Groundwater quality against a background of human activities and impact of peatland area

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Abstract. The main objective of the study was an analysis of groundwater quality in a well on an extensive agricultural farm located near in the vicinity of peatlands. The influence of peatland and human activities on water quality was analysed. Thirty-six series of water samples were collected for the period from May 2000 to November 2005 from the well located at the farm and from wells located in the transect on the peatland area. In the collected water samples of pH and concentration of $N\text{-}NO_3$, $N\text{-}NH_4$, P, DOC, Na, K, Fe and Cl were determined. Mean values of $N\text{-}NO_3$, K, Na and Cl concentrations in water from the farm well were higher than concentrations recorded in the control wells from the transect located on the peatland area. Higher $N\text{-}NH_4$ and DOC concentrations were observed in water from the peatland. The results of these investigations showed that human activities on the farm area have a larger impact on groundwater quality than the peatland located near the farm.

Key words: peat soils, groundwater, farm well, water pollution

INTRODUCTION

The research was conducted in the Biebrza River Valley where wetlands (non-drained and drained) occupied about 30% of the total area (Dembek, 2004). Organic soils of the sites are highly sensitive to moisture regime changes, which are often induced by human activities. Drainage of these soils led to organic matter decession caused by mineralization and humification processes (Okruszko & Kozakiewicz, 1973). These processes caused ground and surface water pollution by the products of chemical and biological transformations of the soils (Sapek B., 1996; Kalbitz et al., 2002; Kalbitz & Geyer, 2002; Sapek, 2002). Mineral and organic substances released during mineralization and humification processes can create the potential hazard of water quality decrease (Zahn, 1993; Dojlido, 1995; Smoroń, 1998; Nadany & Sapek, 2004). It is especially important in the area adjacent to peatlands where the danger of water pollution is very high and groundwater is used for fulfilment of human and livestock water needs. Agricultural production in rural areas and domestic wastes also can create the hazard of water pollution. Rural areas located near peatlands are subject of groundwater pollution by agriculture and by products of soil mineralization and humification.

The main objective of the study was an analysis of groundwater quality in a well located on an extensive agricultural farm located in the vicinity of peatlands. The influence of peatlands and human activities on water quality was analysed.

MATERIALS AND METHODS

Water samples were collected from the traditional (meaning made of rings) farm well located within an agro-tourist farm in Gugny village in the Middle Biebrza River Basin within the Biebrza National Park (Fig. 1). The examined farm was typical of the surrounding farms of the village. The population density of the area is very low and some farms are used only during the summer season. The livestock production is aimed to fulfil the needs of the inhabitants and tourists. The observation well was about 4 m deep and the groundwater level ranged from 1.5 to 2 m below the soil surface. The farm was located on a small mineral island at a distance of about 100 m from the border of the peatland. In the considered village the typical agricultural production had been abandoned, therefore the potential water pollution could only be the result of improper waste management.

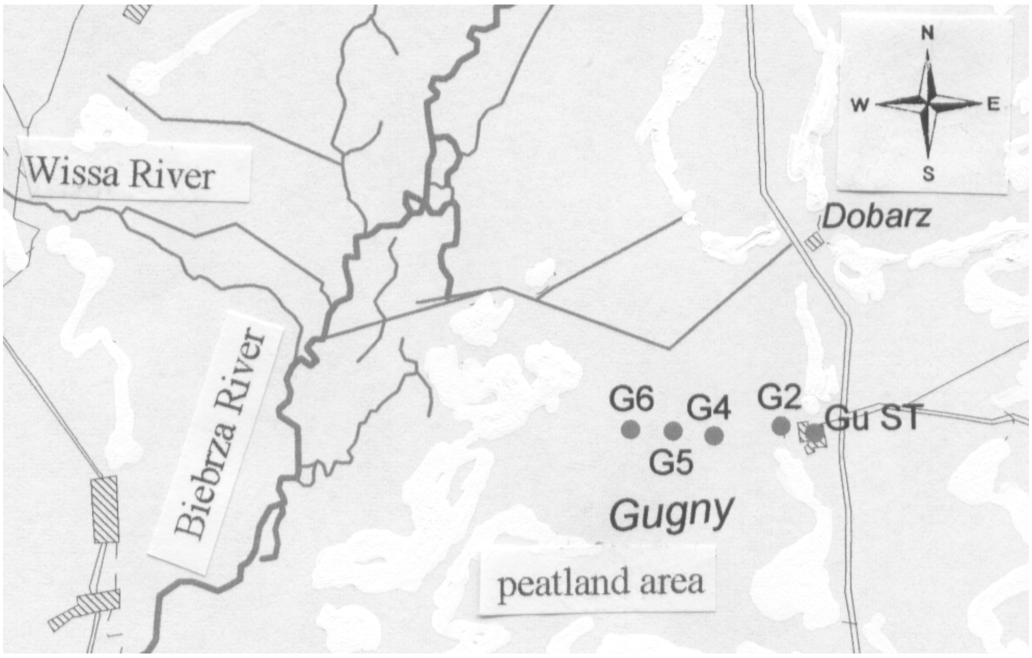

Fig. 1. Location of the transect and the farm well (Gu ST - the farm well; G2. G4, G5, G6 - control wells on peatland).

In order to study the influence of the peatland on the farm well water quality, control wells were installed in a transect created within the Biebrza River flooding area. The four wells were installed at a distance of 150, 400, 700 and 1000 m from the border of Bagno Ławki peatland, respectively. The walls of each well were perforated and placed within peat layers at the depth of about 60 cm. The study area was not drained and in the past had been used as extensive meadows. Cutting of meadows common in the 20th century was abandoned in the mid-1990's. Peat soils of this area are characterised by the low advance of the moorshing process and by very low intensity of peat accumulation. The groundwater level in control wells has fluctuated from 0-50 cm, sporadically 80–90 cm.

Thirty-six series of water samples were collected from May 2000-November 2005 at an average interval of 6 weeks. In the collected samples, pH and concentrations of nitrate, ammonia, phosphates and dissolved organic carbon (DOC) were determined using the colourymetric method; concentration of sodium and potassium, using the atomic spectrometric adsorption method, and concentration of chlorides, by titration. The Polish standards for groundwater quality (Polish regulations, 2004) were used for the assessment of quality of sampled water in the wells. According to the Polish standards the maximum allowed concentration values must not exceed the following: 100 mg dm^{-3} (22.6 N-NO_3) for nitrate nitrogen, 3 mg dm^{-3} (2.34 N-NH_4) for ammonia nitrogen, 5 mg dm^{-3} (1.63 P) phosphorus, 20 mg dm^{-3} for potassium, 500 mg dm^{-3} for chlorides and 300 mg dm^{-3} for sodium. In the case of dissolved organic carbon content the maximum allowed concentration values must not exceed 20 mg dm^{-3} for Vth class (the worst one). The above mentioned standards are not related to drinking water for which requirements are higher.

The correlation coefficients were calculated for concentrations between all ions which were measured in water from the farm well and control wells. Also calculated were mean values of each investigated compound and percentage of samples in Vth water quality class.

RESULTS

The greatest menace to water quality in the farm well resulted from the presence of potassium (Table 1). Overload concentration of this component was recorded in 86% of analysed water samples. Well water quality was also made worse by nitrate: concentration in certain periods reached a value of 130–250 mg dm^3. Relatively large numbers of water samples were characterised also by concentration of dissolved organic carbon higher than normal value, but concentrations never exceeded 30 mg dm^3. The water from the farm well showed satisfactory quality, taking into consideration sodium, chlorides and magnesium concentrations with regard to normal values. Asignificant, positive correlation between nitrate and chlorides, sodium, potassium and magnesium concentration in water samples was found (Table 2). Chlorides, as well as sodium and potassium in the well water, can derive from domestic wastes (Sapek A. 1996; Misztal, Sapek 1997; Ostrowska, Płodzik 1999; Ostrowska in 1999; Sapek B. 2002). The high sodium concentration is caused by wastewater, while livestock production can strongly influence increased potassium concentration in groundwater. Potassium predominance in the farm well water samples was observed during the first research period (May 2000 – July 2002), probably caused by livestock production on the farm before abandonment. The positive correlation between potassium and dissolved organic carbon concentrations was also observed. In the course of the research, water samples exhibited high concentrations of sodium, indicating that wastewater from the farm strongly influenced groundwater quality. Lack of correlation between nitrate, ammonia, chlorides, sodium and concentration of dissolved organic carbon indicates insignificant participation of organic matter in nutrient transfer from farmstead to groundwater (Table 2).

Table 1. Characteristics of water quality from the farm well.

Statistics	Concentration (mg dm^{-3}) of components							pH
	NO_3	NH_4	PO_4	K	Na	Cl	DOC	
Mean	88.5	0.4	0.81	38.4	37.1	35.9	20.5	7.4
Standard deviation	57.2	0.9	0.46	17.5	20.9	19.8	5.0	
Percentage of samples in Vth water quality class	39	3	0	86	0	0	46	

Table 2. Correlation coefficients, significant at P <0.05 for water samples from farm well (n = 36). Sign "-" – an inessential correlation.

	N-NO$_3$	**N- NH$_4$**	**Cl**	**Na**	**K**	**Mg**	**Ca**	**Fe**	**DOC**
P	-	-	-0,41	-	-0,33	-0,35	-	-	-
N-NO$_3$		-	0,60	0,72	0,37	0,69	0,33	-	-
N- NH$_4$			-	-	-	-	-	0,51	-
Cl				0,88	0,77	0,80	0,60	-	-
Na					0,68	0,78	0,56	-	-
K						0,59	-	0,37	0,44
Mg							0,41	-	-
Ca								-	-
Fe									0,47

Table 3. Characteristics of water quality from the control well located in the transect at distance of 150 m (no. 1) from the border of the peatland.

Statistics	Concentration (mg dm^{-3}) of components							pH
	NO_3	NH_4	PO_4	K	Na	Cl	DOC	
Mean	5.9	2.1	0.7	1.4	5.6	7.7	18.0	6.5
Standard deviation	6.9	7.2	0.8	0.9	1.5	2.1	9.0	
Percentage of samples in Vth water quality class	0	9	0	0	0	0	31	

Table 4. Characteristics of water quality from the control well located in the transect at distance of 400 m (no. 2) from the border of the peatland.

Statistics	Concentration (mg dm^{-3}) of components							pH
	NO_3	NH_4	PO_4	K	Na	Cl	DOC	
Mean	7.2	1.2	0.3	1.8	8.3	7.5	27.0	6.8
Standard deviation	6.6	2.3	0.3	1.0	2.0	2.4	17.0	
Percentage of samples in Vth water quality class	0	12.5	0	0	0	0	60	

Table 5. Characteristics of water quality from the control well located in the transect at distance of 700 m (no. 3) from the border of the peatland.

Statistics	Concentration (mg dm^{-3}) of components							pH
	NO_3	NH_4	PO_4	K	Na	Cl	DOC	
Mean	8.3	2.9	0.9	1.8	8.7	6.5	26.9	6.5
Standard deviation	11.5	9.5	2.0	1.5	1.5	2.6	12.9	
Percentage of samples in Vth water quality class	0	14	6	0	0	0	67	

Table 6. Characteristics of water quality from the control well located in the transect at distance of 1000 m (no. 4) from the border of the peatland.

Statistics	Concentration (mg dm^{-3}) of components							pH
	NO_3	NH_4	PO_4	K	Na	Cl	DOC	
Mean	11.4	8.7	2.0	3.3	9.5	8.3	50.9	6.8
Standard deviation	26.4	29.3	4.7	3.3	1.9	2.0	27.5	
Percentage of samples in V^{th} water quality class	3	18	15	0	0	0	92	

The average concentrations of nitrate, potassium, sodium and chlorides in water from all four-control wells located in the transect were lower in comparison with concentrations measured in the farm well water (Tables 3–6).

In the case of ammonia ion and dissolved organic carbon, concentrations in the wells located in the transect were higher in comparison to the farm well. Average phosphate concentration in water from control wells no. 1 and 2 was lower than in the farm well, but were higher in control wells no. 3 and 4. It was observed that average concentration of all considered components was higher towards the centre of the peatland. Ammonia ion was four times more present in the last well than in the first. Significant differences were observed also for phosphates, potassium and dissolved organic carbon concentrations.

The differences of pH in the water samples from control wells are caused mainly by higher concentration of ammonia ion in water, which essentially influences pH values (Tables 3–6).

Some water samples from control wells no. 1 and 2 can be classified into V^{th} class of aquifer ground water quality because ammonia ion and dissolved organic carbon concentrations (Tables 3–6) were exceeding the critical norm values. Additionally, in control wells no. 3 and 4 the phosphate concentration and, in one water sample of control well no. 4, both phosphate and nitrate were exceeding the critical norm values.

Potassium, sodium and chloride concentrations in control wells water were relatively low and stable during the entire research period. However, precipitation water or river flooding could bear a strong influence on concentrations of the above-mentioned components.

Significant positive correlation between ammonia ion and phosphate concentration is often observed in peatlands groundwater. This correlation was also detected in water samples from control wells no. 2 and 4., but did not occur in water samples from control wells no. 1 and 3 (Tables 7–10). In water from the control wells positive correlation between concentration of dissolved organic carbon, potassium and sodium concentration as well as phosphates in control well no. 4 was observed. In contrast with water from the farm well, correlation between nitrate and other considered components was not observed in the control wells.

Table 7. Correlation coefficients, significant at $P < 0.05$ for water samples from control well no. 1; ($n = 36$). Sign "-" – an inessential correlation.

	$N\text{-}NO_3$	$N\text{-}NH_4$	Cl	Na	K	Mg	Ca	Fe	DOC
P	-	-	-	-	-	-	-	-	-
$N\text{-}NO_3$		-	-	-	-	-	-	-0,37	-
$N\text{-}NH_4$			-0,43	0,55	0,42	0,54	-	-	-
Cl				-	-0,45	-0,37	-	-	-
Na					0,73	0,82	-	-	0,57
K						0,74	-	-	0,65
Mg							-	-	0,54
Ca								-	-
Fe									-

Table 8. Correlation coefficients, significant at $P < 0.05$ for water samples from control well no. 2; ($n = 36$). Sign "-" – an inessential correlation.

	$N\text{-}NO_3$	$N\text{-}NH_4$	Cl	Na	K	Mg	Ca	Fe	DOC
P	-	0,36	-	-	-	-0,36	-	0,70	-
$N\text{-}NO_3$		-	-	-	-	-	-	-	-
$N\text{-}NH_4$			-	-	-	-	-	-	-0,48
Cl				-	-	-	-	-	-
Na					-	0,42	-	-	0,39
K						-	-0,37	-	-
Mg							0,63	-	-
Ca								-	-
Fe									-

Table 9. Correlation coefficients, significant at $P < 0.05$ for water samples from control well no. 3; ($n= 36$). Sign "-" – an inessential correlation.

	$N\text{-}NO_3$	$N\text{-}NH_4$	Cl	Na	K	Mg	Ca	Fe	DOC
P	-	-	-	0,43	0,44	-	-	0,40	-
$N\text{-}NO_3$		-	-	-	-	-	-0,36	-	-
$N\text{-}NH_4$			-	-	-	-	-	-	-0,40
Cl				-	0,35	-	-	-	-
Na					0,55	0,39	-	-	-
K						-	-	-	-0,32
Mg							0,59	-	-
Ca								0,55	0,40
Fe									0,37

Table 10. Correlation coefficients, significant at $P < 0.05$ for water samples from control well no. 4; ($n = 36$). Sign "-" – an inessential correlation.

	$N\text{-}NO_3$	$N\text{-}NH_4$	Cl	Na	K	Mg	Ca	Fe	DOC
P	-	0,89	0,47	-	0,89	0,66	0,72	0,64	0,51
$N\text{-}NO_3$		-	-	-	-	-	-	-	-
$N\text{-}NH_4$			0,54	-	0,92	0,76	0,73	0,50	-
Cl				-	0,46	0,53	0,43	-	-
Na					-	0,52	0,33	-	0,52
K						0,62	0,59	0,45	0,33
Mg							0,79	0,50	0,48
Ca								0,73	0,58
Fe									0,64

In this study, positive correlation between dissolved organic carbon and iron in water from farm well (r = 0,47; n = 26) and control well no. 3 (r = 0,37; n = 27) and no. 4 (r = 0,64; n = 25) was also observed. This relationship was stronger towards the centre of the peatland.

DISCUSSION

Mean values of nitrate, potassium, sodium and chlorides concentrations in water from the farm well were higher than concentrations recorded in the wells from the transect located on the peatland area. Even the highest concentrations of the above parameters in the wells from the transect were lower than the lowest concentrations measured in water from the farm well. This means that the peatland area is not polluting the water in the farm well. The high mineral concentrations and continuous pollution were the result of improper waste management at the farm. This is confirmed by the obtained relationships between concentrations of nitrate and potassium as well as sodium and chlorides in water from the farm well. Such relationships were not obtained for the water collected from the transect wells, indicating different sources of origin of the above mentioned parameters (Ballestro & Douglas, 1997; Sapek & Sapek, 2007).

The mineralization of peat organic material resulted in higher concentrations of ammonia nitrogen in the wells located in the peatland area in comparison with those measured in the farm well. During the first stage of peat mineralization, the ammonification process is dominating, leading to ammonium emission.

The concentrations of dissolved organic carbon in water from the farm well can be influenced by wastewater management on the farm area as well as by humus substance concentrations in the water from the peatland area. The average concentration of dissolved organic carbon recorded in the farm well was very close to the values measured in the transect well no 1 which was located 150 m from the border of the peatland. It was observed that the higher concentrations of dissolved organic carbon in those wells correspond to higher iron concentrations. Fulvic and humic acids, which are the products of peat soils organic matter decomposition, are closely related to iron transformation (Sapek & Sapek, 1994). Positive correlation between dissolved organic carbon and iron in water from the farm well and control wells no. 3 and 4 was recorded. This relation has not been observed in water from wells no. 1 and 2, placed nearer to the farm well. Therefore it is probable that the dissolved organic carbon pollution was not caused by the peat organic matter decomposition.

The degradation processes of peat soils organic matter are the source of many mineral compounds and new organic substances which are leaching out to groundwater and surface water, causing their pollution. The results of these investigations showed that human activities have a larger impact on groundwater quality than the nearby peatland.

CONCLUSIONS

1. Human activities on the farm area had greater impact on farm well water quality than pollution present in groundwater of the neighbouring peatland.

2. Mean nitrate, potassium, sodium and chloride concentrations in water from the traditional well located at the farm were larger than in groundwater from the control wells located in the peatland.
3. Higher ammonium and dissolved organic carbon concentrations were observed in the wells located in the middle of the peatland area.
4. Overload concentration of potassium, dissolved organic carbon and nitrate was recorded respectively: in 86%, 46% and 39% of the samples collected from the farm well.

REFERENCES

Ballestro, P.& Douglas, E.M. 1997. Comparison between the nitrogen fluxes from composting farm wastes and composting yard wastes. *Trans. ASAE* 39 (5) s. 1709–1715.

Dembek, W., Pawlaczyk, P., Sienkiewicz, J. & Dzierża P. 2004. Obszary wodno-błotne w Polsce. *IMUZ at Falenty* (in Polish).

Dojlido, J. 1995. Chemia wód powierzchniowych. Białystok: Wydawnictwo Ekonomia i Środowisko (in Polish).

Kalbitz, K. & Geyer, S. 2002. Different effects of peat degradation on dissolved organic carbon and nitrogen. *Organic Geochemistry* **33**, 319–326.

Kalbitz, K., Rupp, H. & Meissner, R. 2002. N-, P and DOC-dynamics in soil and groundwater after restoration of intensively cultivated fens. In: Wetlands in Central Europe. *Springer,* pp. 99–116.

Misztal, A. & Sapek, A. 1997. Water quality in wells and agricultural/sociological characteristic of farms in the selected catchments of Dobczyce Reservoir. *Zesz. Edu. Wydaw. IMUZ Falenty* **3** s. 83–99.

Nadany, P. & Sapek, A. 2004. Variability of organic carbon concentrations in ground water of differently used peat soils. *Woda Środ. Obsz. Wiej.* **t. 4**, z. 2b(12), 281–289.

Okruszko, H. & Kozakiewicz, A. 1973. Humification and mineralization as mucking process elements in peat soils. *Zesz. Prob. Post. Nauk Rol.* **z. 146**, 63–76.

Ostrowska, B., Płodzik, M., Sapek, A., Wesołowski, P. & Smoroń ,S. 1999. Water quality in the farm wells. *Wiad. IMUZ t.* **20** z. 1 s. 7–18.

Ostrowska, B. & Płodzik, M. 1999. The influence of farmyard on the water quality. Wiad. IMUZ t. **20** z. 1 s. 19–7.

Polish regulations: Rozporządzenie Ministra Środowiska z dn. 11 lutego 2004r. w sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz sposobu interpretacji wyników i prezentacji stanu wód. Dz. U. 2004 Nr 32, poz. 284.

Sapek, A. & Sapek, B. 1994. The application of ion-exchanger and molecular sieves to fractionation of alkali soluble organic matter from moorsh and peat samples. Proc. of the International Symposium: "Conservation and Management of Fens", Warsaw-Biebrza, 6–10 June 1994, pp. 177–186.

Sapek, A. & Sapek, B. 2007. The water and soil quality changes in a farmstead and its vicinity as regards of storage way of natural fertilizers. *Zesz. Eduk. Wydaw. IMUZ Falenty* **11/07,** ss. 114.

Sapek, A.1996. Impact of agriculture on water pollution with nutrients . *Zesz. Eduk. Wydaw. IMiUZ Falenty* **1/96**. s. 9–33.

Sapek, B. 1996. Mineralization of organic matter in grassland silos as a nitrogen source. *Zesz. Eduk. Wydaw. IMiUZ Falenty* **1/96,** 75–85.

Sapek, A. 2002. Dispersion of phosphorus into environment – mechanisms and effects. *Zesz. Edu. Wydaw. IMiUZ Falenty* **7/02**, 9–24.

Sapek, B. 2002. Soil land Water quality in the demonstrational farms. Zesz. Edu. Wydaw. IMUZ Falenty nr 7 s. 57–71.

Smoroń, S. 1998. Eutrophication of surface water as an influence of biogenic compounds penetration from the agriculture sources to the environmental. Zesz. Edu. *Wydaw. IMUZ Falenty* **5**/98, 57–70.

Zahn, M.T. & Grimm, W-D. 1993. Nitrate and chloride loading as anthropologic indicators. *Water, Air and Soil Pollution* **68**, 469–483.