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Content of chemical elements in soils and grassland vegetation in southern part of Gryfiński Polder within Lower Odra Valley Landscape Park

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The Międzyodrze area in the Lower Odra Valley is filled with one of the larger peat deposits in Poland; its fragments occur even in the Szczecin agglomeration.

This vast and hardly accessible landscape of swamps and marshy meadows as well as the rich diversity of flora and fauna species contributed to the establishment of Polish–German Landscape Park on the area of 60.09 km^2 in 1993. The Gryfiński Polder is situated in the centre of the Park.

The studies were conducted within the Gryfino-Mesherin transect on six study areas drilled to determine the thickness of peat deposit. The bulk soil samples (in two replications) from the depth of 0–10 cm and 10–30 cm and the samples of grassland vegetation were also taken.

It has been found that the surface layer of peat (0–30 cm) is developed from muck with mud admixture and contains a varying amount of organic matter (15.1 to 82.0%). Its reaction is mostly strongly acid (pH 4.07–4.78), and the C : N ratio is 11.2–13.8 : 1.

The content of elements soluble in $HNO_3 + HClO_4$ in the 0–30 cm layer was on average (g kg^{-1}): K – 3.66; P – 0.78; Mg – 4.0; Ca – 16.8; Na – 0.9.

The average content of heavy metals (mg kg^{-1}) was on, as follows: Cd – 3.1, Pb – 60.8, Zn – 184.9, Cu – 37.6, Ni – 38.3, Mn – 225.1, Co – 8.1. Within the area under study, the following grass communities were found: *Carex acuta* with *Calamagrostis canescens, Calamagrostis canescens* with *Carex acuta* and *Glyceria maxima*. *Glyceria maxima* contained the greatest amount of macroelements, whereas *Carex acuta* had the highest level of Cd, Zn, Ni and Mn.

Key words: organic soils, grassland vegetation, chemical element content

INTRODUCTION

The Odra in its lower course, in Widuchowa (on 704.1 km), branches into the Western and the Eastern Odra, forming a vast area called Międzyodrze, filled with one of the largest peat deposits in Poland, extending as far as the Szczecin agglomeration.

Due to the abundance of numerous passable or impassable forks and waterway connections exceeding the area of 600 ha, and frequent floodings Międzyodrze is barely accessible. Backwater from the Szczecin Lagoon and Lake Dąbie caused by storm northerly winds, contributes to flooding. As a result, the majority of the Międzyodrze landscape, including the Gryfiński Polder, is dominated by rushes, sedges, swampy meadows and riparian forests, and gained the reputation of "the most natural" area of Central Europe. This area is clearly distinguishable by the richness of flora and fauna species, typical of a water-mud habitat, with many plant and animal species under protection or in danger of extinction.

In the past, however, the current natural environment of Międzyodrze was exposed to anthropopression connected with control work in the Lower Odra valley, in the years 1904–1932 (Dreyer, 1914). The construction of the Widuchowa–Gryfino canal led to the formation of the second river bed, called the Eastern Odra – Regalica. Apart from improving the Odra outflow, the works aimed at the utilisation of Międzyodrze soils for agricultural purposes. Due to war operations of 1945, the control project had never been completed. Thus, the area of Międzyodrze, with the exception of Pucka island within Szczecin, has not been used for agriculture because of its marshy character and limited accessibility.

The above-mentioned features contributed to the establishment of the Polish–German Landscape Park on 60.09 km^2 of this area in 1993. The Gryfiński Polder is located in its central part. The Widuchowski Polder lies on its southern side and the Szczecin Polder on the northern side.

According to the present Classification of Polish Soils (1989), the prevailing soils of Międzyodrze are organic, mostly bog, soils belonging to the subtype of peat-mud soils with a varying degree of silting decreasing northward, and post-bog soils with a clearly noticeable muck formation process classified as muck soils.

The soil, environment and contamination of the Widuchowski Polder have been thoroughly studied and recognised (Krzywonos, Durkowski, 1983; Niedźwiecki et al., 2002a, 2002b, 2004).

In 2005, detailed studies were undertaken on the southern part of the Gryfiński Polder (Niedźwiecki et al., 2006). This paper is a continuation of those studies.

The aim of this paper is to present the content of macro and microelements in the surface soil layers (0–10 and 10–30 cm) and their vegetation cover.

MATERIALS AND METHODS

The studies were conducted on six study areas within the Gryfino-Mesherin transect (Fig. 1). From these sites, composite soil samples from the depth 0–10 and 10–30 cm were taken in two replications, as well as meadow vegetation samples – at full blooming at the end of June. Each composite soil sample (3 kg fresh weight) consisted of ten individual samples. Within the investigated transect, the following grass communities were isolated: *Carex acuta* with *Calamagrostis canescens* – objects 1 and 3; *Calamagrostis canescens* with *Carex acuta* – objects 2 and 4; *Glyceria maxima* – objects 5 and 6. These associations differed in their floristic composition. At the same time, samples of *Glyceria maxima*, *Carex acuta* and *Calamagrostis canescence* were collected from the above-mentioned objects.

After grinding and drying, the sampled soil and plant material were mineralised in a mixture of concentrated HNO_3 + $HCIO_4$ acids (1 : 1), which made it possible to determine their chemical content. K, Ca, Na contents were determined by flame photometry, P – colorimetrically, C , N, S with the aid of an elementary analyser (Costech, Italy). The method of atomic absorption (FAAS) spectrometry, using a Unicam Solaar 929 spectrophotometer, was employed to study the composition of Mg, Cd, Pb, Zn, Cu, Ni, Mn, Co and Fe.

Besides, pH_{KCl} was determined potentiometrically and by losses on ignition at a temperature of 550 °C.

RESULTS AND DISCUSSION

Area observation and analytical data (Table 1) indicate that, within the examined transect, the surface soil layer 0–10 cm consisted of an organic formation developed from muck soil with a considerable admixture of silt and 44.49 to 84.97% (mean 69.53%) of organic matter. Below this layer, 10–30 cm, the content of organic matter definitely decreased and was within 15.10–38.70% (mean, 23.37%). Substantial variations in organic matter content in the surface layers were also observed in earlier studies on the Widuchowski Polder. They might have been the effects of land drainage in the years 1904–1932 and covering it with the layer of bottom sediments from dredging, which had to improve the value of new agricultural land (Niedźwiecki et al., 2002a, 2002b).

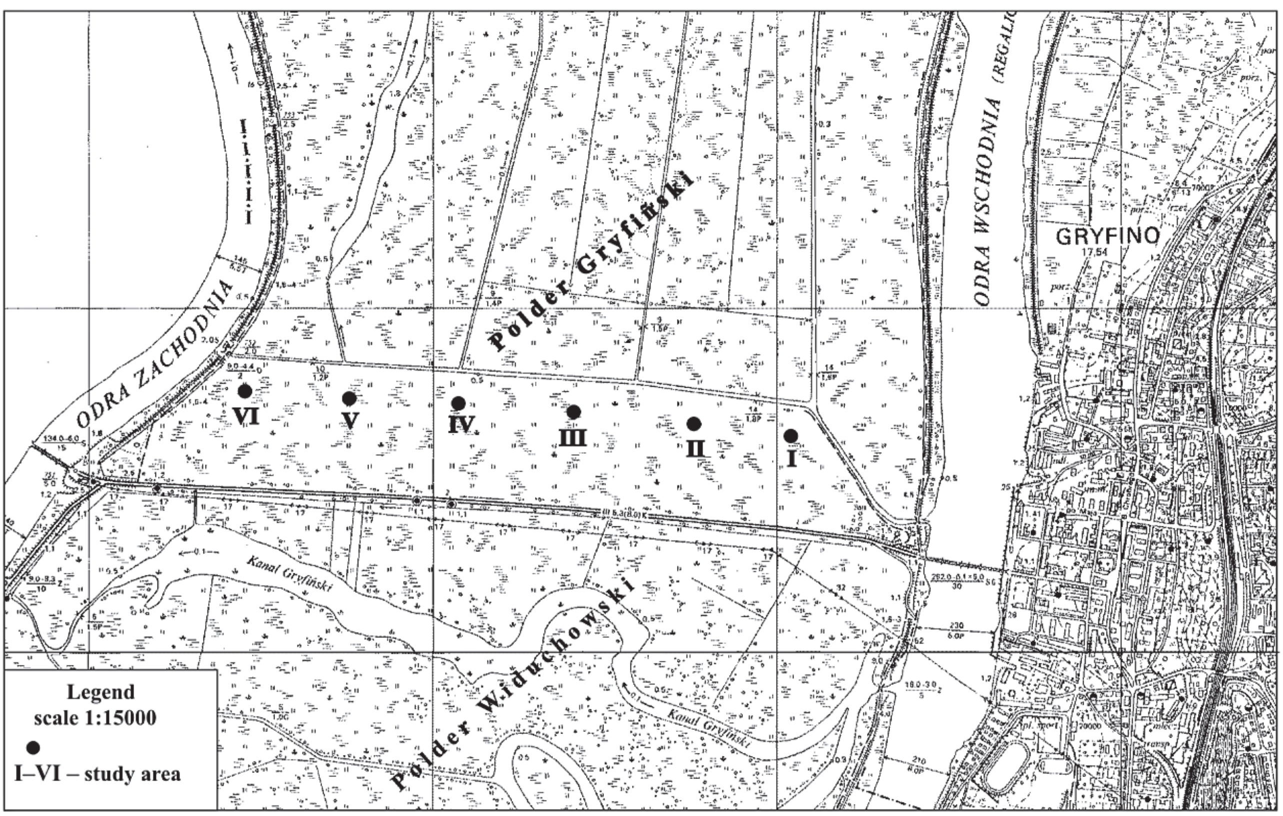

Figure. Location of study areas (Niedźwiecki et al., 2006)

Table 1. **Reaction and content of organic matter, organic carbon, total nitrogen and sulphur in organic soils of the southern part of Gryfiński Polder**

Depth (cm)	Value	pH		Losses of ignition %	C	N	S	C : N
		H_2O	KCl		g · kg⁻¹			
0–10	Min	4.26	4.07	44.44	228.9	17.34	7.08	12.4
	Max	4.83	4.45	81.97	406.2	28.31	14.48	14.9
	Mean	**4.48**	**4.20**	**69.53**	**344.9**	**24.95**	**11.46**	**13.8**
	S	–	–	11.35	54.6	3.62	2.20	0.7
10–30	Min	4.72	4.19	15.10	72.5	6.57	1.70	10.7
	Max	5.35	4.78	38.70	193.3	15.08	6.66	12.8
	Mean	**5.00**	**4.38**	**23.37**	**109.8**	**9.70**	**3.34**	**11.2**
	S	–	–	6.32	32.2	2.34	1.31	0.6

Table 2. **Content of macroelements soluble in concentrated acids HNO_3+$HClO_4$ in organic soils**

Depth (cm)	Value	P	K	Mg	Ca	Na
		g · kg⁻¹				
0–10	Min	0.77	0.82	1.56	15.71	0.80
	Max	1.31	3.77	4.18	28.52	1.28
	Mean	**1.03**	**1.72**	**2.22**	**20.70**	**1.04**
	S	0.15	0.87	0.79	3.76	0.15
10–30	Min	0.26	4.58	2.91	11.44	0.58
	Max	1.06	6.50	6.70	15.86	0.93
	Mean	**0.53**	**5.60**	**5.77**	**12.94**	**0.74**
	S	0.18	0.62	1.02	1.29	0.10

Table 3. **Content of heavy metals soluble in concentrated HNO_3 + $HClO_4$ acids in organic soils**

Depth (cm)	Value	Fe	Mn	Zn	Cu	Ni	Pb	Cd
		mg · kg⁻¹						
0–10	Min	11100	176.0	161.0	31.2	22.9	54.9	3.95
	Max	23265	400.0	265.0	53.1	33.0	90.5	6.49
	Mean	**14268**	**262.6**	**217.6**	**40.9**	**27.3**	**72.3**	**5.06**
	S	3409	80.5	32.0	6.4	3.3	12.2	1.06
10–30	Min	22015	151.0	106.0	30.2	30.9	31.7	0.05
	Max	50240	352.0	193.0	42.0	37.2	72.7	3.75
	Mean	**31435**	**187.5**	**152.3**	**34.4**	**34.8**	**49.3**	**1.18**
	S	9015	64.3	25.6	3.2	1.9	12.5	1.13

In the southern part of the Gryfiński Polder, in the surface soil layers under study, pH was mostly strongly acid and the average content of total nitrogen 9.70 to 24.95 g · kg⁻¹, with the highest amount in the layer 0–10 cm. The C : N ratio was favourable (11.2 : 1 to 13.8 : 1) which, according to Okruszko and Piaścik (1990), means that such organic matter is susceptible to biological transformations.

Total sulphur content (Table 1) shows a great accumulation of this element, especially in the surface 0–10 cm layer in which the mean value was 11.46 g · kg⁻¹. A 3.5-fold decrease in sulphur content was found in the layer 10–30 cm. Accumulation of sulphur in the surface layer of organic soils near industrial objects emitting SO_2 was also reported by Motowicka-Terelak and Terelak (1998).

The content of phosphorus soluble in a mixture of concentrated HNO_3 + $HClO_4$ acids (generally called the total content) in the surface layer of soils is maintained at the level of 1.03 g · kg⁻¹ dry matter and is decreasing with the depth of the soil profile (Table 2).

In the light of these results, despite great variations, potassium content is much more beneficial (1.72 g · kg⁻¹ dry matter) in the 0–10 cm layer and increases with the depth. This regularity was earlier observed in the soils of the Widuchowski Polder by Niedźwiecki et al. (2002b). In total, the content of this form of potassium in the examined soils may be regarded as high.

As one can see in Table 2, the level of total magnesium was similar to potassium content distributed in the upper part of soil profile and should be considered as high. A high content of calcium and sodium is characteristic of the silted soils of southern part of Międzyodrze (Niedźwiecki et al., 2002b).

In Poland, heavy metal content assessment is regulated by the ordinance of the Minister of Environment concerning the soil and land quality standards (2002) and heavy metal content

Table 4. **Content of macroelements in meadow vegetation**

Investigated plants	Investigated area	C	N	S	P	K	Mg	Ca	Na
		g · kg⁻¹							
Total meadow sward	1	438.4	23.6	2.6	2.49	19.17	1.70	5.37	0.13
	2	448.0	18.7	2.5	2.11	16.09	1.70	5.71	2.60
	3	449.2	19.1	2.4	2.00	17.31	1.45	4.70	0.87
	4	447.3	19.1	2.3	2.00	17.47	1.30	4.07	1.03
	5	436.8	25.5	3.0	2.00	18.21	1.91	7.00	2.02
	6	422.7	24.6	3.4	3.01	18.91	1.73	6.58	1.41
	Mean	**440.4**	**21.8**	**2.7**	**2.27**	**17.86**	**1.63**	**5.57**	**1.34**
Carex acuta	1	450.0	21.2	2.6	1.74	15.13	1.14	2.83	0.08
	3	445.6	22.0	2.7	1.78	16.03	1.30	2.82	0.08
	Mean	447.8	21.6	2.7	**1.76**	**15.58**	**1.22**	**2.83**	**0.08**
Calamagrostis canescens	2	450.1	19.9	2.0	1.91	12.02	1.32	3.07	0.07
	4	442.9	17.5	1.9	2.02	12.36	1.10	2.19	0.07
	$\bar{x}$	**446.5**	**18.7**	**1.9**	**1.97**	**12.19**	**1.21**	**2.63**	**0.07**
Glyceria maxima	5	432.3	18.4	2.8	2.16	18.34	1.23	5.27	1.28
	6	431.5	23.4	3.1	2.86	19.61	1.43	5.06	1.20
	Mean	**431.9**	**20.9**	**3.0**	**2.51**	**18.97**	**1.33**	**5.17**	**1.24**

Table 5. **Content of microelements in meadow vegetation**

Investigated plants	Investigated area	Fe	Mn	Zn	Cu	Ni	Pb	Cd
		mg · kg⁻¹						
Total meadow sward	1	68.92	93.59	28.48	4.58	2.10	1.10	0.585
	2	85.23	143.90	23.16	3.80	1.04	1.11	0.190
	3	54.70	123.20	22.89	4.00	0.77	0.28	0.156
	4	59.18	145.00	21.13	4.33	4.39	0.64	0.310
	5	56.96	115.00	21.61	4.77	1.35	1.03	0.114
	6	73.68	102.10	25.79	9.33	1.24	1.36	0.242
	Mean	**66.45**	**120.47**	**23.84**	**5.13**	**1.82**	**0.92**	**0.266**
Carex acuta	1	57.19	93.90	23.39	4.21	0.90	0.29	0.176
	3	57.25	124.10	22.92	3.63	8.44	0.30	0.138
	Mean	**57.22**	**109.00**	**23.16**	**3.92**	**4.67**	**0.29**	**0.157**
Calamagrostis canescens	2	56.09	74.31	20.65	3.60	2.44	0.00	0.032
	4	51.94	94.42	18.32	3.32	2.42	0.73	0.042
	Mean	**54.02**	**84.37**	**19.49**	**3.46**	**2.43**	**0.37**	**0.037**
Glyceria maxima	5	74.25	75.18	18.81	3.04	3.51	0.64	0.000
	6	59.50	61.28	20.73	5.18	3.27	0.81	0.003
	Mean	**66.88**	**68.23**	**19.77**	**4.11**	**3.39**	**0.72**	**0.002**

limits in the surface soil layers, corresponding to varying degrees of contamination, developed by Kabata-Pendias et al. (1993).

The obtained heavy metal contents in the surface layer of examined soils are not high in view of the above-mentioned legal regulations and Kabata-Pendias et al. (1993) recommendations. The only exception is cadmium content in the 0–10 cm layer – 5.06 mg · kg^{-1} dry matter, which indicates a medium contamination of the soil with this element. In this layer, elevated contents of lead (mean 72.3 mg Pb · kg^{-1} dry matter) and zinc (217.6 mg Zn · kg^{-1} dry matter) were found. These values were considerably reduced in deeper layers (Table 3). Pasieczna and Lis (2006) also detected an increased and occasionally high heavy metal content in the topsoil of Międzyodrze.

A relatively high content of sulphur and elevated contents of zinc, lead and cadmium in particular, may result from the emissions of the power plant "Dolna Odra" located in the vicinity of sampling sites (Nowe Czarnowo near Gryfino). Frequent inundations of the area with the overflowing rivers (the Western Odra and the Eastern Odra – Regalica) may have also had a negative influence since the sediments carried by their waters contained considerable amounts of pollutants, including heavy metals (Protasowicki et al., 1997, 1999).

The analysed plant communities were dominated by the specific species building up these associations i. e. *Carex acuta*, *Calamagrostis canescens* and *Glyceria maxima*. The floristic composition was typical of a swampy, wet or damp habitat where not only dominants (species building up a given community) but also other plants such as *Carex versicana*, *Typha latifolia*, *Equiesetum fluviale*, *Comarum palustra*, *Lythum salicarpa*, *Oenathe aquatica*, *Rumex hydrolapathum*, *Epilobium palustris* and *Iris pseudoacoacorus* occurred.

Generally, the discussed communities were composed of grasses (33.00–94.10%), sedges (0.40–63.95%), dicotyledonous plants (herbs and weeds) (3.00–42.50%) and small amounts of papilionaceous plants (0.2–0.4%).

It is worth mentioning that the *Glyceria maxima* communities differed in botanic sward composition. The sward of the community on the study object No. 5 had a greater floristic diversity and a high percentage (42.5%) of dicotyledons in comparison with object No. 6. The *Calamagrostis canescens* with *Carex acuta* association on object No. 4 was covered with a greater number of dicotyledoneous plants (25%) compared with objects 1, 2, 3.

Despite the high sulphur accumulation in the soil, its mean content in the sward was only 2.7 g · kg^{-1} dry matter, with the highest content in the *Glyceria maxima* community (Table 4).

Such sulphur values are characteristic of the majority of plants and, according to Kabata-Pendias et al. (1993), range within 0.20–0.50% dry matter.

Falkowski et al. (2000) present the optimum nutrient content in hay: P – 3.0; K – 17.5; Mg –2.5; Ca – 7.0; Na – 2.0 g · kg^{-1}. In this light, the analysed communities were characterised by:

– a low content of phosphorus, magnesium, potassium, calcium and sodium, especially in the community with *Carex acuta* and *Calamagrostis canescens*;

– an almost optimum potassium content, especially in the *Glyceria maxima* community (Table 4 – study areas 5 and 6).

A comparison of the obtained results with the content of mineral elements in grasses, cited by Oświt and Sapek (1982), shows that the sward condition is much more favourable as far as its chemical composition is concerned. In these authors' opinion, the content of mineral elements in the grasses of Polish meadows amounts to: P – 2.8; K – 14.1; Ca – 4.5; Mg – 1.6; Na – 0.7 g · kg^{-1}, whereas Rogalski (2004) points out that 10.0 g · kg^{-1} of K in plants covers their requirement completely.

Another indicator for estimating plant nutritive value is the content of microelements whose physiological amounts are essential to the life of organisms, but their excessive concentration may be harmful.

The Polish standards for cows fodder quality assessment are the following (mg · kg^{-1} dry matter): Zn – 50, Cu – 10, Mn – 50 and Fe – 30. According to Gorlach (1991), fodder plants should not contain more than 0.5 mg Cd · kg^{-1} dry matter, whereas lead content in grass is generally 0.3–3.5 mg · kg^{-1} dry matter and nickel within 0.1–5.0 mg · kg^{-1} dry matter (Table 5).

Compared with the cited results, our findings reveal copper and zinc deficiency in the swards In the case of zinc it is difficult to explain, because its content in the soil is high, and on certain parts of the Widuchowski Polder excessive amounts were found in the vegetation cover (Niedźwiecki et al., 2002b).

Among the analysed species, the highest levels of cadmium, nickel and manganese were found in *Carex acuta*. The low content of copper in the examined habitat of marshy meadows may result, in the opinion of Oświt and Sapek (1976), from insufficient aeration.

To sum it up, in the soils of the southern part of the Gryfiński Polder the level of macro and microelements is relatively favourable. Sporadic elevated amounts of cadmium, lead and zinc in the surface layers did not have a negative effect on the chemical composition of the vegetation cover.

These soils, maintained almost in their natural state, should function in order to preserve nature reserves of high value. The obtained results concerning the condition of soil and its vegetation cover prove that it contributes to an appropriate functioning of this ecosystem.

Therefore, the Lower Odra Valley Landscape Park, established in 1993, represents an extremely valuable object of research for many fields of science and is the major focus of constant Polish-German scientific, didactic-ecological and tourist cooperation.

CONCLUSIONS

1. The topsoil of bog soils, predominantly peat-mud, in the southern part of the Gryfiński Polder was characterised by 69.53% of organic matter, a beneficial C : N ratio (11.2–13.8 : 1), a strongly acid reaction (pH_{KCl} below 4.5) and a relatively favourable level of macroelements (K, P, Mg, Ca, Na) soluble in a mixture of concentrated HNO_3 + $HClO_4$.

2. In the light of Polish regulations and recommendations, the content of heavy metals, cadmium and lead in particular, in the surface layer of examined soils was elevated.

3. The enhanced content of heavy metals in the soil did not cause their bioaccumulation in the vegatative cover, which indicates their poor mobility under the current soil conditions of the Polder.

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CHEMINIŲ ELEMENTŲ KONCENTRACIJOS GRYFIŃSKI POLDERIO PIETINĖS DALIES, ŽEMUTINĖS ODROS SLĖNIO KRAŠTOVAIZDŽIO DRAUSTINIO DIRVOŽEMIUOSE IR PIEVŲ AUGALIJOJE

Santrauka

Žemutinės Odros slėnio Międzyodrze apylinkėse plyti vienas didžiausių Lenkijos durpynų, kurio fragmentai slūgso net ir Szczecino aglomeracijoje.

Šis didžiulis ir sunkiai prieinamas pelkių ir užpelkėjusių pievų kraštovaizdis, turtingas faunos ir floros rūšių, paskatino 1993 m. įsteigti Lenkų–Vokiečių kraštovaizdžio parką, užimantį 60,09 km^2. Gryfiński polderis yra šio parko centre.

Tyrimai buvo daryti Gryfino–Mesherin katenos 6 dirvožemio gręžinių tyrimo aikštelėse, kuriose nustatytas durpių klodo storis. Tūriniai dirvožemio ėminiai (du pakartojimai) buvo paimti iš 0–10 ir 10–30 cm sluoksnių, lygiagrečiai surinkti ir augalijos ėminiai.

Tyrimai parodė, kad paviršinis durpyno sluoksnis (0–30 cm) yra susidaręs iš puvenų su purvo priemaiša, organinių medžiagų jame – nuo 15,1 iki 82,0%. Dirvožemis itin rūgštus (pH 4,07–4,78), C / N – 11,2–13,8 : 1. $HNO_3 + HClO_4$ tirpiklyje ištirpusių elementų kiekis buvo vidutiniškai: K – 3,66, P – 0,78, Mg – 4,0, Ca – 16,8, Na – 0,9 g · kg^{-1} dirvožemio. Jame aptiktos tokios vidutinės sunkiųjų metalų koncentracijos: Cd – 3,1, Pb – 60,8, Zn – 184,9, Cu – 37,6, Ni – 38,3, Mn – 225,1, Co – 8,1 mg · kg^{-1}. Tyrimų vietose buvo aptiktos šios žolių bendrijos: *Carex acuta* su *Calamagrostis canescens, Calamagrostis canescens* su *Carex acuta* ir *Glyceria maxima.* Daugiausia makroelementų sukaupė *Glyceria Maxima* bendrijos žolynai, tuo tarpu *Carex acuta* bendrijos žolynuose aptiktos didžiausios Cd, Zn, Ni ir Mn koncentracijos.

Raktažodžiai: organinis dirvožemis, pievų augalija, cheminių elementų koncentracija