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DYNAMICS OF MINERAL NITROGEN FORMS CONTENT IN OMBROPHILOUS ORGANIC SOIL AND IN UNDERGROUND WATER

DYNAMIKA ZAWARTOŚCI MINERALNYCH FORM AZOTU W OMBROFILNYCH GLEBACH ORGANICZNYCH I W WODACH GRUNTOWYCH

Abstract: The determination of dynamics mineralisation of organic nitrogen compounds in ombrophilous organic soil and in underground water at Zielony Mechacz and Budwity objects was the aim of these researches.

Habitat conditions, and especially aqueous properties of the raised bog significantly influenced on mineralisation dynamics of organic nitrogen compounds and on the quantity of accumulated NO_3-N and NH_4-N in soil and in underground water. In ombrophilous organic soil in the reserve, where natural habitat conditions are kept as well as in peat soil located in peat mine; the mineralisation of the organic compounds in studied seasons was small. In the case of raised bog, very small quantities of nitrates have been found. Only in the case of bog's forest peat which was located on the boundary between the reserve and the peat mine the content of that form of nitrogen was average and large. It means about stopping the nitrification process and the degradation of peat soil. The concentration of the mineral nitrogen compounds in underground water land ombrophilous peat bog was differentiated and depended on the dynamics of organic matter mineralisation carrying out in ombrophilous organic soil.

Keywords: mineralization, raised bog, groundwater, habitat conditions

In the areas where the exploitation of peat deposits is carried out the level of underground water is artificially reduced. The deep dehydration of deposits earmarked for mining also causes the lowering of water in area neighbouring with the mine. The enlarged quantity of air in the soil initiates many physical and chemical processes which lead to organic compounds decomposition which releases considerable quantities of biogenic components [1]. In the mineralisation process of organic nitrogen is released mineral nitrogen (NO_3-N, NH_4-N), which is assimilated through plants. In organic soil deeply drained comes to the intensive freeing of mineral nitrogen

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which quantity often exceeds alimentary needs of plants. The unused nitrogen can diffuse to underground water and causes its eutrophication [2, 3]. In the aspect of environment protection, the dehydration of peat bog and connected with that process and an organic nitrogen compounds mineralisation poses a threat to the existence of these habitats. That is why one should control processes causing the changes of peat soils as a result of their dehydration [4]. So far the researches on the mineralisation of organic nitrogen compounds were carried out mainly in peat soils of reophilic peat bog [5, 6].

The mineralisation course of organic nitrogen compounds in the peat soil of ombrophilous peat bog in different seasons of a year, and the researches on nitrate and ammonium content in underground water of that soil have not been carried out yet, that is why such researches were undertaken. The determination of mineralisation dynamics of organic nitrogen compounds in the peat soil of raised bog in the various seasons of a year considering existing habitat conditions was the aim of these researches. The seasonal changes of nitrate and ammonium content have been also shown in underground water of these soils.

Materials and methods

Dynamics of mineral nitrogen compounds content in ombrophilous peat soil and underground water at Zielony Mechacz and Budwity objects were studied. The raised bog of the area 366 hectares is located in Maldyty community in Warmia and Mazury province, in the eastern part of Ilawa Lake district [7]. The stratigraphic researches of layers have confirmed that raised bog of the continental type was formed in the continental glacier process of a shallow moraine lake, created after the retreat of the Scandinavian continental glacier in the Holocene period [8]. Under eutrophical conditions the lake covering followed by detritus gytia deposition which depth fluctuates from 0.5 m to 3.5 m. After filling a lake with sediment deposits started to appear the vegetation of reophilic peat bog vegetation, creating layers of sedge and sedge-alder swamp forest peat, covering on the gytia. Overgrowing the aqueous reservoir was carried out from banks to the centre of a lake. The development of bog boric habitats took place in further structural constituent [9–11]. No larger aqueous watercourse does not get into the lake basin what created favourable conditions for oligotrophication of the habitat. Poor and acid rains were the main source supplying water into the habitat, therefore ombrogenic type of hydrological supplying was dominating – THZ [12]. The depth of the formed high bog at Zielony Mechacz and Budwit was about 4.5 metres. It is characterized by a faint degree of decomposition (R1) and does not show larger morphological differentiation. The Hypnum-moss peat provided litter raised bog is a sedge low moor peat. These researches have confirmed that at Zielony Mechacz and Budwit is a boggy peat soil, ombrophilic in the accumulation phase, formed from a week decomposed peat PtIIIaa. On account of profitable aqueous proprieties and a weak decomposition degree, that soil should rate to the Prognostic Humidity Complex of Soils – wet A and to Potential Hydrological Humidity Habitat – ombrogenic wet. The high peat bog is characterized by diverse

aqueous conditions. There are undisturbed aqueous conditions in its south part where, the boggy process takes place. The reserve "Zielony Mechacz" has been formed in that area of 94.3 hectares in order to "preserve and protect sites of glacial relict such as the "moroszka" raspberry (*Rubus chamaemorus*) and a "raised bog" [13]. The northern part of peat bog possesses disturbed aqueous relations because of the desiccation of this terrain in order to exploitation of the peat. At present where the mining of peat was finished, the reclamation process of the soil is carried out.

The mineralisation rate of organic nitrogen compounds in peat soil and the content of NO_3-N and NH_4-N in underground waters of the soils were studied in the vegetation season and in winter in the period 1999–2001 as well as in 2008. The presented results of the mineral nitrogen release course were the continuation of broadened researches about mineralisation intensity of organic nitrogen compounds in peat soils in four seasons on the background of diverse habitat conditions of young glacial areas [6]. The researches have been carried out in four soil open pits on a raised bog, strongly boggy formed from the peat weakly decomposed (PtIIIaa). Three soil open pits were situated in the south part of a raised bog, provided with a reserve protection. The mineralisation rate of organic nitrogen compounds in the reserve soils was studied in periodically dried ombrophilic peat soils located at the border of the reserve and the mine (open pit I) and in peat soils with undisturbed aqueous conditions (open pit II, open pit III).

The fourth soil open pit was located in the northern part of peat bog on terrains after the former mine of the peat, where the renaturation process is carried out. The GPS satellite navigation system permitted to co-ordinate geographical positions of soil open pits. From layers: 5–10, 25–30, 35–40 and 50–60 cm, the soil samples with small cylinders of the capacity about 100 cm^3, were taken with preserving structure, where: the ash (by combustion of soil samples at 550 ^oC), volumetric mass density after desiccation of samples at 105 ^oC, general porosity (calculated on the basis of mass volumetric density and the ash content), the moisture of soils (determined with the drier method), reaction of soils (pH measured with a potentiometric method in H_2O and in 1 mol $\cdot$ dm^{-3} KCl solutions), total nitrogen content with Kjeldahl method [14] have been determined. The content of NO_3-N and NH_4-N in the soil was studied in the extract of 1 % K_2SO_4 after 14-day incubation at 28 ^oC [15]. The evaluation of NO_3-N was carried out, based on border numbers according to Gotkiewicz [16]. In piezometers installed next to soil open pits, levels of underground water have been measured and the water was taken to chemical analyses. Nitrate nitrogen in underground waters was determined by colorimetric method with disulfonic acid while ammonium nitrogen with Nessler's solution [17].

Results and discussion

Physical and chemical proprieties of soils at Zielony Mechacz and Budwit objects are typical for the oligotrophic raised bog with a low (R1) decomposition degree (Table 1).

The ash content of peat was very low especially in layers below 75 cm (2.0 to 1.5 % of dry residue). The volumetric mass density of peat bog was also very low and did not

Table 1

Physical and chemical properties of ombrophilous organic soil bog at Zielony Mechacz and Budwity objects

Layer	Level	Ash content	Volume density	Specific density	Total porosity	pH in 1 M KCl	pH in H_2O	Profile I	Profile II	Profile III	Profile IV
[cm]		[% d.m.]	[g · cm^{-3}]		[%]			total N [%]			
5–10	Otwy*	4.2	0.081	1.508	94.8	2.8	3.6	1.03	1.07	0.88	0.96
15–20	Otwy	5.7	0.080	1.527	95.0	2.7	3.6	—	—	—	—
25–30	Otwy	6.7	0.105	1.538	93.1	2.9	3.8	1.00	0.99	0.85	0.93
35–40	Otwy	3.3	0.079	1.498	95.0	2.9	4.0	0.91	0.77	0.75	0.82
55–60	Otwy	3.2	0.079	1.497	94.8	2.9	3.8	0.81	0.41	0.49	0.79
75–80	Otwy	2.0	0.081	1.482	94.5	2.9	3.7	—	—	—	—
95–100	Otwy	1.5	0.079	1.478	94.6	2.7	4.2	—	—	—	—

* Otwy – raised bog peat.

exceed 0.1 g · dm^{-3}. Specific mass density in studied layers of peat bog on average was 1.5 g · dm^{-3} and it was insignificantly lowering in deeper layers. The raised bog – Zielony Mechacz and Budwity was characterized by a high general porosity, (93–95 % vol.). So high porosity is connected with a low degree of peat decomposition and testifies about exceptionally small refinement of the soil and huge possibilities of water accumulation. The reaction of the peat was qualified as the strong acidic [18].

The content of total nitrogen in studied raised peat was insignificantly diversified and in the comparison with eutrophical peat was low. In the soil open pit I it fluctuated from 1.03 to 0.81 %, in the open pit II from 1.07 to 0.41 %, it was the lowest in the open pit III – from 0.88 % to 0.49 %. However, it fluctuated from 0.96 to 0.79 % in the open pit IV, on the terrain of the former mine.

The studied soils of a raised bog differed in levels of underground water and moisture (Table 2).

Table 2

Average moisture [%] and underground water levels [cm] of Zielony Mechacz and Budwity rasied bog

Profile GPS coordinates	Layer [cm]	Seasons of the year			
		Spring	Summer	Autumn	Winter
		Moisture of soil [%]			
Profile I GPS: N 53°54′ 669″; E 19°41’ 836”	5–10	68.29	61.98	73.60	71.30
	25–30	69.98	63.65	64.00	69.90
	35–40	75.57	78.65	61.80	76.35
	50–60	79.78	82.32	71.30	75.80
Profile II GPS: N 53°54′ 645″; E 19°41′ 873″	5–10	75.89	79.87	82.19	80.50
	25–30	79.98	77.45	84.34	85.55
	35–40	84.57	83.98	80.38	83.95
	50–60	89.58	89.53	89.76	95.60
Profile III GPS: N 53°54′ 427″; E 19°41′ 677″	5–10	95.51	94.90	94.10	97.55
	25–30	96.00	95.40	96.60	96.45
	35–40	97.82	96.50	96.30	96.90
	50–60	97.86	94.50	95.50	97.80
Profile IV GPS: N 53°54′ 615″; E 19°41′ 546″	5–10	91.80	89.80	87.20	88.00
	25–30	91.93	84.80	85.70	87.60
	35–40	94.53	90.25	96.50	97.25
	50–60	97.87	95.35	91.80	97.30
Underground water level [cm]					
Piezometer I		67	115	78	68
Piezometer II		30	35	25	15
Piezometer III		*	3	*	*
Piezometer IV		*	5	2	5

* Water on the surface of soil.

The mine bordering on the reserve caused that the lowest level of underground water was kept in the piezometers I. The underground water was on the depth from 67 cm to

115 cm there. The higher level of underground water and its insignificant variations during the year occurred in the piezometer II. The level of underground waters was kept on the depth from 15 to 35 cm in studied seasons of the year. In piezometers III and IV the underground water was the most often kept on the surface of the soil or from 2 to 5 cm below its surface. The studied peat soils differed in its moisture. The high moisture of peat bog in all seasons of the year kept in open pits III and IV (from 84.8 to 97.8 % vol.). The lowest moisture was characterized the top layers of soils of a raised bog situated near the mine. In the open pit I moisture in the layer 5–10 cm was kept in the range 61.9 to 73.6 % vol. and in the open pit II from 75.9 to 82.2 % vol., respectively.

During the year larger differences in moisture occurred only in layers 5–30 cm, in the open pit I and II of peat bog. In the deeper layers of these open pits similarly as in remaining studied ones was high moisture. Prevailing aqueous conditions at Zielony Mechacz and Budwity high bog are profitable from the soil protection point of view, because they limit changes proceeding in organic soils. The aqueous proprieties of a raised bog and kept their naturalness degree, had a significant effect on the mineralisation dynamics of organic nitrogen compounds, and on the quantity of accumulated NO_3-N and NH_4-N in the soil and in underground water. In ombrophilous organic soil in the reserve where natural habitat conditions are kept as well as in peat soils located on terrains after the former peat mine the mineralisation of organic matter where the renaturation process happens was also small (Table 3). The biggest amount of mineral nitrogen was released in peat soils of boggy forest located on the boundary of the reserve near the former pit mine (an open pit I). The large release of mineral nitrogen in that soil especially happened in the summer periods in surface layers. The predominated form in the mineralisation process of organic nitrogen compounds was NO_3-N, which content in the soil was high and average, however the affluence of these soil layers in NH_4-N was smaller and ranged 7.3–8.3 mg $\cdot$ dm^{-3}. In the remaining seasons the mineralisation rate in the soil of an open pit I was smaller. The content of NO_3-N in spring was low whereas in autumn was low and average. In the peat soil located near the former mine the ratio of NO_3-N to NH_4-N in the vegetation season was above the unity, what testifies about convenient conditions to the course of the nitrification process. The inhibition of organic nitrogen compounds mineralisation in winter was stated. The content of N-NO_3 was very low whereas NH_4-N content did not exceed 3.9 mg $\cdot$ dm^{-3}.

In peat soil on the terrain of the former mine, low contents of mineral nitrogen have been found. The NH_4-N form was predominated, which content did not exceed 5.7 mg $\cdot$ dm^{-3}, and the affluence of the peat in NO_3-N was very low. In II and III open pits in all studied layers of soil profile were very small quantities of NO_3-N. The larger seasonal fluctuations of nitrates were not also found as it took place in the case of a reophilic peat bog mineralisation process. The largest concentrations of mineral nitrogen appeared in underground water in a piezometer I, installed on the boundary between the reserve and the mine, and in the piezometer IV in the terrain of the former mine (Table 4).

Table 3

Mineral nitrogen content of ombrophilous organic soil bog at Zielony Mechacz and Budwity objects

Season	Layer	Profile I GPS coordinates: N 53°54′ 669″; E 19°41′ 836″				Profile II GPS coordinates: N 53°54′ 645″; E 19°41′ 873″				Profile III GPS coordinates: N 53°54′ 427″; E 19°41′ 677″				Profile IV GPS coordinates: N 53°54′ 615″; E 19°41′ 546″			
		NO_3-N	NH_4-N	N-min.	NO_3-N/ NH_4-N	NO_3-N	NH_4-N	N-min.	NO_3-N/ NH_4-N	NO_3-N	NH_4-N	N-min.	NO_3-N/ NH_4-N	NO_3-N	NH_4-N	N-min.	NO_3-N/ NH_4-N
	[cm]	[mg · dm^{-3}]				[mg · dm^{-3}]				[mg · dm^{-3}]				[mg · dm^{-3}]			
Spring	5–10	9.85	7.63	17.48	1.29	4.01	5.77	9.78	0.69	0.89	2.59	3.48	0.34	0.98	3.41	4.39	0.29
	25–30	6.57	5.93	12.50	1.11	4.11	6.26	1.37	0.66	0.88	2.89	3.77	0.30	1.21	3.21	4.42	0.38
	35–40	6.50	5.56	12.06	1.17	2.46	3.96	6.42	0.62	0.73	2.35	3.08	0.31	021	1.89	2.10	0.11
	50–60	7.98	5.69	13.67	1.40	2.52	1.87	4.39	1.35	0.89	2.43	3.32	0.37	0.45	1.31	1.76	0.34
Summer	5–10	24.68	8.30	32.98	2.97	1.77	4.06	5.83	0.43	0.80	3.59	4.39	0.22	1.01	5.27	6.28	0.19
	25–30	17.73	7.29	25.02	2.43	1.75	3.25	5.00	0.53	0.90	3.90	4.80	0.23	1.12	3.15	4.27	0.36
	35–40	15.98	2.87	18.85	5.57	0.86	3.88	4.74	0.22	1.34	2.75	4.09	0.49	0.33	2.89	3.22	0.11
	50–60	15.65	0.99	16.64	15.81	1.18	3.17	4.35	0.37	0.27	2.59	2.86	0.10	1.49	2.13	3.62	0.70
Autumn	5–10	10.45	5.93	16.38	1.76	0.99	3.11	4.10	0.32	1.00	2.49	3.49	0.40	1.20	5.74	6.94	0.21
	25–30	9.98	1.45	11.43	6.88	1.51	2.91	4.42	0.52	0.76	1.53	2.29	0.50	0.44	4.08	4.51	0.11
	35–40	5.35	2.23	7.58	2.40	2.62	4.67	7.29	0.56	0.26	2.55	2.81	0.10	0.47	4.06	4.53	0.12
	50–60	4.95	3.63	8.58	1.63	2.41	3.73	6.14	0.65	0.77	2.06	2.83	0.37	0.45	2.99	3.44	0.15
Winter	5–10	2.42	3.89	6.31	0.62	0.95	2.86	3.81	0.33	0.69	2.05	2.74	0.34	0.96	2.63	3.59	0.36
	25–30	2.98	3.01	5.99	0.99	1.01	2.96	3.97	0.34	0.80	1.98	2.78	0.40	1.15	3.01	4.16	0.38
	35–40	1.71	1.92	3.63	0.89	1.04	2.01	3.05	0.51	—	—	—	—	—	—	—	—
	50–60	1.70	1.78	3.48	0.95	1.14	1.96	3.10	0.58	—	—	—	—	—	—	—	—

Table 4

Average nitrogen content of underground water at Zielony Mechacz and Budwity objects

Season	GPS coordinates: N 53°54′ 669″; E 19°41′ 836″			GPS coordinates: N 53°54′ 645″; E 19°41′ 873″			GPS coordinates: N 53°54′ 427″; E 19°41′ 677″			GPS coordinates: N 53°54′ 615″; E 19°41′ 546″		
	NO_3-N	NH_4-N	N-min	NO_3-N	NH_4-N	N-min	NO_3-N	NH_4-N	N-min	NO_3-N	NH_4-N	N-min
	[mg · dm^{-3}]											
Spring	0.463	0.967	1.430	0.259	0.328	0.587	0.238	0.318	0.556	0.441	0.787	1.228
Summer	0.890	0.568	1.458	0.300	0.431	0.731	0.241	0.314	0.555	0.483	0.897	1.380
Autumn	0.569	0.867	1.436	0.234	0.622	0.856	0.231	0.312	0.543	0.426	0.825	1.251
Winter	0.576	0.797	1.373	0.201	0.342	0.543	0.221	0.310	0.531	0.451	0.796	1.247
Average	0.624	0.800	1.424	0.248	0.431	0.679	0.233	0.313	0.546	0.450	0.826	1.276

The high concentrations of mineral nitrogen in water of the piezometer I were connected with the large dynamics mineralisation of organic matter and its acid reaction which favoured washout of mineral nitrogen compounds to underground water. Whereas the high concentrations of mineral nitrogen in the water after the mine exploitation are connected with washout of these compounds to deeper layers in the period, when these soils were dried and the peat was exploited and the organic matter mineralisation took place there. The NH_4-N form was predominated in all water sections, and the largest its concentration appeared mostly in autumn.

Conclusions

1. The dynamics of organic nitrogen compounds mineralisation in ombrophilous peat soils in Zielony Mechacz and Budwit objects is distinctly limited through prevailing habitat conditions. The raise of underground water level in terrains after exploitation of peat, favours the renaturation process and significantly limits the discharge rate of mineral nitrogen forms both in peat in the terrain of the former mine, and in peat in the terrains of the neighbouring reserve.

2. In raised bog of Zielony Mechacz and Budwity objects very small quantities of nitrates have been stated and only in boggy forest peat appeared the influence of the mine on raising that mineral nitrogen content form to average and high quantities. At present the low rate of the nitrification process does not pose any threat to ombrophilous peat soils; however the renaturation process of these soils should be continued.

3. The concentration of mineral nitrogen compounds in underground water of the ombrophilous boggy forest peat was differentiated and depended on mineralisation dynamics of organic matter in soils. The highest concentrations of mineral nitrogen have been found in underground water of boggy forest peat located on the boundary between the peat mine and the terrain after exploitation. It is the intensification effect of the nitrification process and washout of these compounds.

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DYNAMIKA ZAWARTOŚCI MINERALNYCH FORM AZOTU W OMBROFILNYCH GLEBACH ORGANICZNYCH I W WODACH GRUNTOWYCH

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Abstrakt: Celem badań było określenie dynamiki mineralizacji organicznych związków azotu w ombrofilnych glebach organicznych i w wodach gruntowych na obiektach: Zielony Mechacz i Budwity.

Warunki siedliskowe, a zwłaszcza właściwości wodne torfowiska wysokiego, istotnie wpływały na dynamikę mineralizacji organicznych związków azotu oraz na ilość gromadzonego $N\text{-}NO_3$ i $N\text{-}NH_4$ w glebie i w wodach gruntowych. W ombrofilnych glebach organicznych w rezerwacie, w którym zachowane są naturalne warunki siedliskowe, jak również w glebach torfowych położonych na terenach po byłej kopalni torfu, mineralizacja materii organicznej w badanych sezonach była niewielka. W torfach wysokich stwierdzono bardzo małe ilości azotanów, a jedynie w torfach boru bagiennego położonego na granicy między rezerwatem i kopalnią zawartość tej formy azotu była średnia i duża. Świadczy to o zahamowaniu procesu nitryfikacji i degradacji gleb torfowych. Stężenie mineralnych związków azotu w wodach gruntowych ombrofilnych torfowisk było zróżnicowane i zależało od zachodzącej w ombrofilnych glebach organicznych dynamiki mineralizacji materii organicznej.

Słowa kluczowe: mineralizacja, torfowisko wysokie, woda gruntowa, warunki siedliskowe