie Peatbog where it reaches 5.0 m (Marek 1998). There have also been other cases where peaty soils were covered by sandstone related deposits several dozen centimetres thick. Many peatlands in the park area were drained for forestry before World War II. Several amelioration attempts were undertaken as early as the nineteenth century. The largest draining works at heavily submerged parts of Great Batorowskie Peatbog took place during that period (Pender 1996).

The aim of this work was to determine physical properties of organic soils developed in different sites of the mountain area of Stołowe Mountains National Park.

MATERIAL AND METHODS

Peat, muck and peat-mud soils in different locations were selected (9 profiles) for examination. Profiles 1, 2, 3, 4, 5, 6, 8 represented peat soils, profile 7 characterised peat mud soil, and profile 9, muck soil. The locations of studied profiles within the park are illustrated in Fig. 1.

Peat cores were collected from each of the study areas using a 6.0 cm diameter Instorfu peat auger (Horawski 1987). Soil horizons were determined on the basis of colour, degree of organic matter decompositon and the quality of vegetable remains. Cores were taken to a depth of 150 cm or until the underlying mineral substrate was encountered. Cores were sectioned to subsamples at intervals at major stratigrafic breaks. Depths of subsamples are shown in Fig. 2. Subsamples obtained from the soil horizons were subsequently packed into plastic bags and taken to the laboratory for testing. Determinations of ash contents and botanical compositions of peat were made using this material. Profiles with different botanical composition of peat were analysed by the microscopic method and subsequently classified according to the Polish standards (Oznaczanie gatunku ... 1977; Table 1). Peat humification was measured using the microscopic method (Lubliner-Mianowska 1951). The ash content was estimated by combusting the material in a muffle furnace at 550 °C for 4 hours. Texture of mineral horizons was studied using the Bouyoucos hydrometer method (Gee and Bouder 1986). The specific gravity (W) in organic soils was calculated using the following formula (Zawadzki 1970): $W = 0.11A + 1.451$, where W is the specific gravity, A is the ash content and constant (1.451) represents the specific gravity of humus.

Some physical properties of organic soil horizons (bulk density, shrinkage, and water characteristics of soil: pF curves, vertical permeability in saturated zone) were analysed in 100 cm^3 stainless Kopecky metal rings with diam. 53 × 50 mm. The rings were inserted into the soil using sample ring kits. These samples were taken from the same depth as the remaining samples. Samples were taken from each horizon and sampling was repeated 3 times. The averages from repeated sampling are shown in Table 2. Bulk density was measured in undisturbed samples by the volumetric method (Blake and Hortage 1986). Shrinkage volume was determined using the paraffin method. Soil water characteristics in the range of pF 0–2.9 were determined using the sandbox and sand/kaolinbox analyser (Topp and Zebchuck 1979). Vertical water permeability in the saturated zone was examined by the falling-head permeability method (Surveys and investigations 1974). The contents of macropores (∅ > 30 μm.) in the individual soil horizons were calculated on the basis of the obtained total porosity values and the field water capacity. Statistical analysis (correlation coefficient; r - value) was performed by the comparison of the averages of particular parameters.

RESULTS

Based on the cores and profiles in top plateau areas (profile 2, 4, 5) the studied soils were classified as Fibric Histosols (FAO 1997). Further geobotanical analyses of peat layers indicate a significant presence of *Sphagnum sp.* fragments (Table 1). Soils of near slope and lowland regions, represented by profiles (1, 3, 6, 7, 8, 9) were classified as Fibric Histosols and Terric Histosols (FAO 1997). Geobotanical analyses of peat from these regions showed (through preserved fragments) significant presence of *Carex sp.* and a relatively small occurrence of *Sphagnum sp.* fragments (Table 1). Sometimes burnt fragments of woody plants were found in immediate contact with mineral base. Characterisation of peat horizons and their classification according to specific contributions were determined by microscopic, examination of remnant vegetable fragments. In fully decomposed peat further determination of presence of fractions was impossible to achieve. The degree of decomposition in some of the analysed levels reached over 80% (Table 1).

In five of the analysed profiles, peat horizons were covered by a layer of spruce litter exceeding

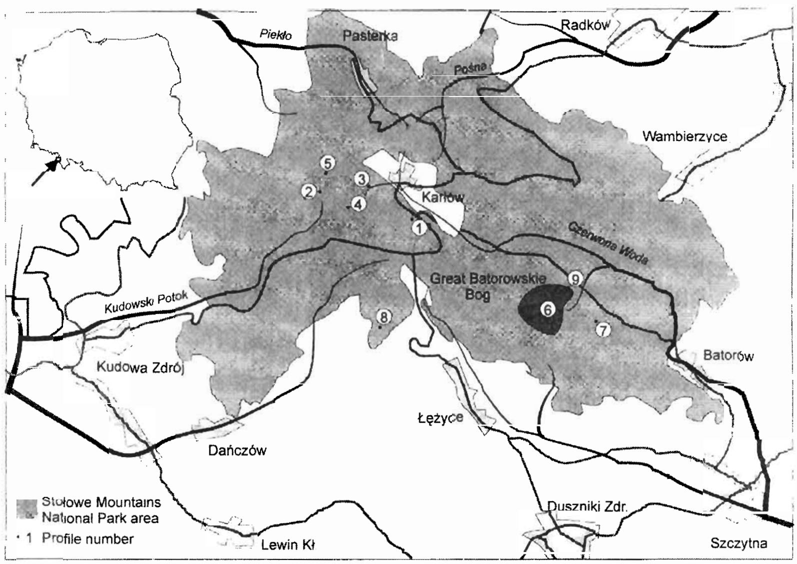

Fig. 1. Location of study areas (with soil sample profiles) in Stołowe Mountains National Park.

10 cm in thickness (Fig. 2). In these areas the process of peat accumulation was stopped.

Investigations show that organic soils in the top plateau were developed on sandy loam or sandy weathered sandstones. Organic soils in lowlands and slopes were developed on loamy silt or clay basement. Schematic representation of soil peat cores from study areas is illustrated in Fig. 2. Basic physical properties of studied soils are summarised in Table 2.

Analysis of the organic horizons showed that the specific gravity was about 1.48–2.25 g cm^{-3}, the bulk density was 0.07–0.62 g cm^{-3}, the total porosity 74.2–95.3% and the ash content 2.2–72.6% dry matter of soil. The shrinkage properties of investigated organic horizons were quite diversified and ranged from 18.0 to 89.6%. The values of vertical water permeability in saturated zone expressed by coefficient K_{10}, ranged from 1.09×10^{-4} cm s^{-1} in muck horizons to 6.64×10^{-8} cm s^{-1} in very strongly humified muddy peat horizons. The macropore ($\varnothing > 30$ µm) content was between 10.9 and 33.9%.

DISCUSSION

Peat horizons in plateau areas exhibit slight and rather slight degree of soil humification 18–65%. They have developed on oligotrophic and mesotrophic types of sites. On these sites ombrogenic type of hydrological input is the predominant mechanism of this soil evolution. In these areas an increased degree of humification is observed deep in the soil horizon. The degree of peat humification in slope and lowland areas was measured and found to be from 43% to more than 90%.

Soils on slopes that are often forming near stream areas at the base of marl formations, represented by profiles 1 and 3, show a high decomposition degree within their organic horizon, usually above 60%. Due to a high decomposition degree soligenic peat soils are prone to muck-forming processes and subsequent degradation (Dembek 1992). Soils in the Park are often shallow (profile 1). This combined with desiccation can accelerate the soil transformation processes. Such soil degradation risks have also been noted by Marcinek and Spychalski (1976) and Okruszko (1976).

Soils situated at lower altitudes (profiles 6, 7, 8, 9) are characterised by a medium decomposition degree of peat of 34–64%, which increases with depth (Table 2). These peat horizons were developed on a mesotrophic type of sites. These areas are under the influence of fluviogenic and soligenic conditions (Woronko 1998).

High values of ash contents observed in some of the surface levels of soils within the park were

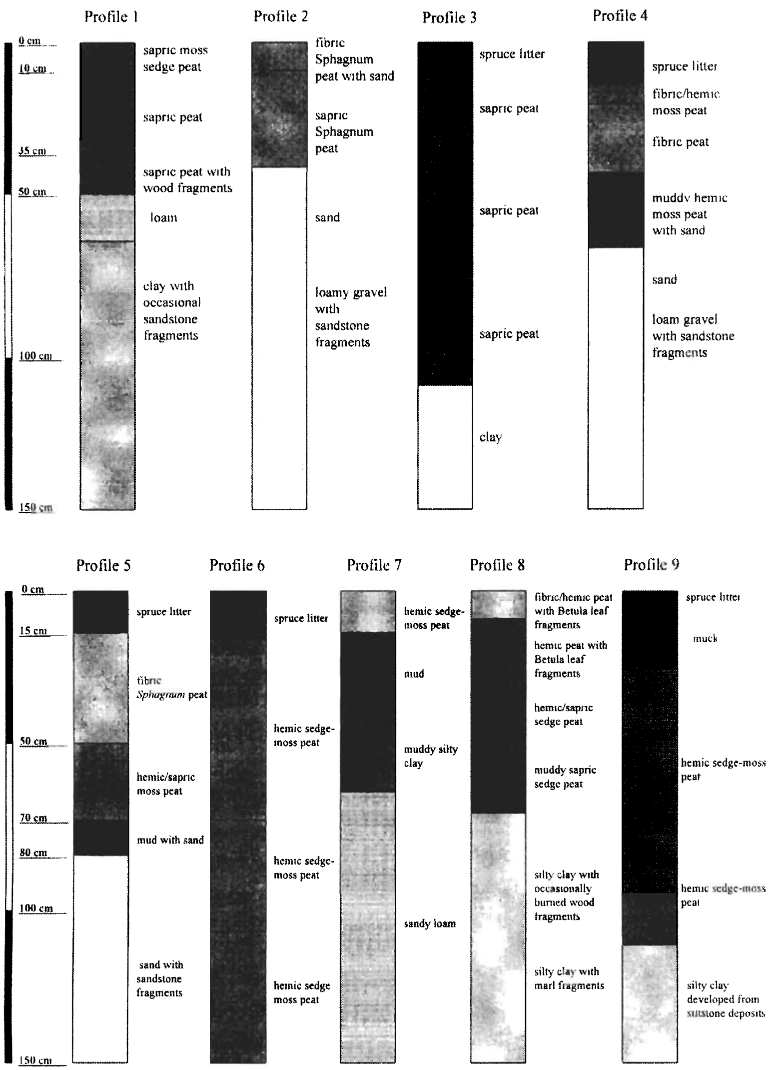

Fig. 2. Schematic representation of peat cores from study areas.

due to the fact that material consisting of weathered sandstones and siltstones was likely to move down the profiles, increasing the concentration of sand and silt in organic horizons. A similar phenomenon of residual deposits of weathering mantle settling on top of peat was reported by Klementowski (1973) in his studies of Karkonosze peatlands.

The values of bulk density of park soils, which are connected with the ash contents (Fig. 3), were higher in the surface layers, than in the lower situated layers (Table 2). This is caused by the desiccation of surface layers of soil, leading to a higher density of soil in this layers. Silins and Rothwell (1998) noted a similar phenomenon during their bulk density studies of soil surface layers in Canadian peatlands under drainage. Chason and Siegel (1998) while researching permeability reported a relationship between permeability and the degree of peat decomposition, while Mathur and Levesgue (1995) noted a negative correlation between permeability and the depth within the profile. Studies of permeability of soil organic horizons within the Park did not confirm the above noted relationship (Table 3).

Macropore contents, based on the values of total porosity and soil moisture at pF = 2.0, ranged from 10.3 to 34.9%, with the highest values found

Table 1. Geobotanical characteristic of peat soil horizons (with decomposition degree of peat) in Stolowe Mountains National Park.

Profile	Depth cm	Humification degree %	% of not humificated plants fragments									Systematic peat position	
			Wood and bark	Leafs	Heather	Sphagnum	Bryales	Sedge	Eriophorum	Other	Not identified	Type	Species
I	0–10	62	15	20P	5	+	+	15		E15	30	low	moss-sedge
	10–35	> 90	-	-	-	-	-	-	-	-	-	decomposed	-
	35–50	80	60	5P	+	+		+		E10	25	low	woody
II	0–10	27	1	18P	+	75	1	+	1		5	hight	hight moss
	10–40	65	7		+	70	+		8		15	hight	hight moss
III	10–30	78	30	30P				+	5	E5	30	low	woody
	30–80	> 90	-	-	-	-	-	-	-	-	-	decomposed	-
	80–110	88	45	20P						E5	30	low	woody
IV	15–23	28	5			30	55	2			8	mediate	mediate moss
	23–42	17	+	1P		98	+				1	mediate	mediate moss
	42–64	48	8	7P	+	50	30	+			5	mediate	mediate moss
V	15–50	18				85		+			15	mediate	mediate moss
	50–70	60				20	12	10			58	mediate	mediate moss
VI	18–70	52	12	15P	+	+	5	15	5		48	mediate	birch
	70–110	47	2	5P		10	8	15	+		30	mediate	birch
	110–150	43	4	1P		+	5	20			65	low	sedge moss
VII	0–15	46		1B		+	7			Cal.80	12	low	sedge moss
VIII	0–10	34	+	40B	+	30	3	15			12	mediate	birch
	10–35	52	2	5B	10	25	+	10		J15	34	mediate	birch
	35–50	57		2P	1			90			9	low	moss sedge
	50–70	64	1		+	+		90			9	low	moss sedge
IX	15–23	39			5	75		10			10	mediate	mediate moss
	23–80	46	3		+	2	1	10			84	low	moss sedge
	80–100	50	2				5	15			78	low	moss sedge

Shortened species names: *P-Picea sp.*, *E-Equisetum sp.*, *Cal. Calamagrostis sp.*, *B-Betula sp.*, *J-Juncus filifornis.*
Empty cells indicate value zero and "-" indicates "not measured".

Table 2. Physical properties of organic soils in Stolowe Mountains National Park.

Profile number	Genetic horizon	Depth horizons *cm*	Shrinkage % *v/v*	Ash content % d.m.	Specific Gravity g cm^{-3}	Bulk density g cm^{-3}	Total porosity %	pF data in % 1.5	2.0	2.7	Macropores ∅ > 30µm. % *v/v*	Vertical permeability cm s^{-1}
I	Otni 2	10–35	65.0	31.25	1.79	0.24	86.6	80.9	70.6	58.6	16.0	$5.61 \times 10^{-7} - 9.81 \times 10^{-8}$
	Otni3	35–50	49.1	60.52	2.12	0.41	80.6	74.8	68.8	57.9	11.8	$1.07 \times 10^{-7} - 6.64 \times 10^{-8}$
II	Otwy1	0–10	32.3	53.33	2.04	0.17	91.7	76.4	63.6	51.3	28.1	$4.25 \times 10^{-7} - 8.32 \times 10^{-7}$
	Otwy 2	10–40	49.9	29.67	1.78	0.22	87.6	79.3	69.3	55.9	18.3	$1.77 \times 10^{-7} - 6.64 \times 10^{-7}$
III	Otni 1	0–10	59.0	22.04	1.69	0.23	86.4	80.7	73.1	62.0	13.3	$1.30 \times 10^{-7} - 2.15 \times 10^{-7}$
	Otni2	10–30	70.5	25.09	1.73	0.25	85.5	80.2	74.6	63.7	10.9	$3.43 \times 10^{-7} - 6.59 \times 10^{-7}$
IV	Olfh	0–15	47.8	17.82	1.65	0.19	88.5	75.5	65.4	53.9	23.1	$1.71 \times 10^{-6} - 1.83 \times 10^{-6}$
	Otpr 1	15–23	46.0	8.91	1.55	0.16	89.7	84.3	72.1	63.2	17.6	$3.14 \times 10^{-6} - 6.68 \times 10^{-6}$
	Otpr 2	23–42	18.0	4.58	1.50	0.07	95.5	88.6	62.4	50.7	33.1	$1.43 \times 10^{-5} - 1.76 \times 10^{-5}$
	Om	42–64	19.6	80.32	2.33	0.60	74.2	66.7	59.6	49.8	14.6	$1.56 \times 10^{-5} - 8.43 \times 10^{-5}$
V	Olfh	0–15	58.0	25.37	1.73	0.18	89.6	73.5	64.9	54.9	24.7	–
	Otpr 1	15–50	76.7	4.42	1.50	0.12	92.0	88.1	74.6	63.4	17.4	–
	Otpr 2	50–70	72.1	46.68	1.96	0.18	90.8	83.4	70.2	58.8	20.6	–
	Om/D	70–90	46.4	84.72	2.38	0.45	81.1	73.9	60.9	46.3	20.2	–
VI	Olfh	0–18	43.0	7.68	1.54	0.18	88.2	72.5	59.0	51.1	29.2	$4.53 \times 10^{-5} - 4.78 \times 10^{-5}$
	Otpr 1	18–70	66.3	4.19	1.50	0.09	94.0	78.9	59.1	50.1	34,9	$3.59 \times 10^{-5} - 9.52 \times 10^{-6}$
	Otpr 2	70–110	69.4	3.88	1.49	0.10	93.3	81.5	63.1	55.6	30.2	$1.37 \times 10^{-5} - 4.69 \times 10^{-6}$
	Otni	110–150	73.1	4.09	1.50	0.11	92.7	85.4	68.1	62.0	24.6	$1.26 \times 10^{-6} - 9.99 \times 10^{-6}$
VII	Om	15–30	64.7	72.60	2.25	0.37	83.6	74.5	65.1	56.9	18.5	$2.19 \times 10^{-7} - 6.69 \times 10^{-7}$
VIII	Otpr 1	0–10	55.7	14.13	1.61	0.43	84.5	78.4	63.2	51.5	21.3	$1.09 \times 10^{-4} - 2.63 \times 10^{-4}$
	Otpr 2	10–35	70.5	20.54	1.68	0.13	91.9	78.9	68.7	62.0	23.2	–
	Otni 1	35–50	74.8	47.77	1.98	0.40	76.2	76.6	65.6	55.5	10.6	$1.20 \times 10^{-4} - 4.72 \times 10^{-5}$
	Otni 2	50–70	63.5	71.09	2.23	0.24	87.9	78.2	62.7	51.3	25.2	$5.12 \times 10^{-5} - 5.65 \times 10^{-5}$
IX	Mtpr	5–15	64.7	9.80	1.56	0.20	87.2	68.1	59.3	48.7	27.9	–
	Mtni	15–23	68.1	2.21	1.48	0.16	89.1	83.1	72.7	60.5	16.4	$1.69 \times 10^{-4} - 9.51 \times 10^{-4}$
	Otni 1	23–80	86.9	2.43	1.48	0.09	93.9	85.4	71.9	71.9	22.0	$6.21 \times 10^{-4} - 1.53 \times 10^{-5}$
	Otni 2m	80–100	53.0	71.28	2.24	0.33	85.3	76.4	69.8	62.3	15.5	$3.08 \times 10^{-4} - 1.42 \times 10^{-5}$

"–" indicates "not measured"

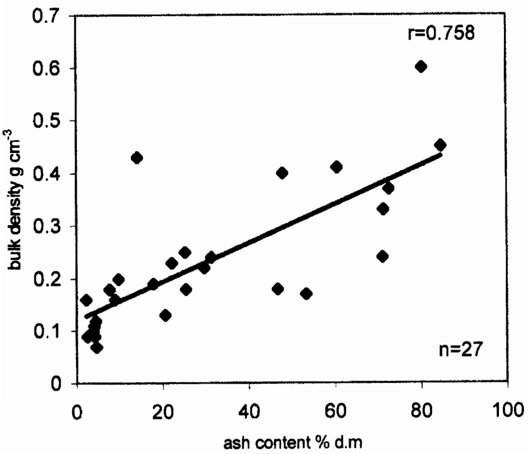

Fig. 3. The relationship between bulk density and ash content in soil samples.

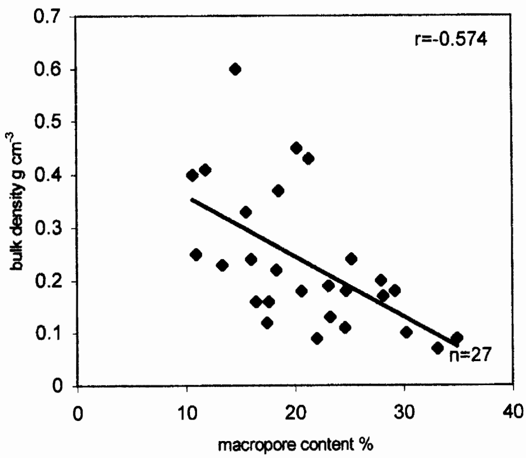

Fig. 4. The relationship between macropore content and field water capacity in soil samples.

in Otpr1 horizon of semi-decomposed peat – profile 4 (Table 2). The macropore contents exceeded 20% in most horizons and were generally lower in surface levels. Silins and Rothwell (1998) observed a decrease in contents of ∅> 600 μm pores in surface levels of forest peatlands under drainage in Alberta province.

Significant correlations were found between the bulk density and ash content (r = 0.758 n = 27 p > 0.05), between bulk density and macropore content (r = –0.574 n = 27 p > 0.05) and the dependence between macropore content (∅> 30μm) and field water capacity (r = –0.627 n = 27 p > 0.05). The correlation among studied physical parameters is presented in Table 3. The selected significant correlations are summarised in Figs. 3 and 4.

Water retention properties of soil were well characterised by water desorption curves (pF 0–2.9). Selected pF curves, for organic and mineral levels respectively, within two profiles are illustrated in Figs. 5 and 6. Presented curves exhibit variations with respect to the kind of deposit (i.e. litter, peat, and muck). In the case of peat deposits they also reveal a dependence upon the degree of decomposition and scale of muck modification.

CONCLUSIONS

Organic soils occupying mostly mesotrophic and eutrophic types of sites and less frequently ombrotrophic sites have developed within Stołowe Mountain National Park. The large variety of organic soil trophism in the Park results from their placement on the base sandstones and marlstones. These soils were classified as Fibric Histosols and Terric Histosols. Peat present in the studied profiles was classified as fibric, hemic and sapric based on the degree of decomposition. Presented organic levels exhibited diverse degrees of thick-

Table 3. Correlation matrix (r-values) among soil properties.

	Humification degree	Ash content	Shrinkage	Field water capacity	Macroporus ∅> 30 μm	Water permeability
Ash content	0.223					
Shrinkage	0.311	-0.303				
Field water capacity	-0.578	0.200	0.459			
Macroporus ∅> 30 μm	-0.639	-0.391	-0.161	-0.627		
Water permeability	-0.198	-0.145	0.241	0.223	-0.105	
Bulk density	0.248	0.758	-0.323	-0.231	-0.574	-0.045

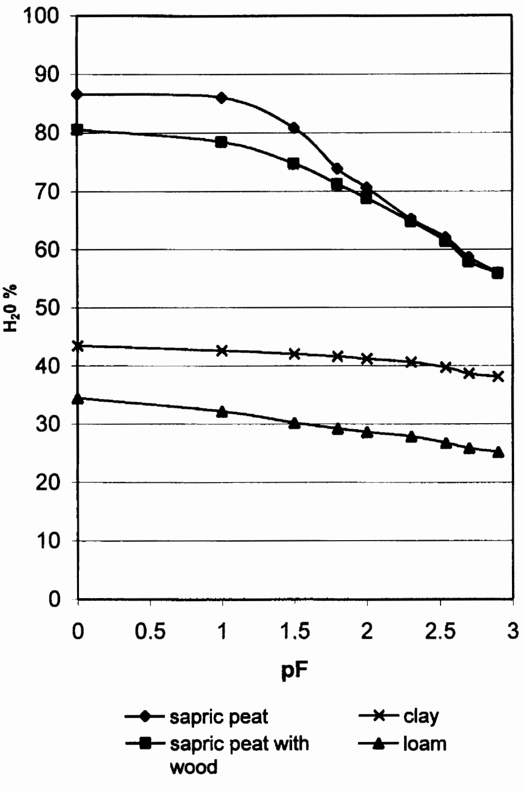

Fig. 5. Water desorption curves in soil horizons (profile 1).

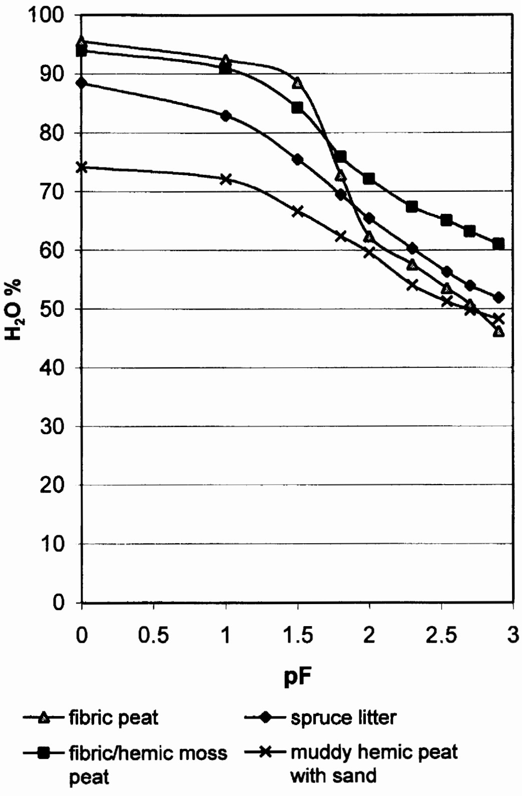

Fig. 6. Water desorption curves in soil horizons (profile 4).

ness and ash content. The significant degree of peat decomposition over 80%, found mostly in slopes and lowlands, did not allow the meaningful recognition of remnant fragments in the peat. The muck process observed in mine regions of the park indicates the necessity for introducing methods to reduce the fast flow of waters especially in the top plateau regions. These efforts would contribute to the restoration of damaged wetland ecosystems, as well as the preservation of existing ones.

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