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Original Article

Peat - Moorsh Soils in the Process of Purification of Ground Water

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Abstract

4.5 km long transect of peatland located on secondary transformed peat-moorsh soils has been subjected to the purification of ground water. There is this element of the landscape in the Agroecological Landscape Park in Turew, 40 km South-West of Poznan, Poland, along Wyskoć ditch. pH, the contents of total and dissolved organic carbon (TOC and DOC), N-total, N-NO_3^-, N-NH_4^+ in peats were determined. Additionally C/N ratios of peats were estimated. In water from Wyskoć ditch and in ground water dissolved total carbon and dissolved organic carbon were also measured. The investigation has revealed the impact of the peatland located on the secondary transformed peat-moorsh soils on the changes of total nitrogen, ammonium, and nitrates as well as total and dissolved organic carbon in ground water. Peatland decreases efficiently the concentration of the following compounds in ground water: nitrates 38.5%, N-organic 10%, N-total 24.5%, ammonium 38.7%, dissolved total carbon 33.1%, dissolved total inorganic carbon 10%, and dissolved organic carbon 57.5%.

Keywords: secondary transformation of peat, N-total, N-NO_3^-, N-NH_4^+, E_4/E_6

1. Introduction

Natural, compatible structures which assist in controlling matter cycles in agricultural landscape are of great importance for enhancement of a countryside resistant to degradation. Various plant cover structures like peatlands, grasslands, stretches of meadows, hedges, shelterbelts, riparian vegetation strips are of special interest.

But most important from the point of ecological engineering, is that the biogeochemical barriers exert controlling effects on nonpoint pollution.

Peatlands belong to the stable elements in the landscape, which regulate water regime in soils, restrain soil erosion, improve microclimate for agricultural production, and create refuge sites for wildlife.

Peatlands show substantial ability to limit spread of chemical elements among the ecosystems in the agricultural landscape [4, 7, 16, 17].

Mechanisms responsible for these processes are still elusive, but are generally assumed that the following processes are important: plant uptake and ion exchange capacities.

A better understanding of the impact of low moor peatland on the decrease the quantities of chemical compounds in ground water should increase our ability to predict the improvement of the quality of ground water.

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Nitrate, ammonium and phosphate pollution caused by using of inorganic fertilizers are especially a great threats for rural areas and led to the eutrophication of ground water. Many physical, chemical, biochemical and biological processes control dispersion of these chemical compounds in soils and finally all these processes depend on the organic matter content and particularly on humic substances [6, 18, 19, 22]. Therefore organic matter plays pivotal roles in several processes, conversions and mechanisms in peatlands, including detoxication of anthropogenic chemicals, C sequestration, water retention, nutrient cycling, soil structure formation and energy supply to soil microorganisms. These processes include biological conversion, biochemical and chemical degradation, reduction, and hydrolysis etc. [2, 9].

Thus they lie at heart of leading environmental and agricultural issues.

The goal of this study was to investigate the influence of peatland located in agricultural landscape on the transformation of inorganic and organic forms of nitrogen in soil, and in water of ditch as well as in ground water in order to understand their role in functioning peatland as biogeochemical barriers. Additionally, the results obtained from the experiments should give a better insight into the changes, which take place in organic matter of secondary transformed peat-moorsh soils, and in water of ditch as well as in ground water of peatland.

2. Material and Method

The research site was a transect of peatland 4.5 km long located in the Agroecological Landscape Park host D. Chlapowski in Turew (40 kilometers South-West of Poznan, West Polish Lowland). Peat - moorsh soils were described and classified according to Polish hydrogenic soil classification [10, 22] and World Reference Base Soil Resources, 1998 [21]. The investigated points were located along to Wyskoć ditch (fig. 1). Two times a month during whole vegetation season the following material was taken from four chosen sites marked as Zbechy (No 1), Bridge (No 2), Shelterbelt (No 3) and Hirudo (No 4):

- samples of peat, from the depth of 0-20 cm,
- samples of water from the ditch,
- samples of ground water from wells established for this investigation.

Soils were sampled from 10 sites of each site. Samples were air dried and crushed to pass a 1 mm-mesh sieve. These 10 sub-samples were mixed for the reason of preparing a "mean sample", which used for the determination of pH (in 1M KCl), dissolved organic carbon (DOC), total organic carbon (TOC), total nitrogen (N-total), and nitrates ($N\text{-}NO_3^-$) as well as ammonium ($N\text{-}NH_4^+$). pH, N-total, $N\text{-}NO_3^-$, $N\text{-}NH_4^+$, DTC (dissolved total carbon) and DOC (dissolved organic carbon) was measured in: groundwater, water from Wyskoć ditch.

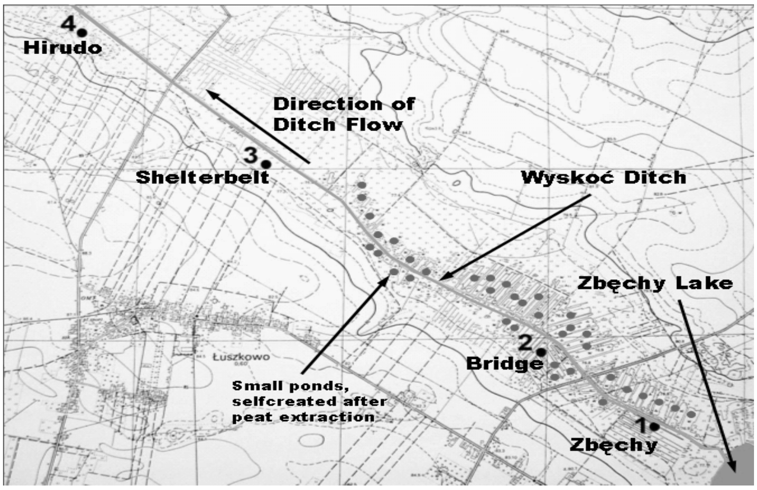

Figure 1. The map of the investigated peatland

Twice distilled water from silica glass equipment was used. For the investigation of DOC, soil samples were heated in redistilled water in 100°C by two hours under reflux condenser.

Extracts were separated by the mean filter paper and analyzed on TOC 5050 A facilities (Shimadzu, Japan) [13].

N-total were evaluated by the semimicro-Kjeldahl methods, ammonium and nitrate ions by Sprurwaya method [11, 14].

Isolation of humic acids (HA) was achieved using standard IHSS procedure (Swift, 1996). According to Chen et al. (1977), 3 mg of HA was dissolved in 10 ml of the following solutions: 0.05 M $NaHCO_3$. Absorbances at λ=465 nm (E_4) and λ=665 nm (E_6) of HA in 0.05 M $NaHCO_3$ were measured and E_4/E_6 ratios calculated from spectrums in visible region. BECKMAN DU®-68 spectrophotometer with 1 cm thickness of layer was used for spectrometric measurements.

Satisfactory precision based on replicate analyses, were: ±0.01 for pH measurements, ±3.5% for TOC, ± 3.4% for DOC, ± 4.3% for N-total, ± 3% for $N\text{-}NO_3^-$, ± 3% for $N\text{-}NH_4^+$.

All the experiments were performed in 5 replicates, and the results averaged. All the chemicals used in this study were of analytical grade. A summary of the soil and water characteristics are presented in table 2 and table 3.

Table 1.Some properties of peat-moorsh soil

Place	Type of peat-moorsh	Stage of soil moorshification, degree of decomposition	Kind of moorsh formation
Zbechy	Wooden-sedge moorsh soil with peat, light degree of moorsh process MtI, deep soil developed with low *Carex-Phragmiteti* strongly decomposed (sapric) peat, 10YR 2/1 black, amorfic-fibrus structure. The upper peat horizon have thin 1-2 mm mineral layers. Peaty muck horizon with subangular blocky structure with low fiber content. Moorsh horizon Mt 0-10cm depth. Polish hydrogenic soil classification (Okruszko, 1976): MtIcc. World Reference Base (WRB, 1998) soil notation: Sapri-Eutric Histosols.	MtIcc 0-20 cm, R3	Z_1
Bridge	Alder, moorsh soil with peat, medium degree of moorsh process MtII, deep soil developed with low strongly decomposed (sapric) wood peat, 10YR 2/1 black, angular blocky structure. Humic muck horizon with subangular blocky microstructure. Very good developed M1 moorsh sod subhorizon and subangular blocky M2 muck undersod subhorizon. Moorsh horizon Mt 0-20cm depth. Polish hydrogenic soil classification (Okruszko, 1976): MtIIcc. World Reference Base (WRB, 1998) soil notation: Sapri-Eutric Histosols.	MtIIcc 0-20 cm R3	Z_2
Shelterbelt	Sedge-rushes, moorsh soil with peat, strong degree of moorsh process MtIII, deep soil developed with low *Carex*-wood decomposed (sapric) peat, 10YR 3/1 very dark gray, angular-fibrus blocky structure. Moorsh horizon strongly draied, subangular blocky microstructure. Good developed subhorizons M1, M2. Degraded moorsh M3 subhorizon have light identificable. Moorsh horizon Mt 0-32cm depth. Polish hydrogenic soil classification (Okruszko, 1976): MtIIIcc. World Reference Base (WRB, 1998) soil notation: Sapri-Eutric Histosols.	MtIIIcc 0-20 cm R3	Z_2 Z_3
Hirudo	Alder, moorsh soil with peat, medium degree of moorsh process MtII, deep soil developed with low wood decomposed (sapric) peat, 10YR 2/2 very dark brown, angular blocky structure. Moorsh horizon strongly draied, subangular blocky macro and microstructure. Good developed sod and undersod subhorizons M1 and M2. Moorsh horizon Mt 0-20cm depth. Polish hydrogenic soil classification (Okruszko, 1976): MtIIcc. World Reference Base (WRB, 1998) soil notation: Sapri-Eutric Histosols.	MtIIcc 0-20 cm R3	Z_2

Mt- stage of soil moorshification, MtI- weakly moorshified, MtII- medium moorshified, MtIII-strongly moorshified; according to classification WRB 1998-Sapri-Eutric Histosols, Z_1- grain moorsh, Z_2- peaty moorsh, Z_3- humic moorsh.

3. Results

Investigated peatland represents different kind of peat-moorsh soils (table 1). Our earlier investigations shown that organic soils of the transect represent different stage of moorshification, which characterized different kind of chemical properties [15]. Zbechy located in the beginning of peatland is characterized by weak moorshfied soil. With an increase of the distance from the edge of peatland soils are medium and strongly moorshified.

The most moorshified is the soil of Shelterbelt, representing peaty and humic moorsh.

All the soils represented from slightly acidic (No 2 and 4) to neutral properties (No 1 and 3).

In peat moorsh soils the values of pH's ranged from 5.82 to 7.56 (table 2)[17].

The highest pH was measured in peat from Shelterbelt and the lowest in Hirudo.

Table 2.Contents of chemical compounds in the peat-moorsh soils

Place of sampling	Oscillation of ground water cm	pH in 1M KCl	DOC %	TOC %	N-total %	TOC/N	HA E_4/E_6
Zbechy	69-109	6.22-6.97	0.37 0.22-0.51	22.54 16.73-32.12	2.01 1.64-2.62	12.33 8.81-19.57	7.12
Bridge	68-119	6.00-6.46	0.43 0.31-0.49	33.25 30.18-36.37	2.14 1.54-2.82	16.25 12.88-21.35	6.19
Shelterbelt	51-111	7.05-7.56	0.49 0.42-0.56	30.23 27.53-33.23	2.01 1.55-2.62	14.37 9.70-20.32	7.02
Hirudo	90-148	5.82-6.41	0.40 0.33-0.48	26.47 14.67-35.9	2.19 1.55-2.54	11.92 6.58-14.14	6.64

HA-humic acids, DOC-dissolved total carbon, TOC-total organic carbon, bold-mean, italic-range

The concentrations of TOC ranged from 14.67% to 36.37% in peat-moorsh soils. The highest yearly mean content of TOC was determined in Bridge and was equal to 33.25% and the smallest was measured in Zbechy and was 22.54%. The concentration of DOC ranged from 0.22 to 0.56%. The smallest yearly mean content of DOC revealed Zbechy and was equal to 0.37%. Although the highest concentration of DOC was characterized in Shelterbelt and was equal to 0.49% (table 2).

Yearly mean content of N-total ranged from 2.0l to 2.19%. However the highest content of N-total was observed in Hirudo and was connected with high concentration of low content of TOC. The ratios TOC/N-total ranged from 11.92 to 16.25. However the highest ratio of TOC/N-total was connected with the highest content of TOC and with high concentration of DOC as well as N-total. Thus, an increase of TOC/N-total ratios was connected with the degree of the secondary transformed peat moorsh soils [15] (table 2).

High value of E_4/E_6 reflects a lower degree of condensation and polyconjugation in the molecules of HA from 7.12 at Zbechy that from other places of the transect (table 2). The values of pH are ranged from 7.11 to 7.80 in the water from Wyskoć ditch (table 3). Low pH was determined in Zbechy and high in Shelterbelt and Hirudo. An increase of the values of pH with an increase of the distance from the edge of peatland was observed. The content of $N\text{-}NO_3^-$ ranged from 0.14 to 1.87 mg/l (table 3). The highest yearly mean content of $N\text{-}NO_3^-$ equaled to 0.83 mg/l was observed in Zbechy in the beginning of peatland. The decrease of the concentration of nitrates with an increase of the distance from the edge of peatland was showed. The decrease of the concentration of nitrates from the edge of peatland was equal to 32.5%. The content of N-total ranged from 1.12 to 16.24 mg/l in the water from Wyskoć ditch (table 3). The lowest yearly mean content of N-total was measured in the water from the Bridge (4.82 mg/l) and the highest was estimated in Shelterbelt (7.19 mg/l).

Table 3. Contents of chemical compounds in the water from Wyskoć ditch and ground water

Place of sampling	pH	$N\text{-}NO_3^-$ mg/l	N-total mg/l	$N\text{-}NH_4^+$ mg/l	N-org mg/l	DTC mg/l	DOC mg/l
Wyskoć ditch							
Zbechy	7.11-7.47	0.83 0.13-2.41	6.99 1.12-12.88	1.80 0.84-2.80	5.19 0.28-10.08	51.82 44.71-71.10	16.34 11.31-19.71
Bridge	7.19-7.70	0.51 0.19-1.04	4.82 1.12-9.52	2.28 1.12-3.36	2.54 0.00-7.84	53.17 46.25-65.00	17.17 14.89-19.85
Shelterbelt	7.21-7.72	0.41 0.16-1.24	7.19 1.68-16.24	2.44 1.12-3.92	4.75 0.56-14.00	66.86 46.25-65.00	20.44 15.73-24.73
Hirudo	7.11-7.80	0.56 0.14-1.87	5.60 1.96-10.64	2.28 1.68-2.80	3.32 0.28-8.40	58.50 45.94-81.86	15.48 12.76-18.21
Ground water							
Zbechy	6.51-7.06	0.52 0.50-0.55	11.39 8.40-14.56	5.76 5.60-5.88	5.60 2.80-8.68	169.73 159.00-183.50	82.75 81.25-84.59
Bridge	6.78-7.52	0.44 0.30-0.63	11.01 8.96-13.44	6.25 5.88-6.16	4.76 3.08-6.72	178.43 171.00-189.50	64.90 60.70-68.50
Shelterbelt	6.40-7.46	0.46 0.35-0.64	10.08 8.96-11.76	3.74 3.36-4.48	7.34 4.48-11.37	137.47 135.70-139.70	32.97 31.00-36.00
Hirudo	6.98-7.44	0.32 0.25-0.35	8.59 7.00-10.08	3.55 1.68-7.28	5.04 2.80-7.00	113.53 108.10-121.90	35.17 30.14-38.09

DTC-dissolved total carbon, DOC-dissolved organic carbon, bold-mean, italic-range

The concentrations of $N\text{-}NH_4^+$ ranged from 0.84 to 3.92 mg/l (Table 3). The highest concentration of $N\text{-}NH_4^+$ was determined in Shelterbelt and the lowest in Zbechy. The highest N-org quantities in water from Wyskoć ditch was equal to 5.19 mg/l in the beginning of the transect (table 3). The decrease of the contents of N-org with an increase of the distances from the edge of peatland was observed. The decrease of the N-org was equal to 36% during entire transekt. In this amounts are included the organic substances representing humic and fulvic acids and also dissolved organic compounds, which chemical structure are well known [16, 8, 1].

The contents of DTC determined in the water from Wyskoć ditch ranged from 44.71 to 81.86 mg/l and DOC from 11.31 to 24.73 mg/l. The concentration of DTC and DOC in water from Wyskoc ditch changed similarly. The highest concentration of DTC and DOC were measured in Shelterbelt and equaled to 66.86 mg/l and 20.44 mg/l, respectively (table 3).

pH's values of ground water from the wells established for this investigation ranged from 6.40 to 7.52 (table 3). High values of pH were observed in Hirudo and the small in Zbechy. The concentration of $N\text{-}NO_3^-$ changed with an increase of the distance from the edge of peatland. The highest yearly mean content of $N\text{-}NO_3^-$ was measured in the beginning of the transect and was equal to 0.52 mg/l and the lowest was determined in Hirudo equaled to 0.32 mg/l, representing the end of the transekt. The decrease of the $N\text{-}NO_3^-$ during whole transect of peatland was equal to 38.5%.

The changes of $N\text{-}NH_4^+$ concentrations were similar like $N\text{-}NO_3^-$. The decrease of $N\text{-}NH_4^+$ quantities with an increase of the distance from the edge of peatland was revealed. However the decrease $N\text{-}NH_4^+$ was equal to 38.5% during entire peatland. In addition the decrease of the concentration of N-total was observed. The highest content of N-total was determined in Zbechy and equaled to 11.39 mg/l (table 3). It was revealed the decrease of the content of N-total with an increase of the distance from the edge of peatland. Along 4.5 km long of the peatland the decrease of the N-total was equal to 25%. The concentrations of N-org decrease with an increase of the distance of peatland. The decrease of organic compounds including nitrogen in their structures was equal to 10%.Two forms of carbon revealed high decrease with an increase of the length of the transect. These forms represent organic compound which are available for plant and microorganisms. During entire vegetation season DTC concentration ranged from 108.1 to 189.5 mg/l. However yearly mean content of DTC was the highest in Zbechy and the lowest in Hirudo 169.73 mg/l and 113.53, respectively. The decrease of the TOC with increase of the distance of peatland was equal to 33.1%.

Similar changes like TOC was measured in DOC in ground water from the special wells established for this investigation. The highest content of DOC was observed in the beginning of the transect and was equal to 82.75 mg/l. The lowest content of DOC was determined in ground water taken from Hirudo and was equal to 113.53 mg/l. The decrease of DOC was equal to 57.5% along the distance of the transect (table 3).

Our investigations revealed that peatland seems to be very effective element of the landscape for removal of dissolving organic carbon and nitrogen compounds from-throug-flowing waters when the nitrogen is in the form of nitrate rather than ammonium N or dissolved organic N. This element of the landscape, representing soil-plant system, plays significant function in the purification of ground water.

4. Conclusions

Our researches has revealed the impact of the peatland located on the secondary transformed peat moorsh soils on the changes of total nitrogen, ammonium, nitrates as well as total and dissolved organic carbon in ground water.

Peatland located on secondary transformed peat moorsh soils acts in the direction of lowering nitrogen and carbon compounds in ground water.
Peatland decreases the concentration of the following compounds in ground water: nitrates 38.5%, N-organic 10%, N-total 24.5%, ammonium 38.7%, dissolved total carbon 33.1%, dissolved total inorganic carbon 10%, and dissolved organic carbon 57.5%.

The transformation of different forms of nitrogen and carbon in ground water is strongly connected with the humification processes in peat.

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