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PEAT SOILS AS A BUFFER SYSTEM FOR VALLEY ECOSYSTEMS

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A b s t r a c t. The research was carried out in the drained lowland bogs of the Lower San Valley. Special attention was paid to the role of peatbogs in reducing migration of the surplus biogenic and toxic elements. Land drainage carried out in a routine way together with synergistic drainage exploitation of deep waters results in progressing degradation of peat soils. Their capability of accumulating nitrogen, calcium and phosphorus, basic biogenic elements influencing eutrophication of the waters is declining. Mineralizing organic matter becomes a secondary source of pollution, releasing huge amounts of biogenes and toxic heavy metals stored on the surface; this process can be seen well in the profile of degraded fragments of the objects under research. Hydrophobic muck horizons also lose their ability to neutralise extreme conditions of droughts and floods. The remaining peat soils of the San Valley require protection, and even renaturization.

K e y w o r d s: peat soils, the San Valley, chemical composition, buffer properties, environment protection.

INTRODUCTION

Natural environment is utilized by man in various ways that sometimes lead to degradation of some its elements, and even of the whole ecosystems. These problems result mainly from a very incoherent and egoistic way of environment treating natural ecosystems is neglected. Natural ecosystems often act as buffers for the environment, soothing any extreme influences. Such significance may be ascribed to peatbogs.

In modern times many peatbogs have disappeared, and most of the remaining ones is under various human influence. For example, as Lipka [8] informs, in the Lower San and Wisłok Valley, in the years 1896 - 1971, the following peatbogs disappeared: 55.2 % of the primary area of the peatbogs near Rudnik on the San, 89.4 % in the region of Leżajsk, and 88.9% near Przeworsk. It should be mentioned that after 1971 the process of peatbogs draining heve been still continuing.

Drainage melioration and deep water intake may be listed among the fundamental factors causing peatbog disappearance. Many authors studied causes and effects of draining bogged areas, and this problem was the subject of study of many authors [1,3,5,6,8,9,14,16,17]. In many cases, the vehement cause of transformations is destruction of soil environment combined with the threat for the quality of ground waters [5,6,12,16]. Drainage of peatbogs may be a direct threat for ground waters, but, as Durkowski and Burczyk [4] say that draining surplus water from the soil profile contributes to an increase in the intensity of washing out mineral components which, in turn, may intensify eutrophication of river waters. On the other hand, progressing degradation of peatbogs leads to exhaustion of many components necessary for plants [10].

Peatbogs accumulate toxic heavy metals on the surface [7,13,16] preventing their rapid migration into other elements of the environment, and play a significant role in soothing extreme conditions of droughts and floods. Mioduszewski [11] says that 30% share of peatbogs in the total catchment area may give up to 60-80% reduction of flood-wave and small peat complexes influence hydrological regime of the watercourse in a similar way as the areas without flow, reducing rapid surface wash. All these features of peatbogs - at least to some extent - may be considered as buffer properties.

MATERIALS

The research was carried out on the drained lowland bogs of the Lower San Valley. The main object of the research was a drained meadow complex, called Przychojec. It is a large complex of drained hydrogenic soils situated near Leżajsk. The Przychojec object was meliorated in the years 1976-1978; the total area of 94 ha was drained then, including 70 ha of peat soils. The primary thickness of peat bed was 1.5-3.3 m. It is low fen peat, mainly alder, eutrophic peat. The area under research has a topogenic type of water supply (the first water-bearing horizon is formed by a groundwater reservoir with a small fall of water table). However, soligenic water supply increasing as the overdrying process develops (leakage and underground high-pressure water) and ombrogenic water supply (rainwater) are also of significance. Soligenic, ombrogenic and fluviogenic processes (inflowing stream waters) are not able to make up for the increasing water shortage which in the case of the drained Przychojec object is further intensified by the active system of water intake from deep wells.

In 1995 samples of muck and peat were collected for analysis from each horizon of the examined peat soils of the Przychojec object. In the case of some profiles, samples of the mineral subsoil were also collected. The research was continued in the years 1996-1998.

The samples of exactly 1 dm^3 were collected for the analysis. The ash content was determined by annealing the samples in muffle oven in the temperature of 550 ^oC.

Soil reaction was tested by a potentiometric method. Total nitrogen content was determined by the Kjeldahl method. Total content of calcium, cadmium and lead were determined by the spectrophotometry of atom absorption after mineralisation peat and muck samples in the mixture of HNO_3, $HClO_4$ and H_2SO_4 in the ration of 20:5:1, respectively. Analytical material from the mineral horizons was etched in $HClO_4$. Due to its low content, cadmium was condensed in the organic phase - methyloizobutyl ketone (MIBK), before determining its total content.

RESULTS AND DISCUSSION

Great significance of peatlands in the landscape presented in the Introduction in the form of a short literature review, justifies the need for continuous examination of their state and changes in the peat soils, also from the point of view of their renaturalization, if possible.

The content of elements, and especially their distribution in the soil profile, are important and sensitive indicators of changes in the drained peat soils.

Table 1 shows variation in the contents of basic biogenic elements: nitrogen, phosphorus and calcium, as well as of the two prevailing toxic heavy metals: lead and cadmium, in the muck and peat horizons, and in their respective mineral subsoils. The eutrophic alder peats of the Przychojec object are characterized by a high content of nitrogen and calcium. Variation in the content of these elements, however significant, does not differ largely from the diversity in the contents of lead and cadmium. However, such generalized results must be supplemented with a broader analysis presented in Table 2. Out of many soil profiles analysed, 4 profiles situated in the fragments of peatland of varied degradation level were chosen for a detailed presentation. Table 3 presents variation in the readings of ash content. Like in the research carried out by other authors [17], it was shown that muck-forming process is accompanied by - among others - an increase in the ash content and gradual soil acidification; hence pH of the surface muck horizons is much lower. The profile marked as E (Tables 2 and 3) was situated in the part of the peatland in the Przychojec object that had been changed most, i.e., burnt on the surface, with the area denivelation reaching 1 m. Lipka [9] writes that peatland fires sometimes bring about their total destruction, and may reduce peatland area even up to 0.55 m annually. Annual loss of the average bed thickness caused by fire resulting from soil overdrying, may be 50 times higher than total disappearance [9]. The G profile was situated in the far less degraded part of the peatland, and the F, and especially

Table 1. Variability of N, P, Ca, Pb and Cd content in the Przychojec object of drained peaty soils and in their mineral subsoil

Specification	Total content of elements				
	N	P	Ca	Pb	Cd
	g kg^{-1} d.m.			mg kg^{-1} d.m.	
1. muck and peat horizons	n=40	n=40	n=40	n=22	n=22
minimum	15.6	0.2	5.7	0.2	0.08
maximum	55.9	1.6	39.3	60.4	3.09
arithmetic mean	34.0	0.7	27.2	15.1	0.95
2. mineral subsoil horizons	n=8	n=8	n=8	n=8	n=8
minimum	0.3	0.1	1.2	2.6	0.13
maximum	1.4	0.7	10.5	14.1	0.42
arithmetic mean	1.1	0.4	4.2	8.1	0.24

H profiles (Table 2 and 3) are characteristic of the least changed parts of peatland that still remain - especially in spring - under the influence of underground high-pressure water.

Variation in the contents of the examined elements in the soil profile, presented in Table 2, confirms the buffer role of peatlands in the environment (contents of Ca and N are even several dozen times higher in the peat soil and in its mineral subsoil). It also illustrates peatland disappearance caused by overdrying. The content of calcium - generally high in the examined peat soils of the Przychojec object - in the profiles with the lowest level of degradation, is distributed evenly in the whole profile. Muck-formation process leads to the release and significant loss of calcium accompanied by soil acidification. Muck horizons are characterized by the lowest Ca content, like the soil of all the profiles situated in the peatland fragments with advanced muck-formation process. The released calcium migrates deep into the soil, towards the ground water. Zimka and Stachurski [17] state that calcium mass that is released during muck-formation process may reach 400 kg ha year^{-1}, and that the mechanism of releasing ions is like ion-exchange reaction; hydrogen ions produced in the oxidation process of N and S are equally exchanged into Ca, Mg, K and Na ions. In such conditions the peatland loses its buffer abilities for binding biogenes (e.g., Ca and N). This is, in turn, related to its ability for ensuring water cleanness. It becomes a secondary source of pollution. Also the nitrogen content is much lower in the muck horizons of the degraded fragments of the object (Table 2). These results are confirmed by many authors: Sapek *et al.* [14] state that the mass of nitrogen released yearly from 1 ha may even reach 800 kg, and Frąckowiak [5] shows that the variation in the mass of released nitrogen ranges from 540 to 1130 kg ha^{-1} year^{-1}.

T a b l e 2. Content of N, P, Ca, Pb and Cd in some horizons of selected profiles of the Przychojec object of drained peat soils

Profile symbol	Depth (cm)	N	P	Ca	Pb acc. to [15]	Cd acc. to [16]
		$g\ kg^{-1}$ d.m.			$mg\ kg^{-1}$ d.m.	
				Muck and peat horizons		
E	0-10	20.3	1.0	5.7	15.0	1.1
	40-50	27.6	0.4	22.1	8.0	3.1
F	0-10	27.6	1.2	29.9	35.9	1.8
	40-50	34.8	0.5	39.3	4.0	0.6
	120-130	32.9	0.4	25.8	0.8	0.2
G	0-10	37.5	1.4	17.8	41.0	1.7
	40-50	22.3	0.3	27.4	6.9	1.0
H	0-10	31.3	0.7	31.2	53.6	1.6
	40-50	42.1	0.6	37.3	4.0	0.3
		34.8	0.4	30.6	0.2	0.2
				Mineral subsoil horizons		
E	80-90	1.1	0.7	2.4	7.8	0.3
	120-130	0.5	0.1	1.2	4.6	0.1
	130-140	0.5	0.2	2.4	7.0	0.2
F	130-140	1.4	0.7	10.5	14.1	0.3
	140-150	1.0	0.7	8.9	12.9	0.3
G	90-100	0.6	0.2	2.4	7.7	0.2
H	140-150	0.7	0.4	3.2	7.9	0.2
	160-170	0.3	0.1	2.3	2.6	0.4

For thousands of years these have been accumulated in the peat-forming vegetation from waters reaching the peatland. They would become environmental pollutants released in great amounts in the process of too vehement mineralization of peat. That is how a thousand-year work of the peat buffer may be wasted within several dozen years.933O

Peatlands are also ecosystems that accumulate anthropogenic pollutants reaching the environment. They reduce their migration and limit their rapid access to water ecosystems and introduction into the food chain. An illustration of the surface accumulation of toxic lead and cadmium is presented by the profiles shown in Table 2. In the former publications [15,16] the problem of lead and cadmium accumulation was analysed together with the ability of these elements to release

T a b l e 3. Content of ash, soil reaction and additions or reduce coefficients of Ca, Pb and Cd in drained peat soils of the Przychojec object (comparison of content in the presented organic horizons and the content in mineral subsoil)

Profile symbol	Depth (cm)	pH_{KCl}	Ash content g kg^{-1} d.m.	Additions or reduce coefficients		
				Ca	Pb	Cd
E	0-10	5.1	748	2.8	2.3	6.2
	40-50	5.4	544	11.0	1.2	17.2
F	0-10	5.7	380	3.1	3.5	5.5
	120-130	6.4	117	2.7	0.1	0.8
G	0-10	5.4	310	7.6	5.3	11.3
	40-50	5.9	430	11.7	0.9	6.6
H	0-10	5.8	284	11.1	10.1	5.4
	90-100	6.5	157	10.9	0.05	0.8

muck formation process and migrate deep into the soil. Surface horizons of the peat soils of the Przychojec object accumulated several dozen times, max. up to 160 times, higher amounts of lead than the deepest organic horizons [15]. So degradation of the peat soils results in the disappearance of a very effective biological filter - some sort of a buffer system reducing the extent and rate of the influence of some anthropogenic pollutants on the water ecosystems. Peatlands play a similar role in eliminating or reducing migration of fertilizer components from the agrosystems. Bieniek [2] emphasises that the capacity of the organic sorption complex in the muck horizons of the soils is lower and corresponds to organic matter of low humification level; he adds that this phenomenon may be caused by some irreversible changes in the nature of muck colloidal system during its periodical drying.

Table 3 presents, among others, accumulation coefficients for several element chosen as examples for the organogenic soils of the Przychojec object. These values confirm earlier conclusions: comparison of the surface organic horizons and the deepest organic horizons of individual profiles with their mineral subsoil allows to state that the content of calcium is largely reduced in the muck-formation process (degraded E profile). Also cadmium is released rapidly - the problem of Cd was presented in an earlier publication [16]. Accumulation coefficients of Ca and Cd in the surface horizons of the most degraded profiles are much lower than the same coefficients for the deepest organic horizons of the same profile. One may be sure here that these elements were released and they migrated deep into the soil.

Migration of some products of the muck-formation process (mineralisation and humification) deep into the profile of the dried peat soils is favoured by the changes in the peat physical properties presented in detail in the publication by Gawlik [6]; disappearance of mezopores is significant for the process of capillary ascension. They are replaced by micropores containing water inaccessible for plants and large macropores which in the conditions of the washing system of the water economy of the dried peatlands, may migrate easily deep into the soil or even into ground waters. Thinner and thinner protective layer of the peatland develops holes, and the whole buffer system practically stops functioning. Of course, the above-mentioned problem concerns badly, quickly and excessively dried peatlands (practically all of them in the San Valley).

While undergoing rapid muck-formation process, peats lose also their ability for soothing extreme conditions of droughts and floods. Hydrophobic muck matter is characterised by very unfavourable water properties [6]. The muck of the surface horizons of the drained peat soils of the Przychojec object does not show any abilities for capillary ascension.

The presented example of the Przychojec object indicates that the effects of melioration that are often intensified by ground water intake, are very different from the expected and they are not able to compensate for the environmental losses. The remaining bogged areas, not only the peat soils, should be protected and renaturalized. Adamczyk [1] stated that in the mountain area draining of bog-springs and field streams, and especially sylvan bog-springs and peatlands, is a complete economical nonsense. In modern times, draining those few and rather small marshlands that are still left in the situation where thirsty cities, economic subjects and agriculture look for water, should be interpreted in a similar way.

CONCLUSIONS

1. Excessively drained peat soils lose their buffer abilities for binding biogenic and toxic matter; and as the process of ovedrying advances, they themselves become a secondary source of pollution.

2. Draining of most of the lowland bogs of the Low San Valley destroyed the system of protective barriers cleaning the water reaching this river from the catchment basin.

3. Peat matter undergoing the process of muck-formation gains hydrophobic properties, which reduces or destroys the ability of peatland to form water relations in the landscape.

4. The remaining peat soils of the San Valley should be protected, and where possible, renaturalized.

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