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QUALITY OF WELL WATERS IN CONTEXT OF THE CONTENT OF NITROGEN AND PHOSPHORUS COMPOUNDS IN THE UPPER NAREW RIVER VALLEY*

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Abstract

The paper dealt with the evaluation of concentration and spatial distribution of nitrogen and phosphorus forms in dug wells in selected farms in the upper Narew River valley. The study was also aimed at assessing the influence of selected elements of a farm on quality of well water. Examinations were carried out in 8 villages in Podlasie region. Three farm dug wells were selected for examination in each village. All wells take water from the first water-carrying level. The study included well waters within the section of the Narew River from the villages Sobótka to Złotoria. The checkpoints were set in: Sobótka, Narew, Ciełuszki, Kaniuki, Zawyki, Uhowo, Topilec, and Złotoria localized along the Narew and its adjacent lands. Water samples were collected in spring, summer and autumn 2006. Ammonia, nitrates (III), nitrates (V), and phosphates were determined in water samples filtered through micropore filters (d = 0.45 μm) by means of colorimetry applying a spectrometer HACH (DR-2000). Parameters of the analytical procedures were adjusted in accordance to the Decree of Minister for Environment (2004). In total, 288 determinations in three series were made. For each of the three wells from every village, the arithmetic means of the analyzed parameters were calculated on the basis of samples collected on three dates. The assessment of underground water quality was made according to the Decree of Minister for Environment of 11 February 2004 on on surface and underground water status, screening performance, interpretation and presentation of the status of such waters. In addition, the Decree of the Minister for Health of 29 March 2007 (Rozporządzenie Ministra Zdrowia, 2007) was referred to. The results were compared to concentrations of forms of particular components ($N\text{-}NH_4$, $N\text{-}NO_2$, $N\text{-}NO_3$) included in the Decree of the Minister for Environment (2004) and the Decree of the Minister for Health (2007) in order to designate water quality classes and principal chemical requirements to the well wa-

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ters examined. The study revealed that the analyzed waters did not meet standards set for potable water due to exceeding permissible values for ammonia and nitrates (V) concentrations. The distance of a well from the nearest farm buildings affected ammonia concentration in well water.

Keywords: well, nitrates, phosphates.

JAKOŚĆ WÓD STUDZIENNYCH W DOLINIE GÓRNEJ NARWI POD WZGLĘDEM STĘŻENIA ZWIĄZKÓW AZOTU I FOSFORANÓW

Abstrakt

Celem pracy było określenie stężenia oraz rozkładu przestrzennego form azotu i fosforanów w studniach gospodarskich (kopanych) z wybranych gospodarstw wiejskich doliny górnej Narwi. Dodatkowym celem pracy było określenie wpływu wybranych elementów zagrody wiejskiej na jakość wód studziennych. Badania prowadzono w 8 wsiach położonych w województwie podlaskim. W każdej wsi do badań wybrano po 3 studnie. Wszystkie studnie czerpią wodę z pierwszego poziomu wodonośnego. Badaniami objęto wody studzienne na odcinku rzeki Narew od wsi Sobótka do wsi Złotoria. Miejsca poboru próbek wody wyznaczono w miejscowościach: Sobótka, Narew, Ciełuszki, Kaniuki, Zawyki, Uhowo, Topilec, Złotoria zlokalizowanych wzdłuż rzeki Narew w jej bezpośrednim sąsiedztwie. Próbki wody pobierano 3-krotnie: wiosną, latem, jesienią 2006 r. W próbkach wody przefiltrowanych przez filtry mikroporowate o średnicy porów 0,45 µm oznaczono metodą kolorymetryczną, na spektrofotometrze HACH typu DR-2000, azot amonowy, azotynowy, azotanowy i fosforany. Parametry metod analitycznych dostosowano do zaleceń Rozporządzenia Ministra Środowiska (2004). Ogółem wykonano 288 oznaczeń w trzech seriach badawczych. Obliczono średnią arytmetyczną zawartość badanych parametrów w próbkach pobranych z 3 studni każdej wsi w trzech terminach. Ocenę jakości wód podziemnych oparto na Rozporządzeniu Ministra Środowiska z dnia 11 lutego 2004 r. w sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz sposobu interpretacji i prezentacji stanu tych wód, z uwzględnieniem Rozporządzenia Ministra Zdrowia z dnia 29 marca 2007 r. Wyniki porównywano ze stężenirm form poszczególnych składników ($N\text{-}NH_4$, $N\text{-}NO_2$, $N\text{-}NO_3$) ujętych w Rozporządzeniach MŚ (2004) i MZ (2007) w celu przypisania badanym wodom klas jakości oraz podstawowych wymagań chemicznych. Wykazano, że: wody nie odpowiadały standardom wody przeznaczonej do spożycia ze względu na przekroczenia wartości dopuszczalnych stężeń azotu amonowego i azotanowego, wody o najniższej jakości stwierdzono w studniach ze wsi Złotoria i Zawyki. W pracy określono również wpływ odległości studni od zabudowań inwentarskich na stężenie azotu amonowego w ich wodach.

Słowa kluczowe: studnia, azotany, fosforany.

INTRODUCTION

Resources of underground waters in Podlasie region occur in Quaternary, Tertiary, Cretaceous, and Jurassic formations. Underground waters in Quaternary formations are practically present all over the region (http://www.mos.gov.pl/).

The depth of water surface in river valleys and depressions of the upper Narew River valley ranges within 0.1-1.0 m, while the height can be up to 5-8 m; it is the main water source in dug wells. Waters at this level vary greatly, depending on the intensity of rainfall and spring thawing (*Studium...* 2004).

Quality of ground water originating from farms is an indicator of this point source of agricultural contamination, mainly associated with animal production, whose influence on area pollution attracts more attention than plant production (SAPEK 2006).

Farms and adjacent land are closely associated with animal production. Animal waste, such as solid and liquid manure as well as poultry droppings, is potential source of ground water contamination with nutrients, mainly nitrogen and phosphorus compounds (DURKOWSKI et al. 1997).

The paper contains an evaluation of the concentration and spatial variability of nitrogen forms and phosphates in farm dug wells localized in the upper Narew River valley. In addition, the purpose of this study has been to assess the influence of selected elements of a farm on well water quality.

MATERIAL AND METHODS

The study was carried out in 8 villages situated in Podlasie region (Figure 1). Three farm dug wells were selected for examination in each village. All wells take water from the first water-carrying level. The study included well waters within the section of the Narew from the villages Sobótka to Złotoria. The checkpoints were set in: Sobótka, Narew, Ciełuszki, Kaniuki, Zawyki, Uhowo, Topilec, and Złotoria, all lying along the Narew and at its adjacent lands. Water samples were collected in spring, summer and autumn 2006.

Samples were collected in such a way to preserve their native character. When the wells were permanently covered, water was taken from pumps or taps after letting some water out to ensure the same parameters as those of underground water. The distance between the wells and the farm buildings, houses and the Narew River was also measured. All the data are presented in Table 1.

Ammonium nitrogen, nitrite nitrogen, nitrate nitrogen and phosphates were determined in water samples filtered through micropore filters (d = 0.45 µm) by means of colorimetry applying a spectrometer HACH (DR-2000). Parameters of the analytical procedures were adjusted in accordance to the Decree of the Minister for Environment (2004).

In total, 288 determinations in three series were made. For each of the three wells from every village, the arithmetic means of the parameters were calculated on a basis of samples collected on three dates.

Fig. 1. Localization of checkpoints for well water sampling

The underground water quality was assessed in compliance with the Decree of the Minister for Environment of 11 February 2004 (*Rozporządzenie...* 2004) on surface and underground water status, screening performance, interpretation and presentation of the status of such waters. In addition, the Decree of the Minister for Health of 29 March 2007 (*Rozporządzenie...* 2007) was referred to. The results were compared to concentrations of forms of particular components ($N\text{-}NH_4$, $N\text{-}NO_2$, $N\text{-}NO_3$) specified in the Decree of the Minister for Environment (2004) and the Decree of the Minister for Health (2007) in order to designate water quality classes and principal chemical requirements to the well waters examined.

Pearson's correlation coefficient was used to evaluate the dependence of the parameters examined on a distance between a given well and the selected characteristics of a farm. The dependence is illustrated by Figure 2.

The data clustering method, based on a notion of a distance between objects or variables in multi-dimensional space, was also used to analyze the results. The technique makes it possible to present grouped objects or their traits in the form of a bundle diagram. Calculation of Euclidean distance is a direct way to estimate the distance between objects. This measure determines the real geometric distance between objects in space, and is calculated using raw data. The method consists of presenting similarity between objects or their features (variables) as a function of distance. Objects

Table 1

Localization of the wells

Village	Well	Distance from farm buildings	Distance from houses	Distance from the Narew
		(m)		
Złotoria	1	13	8	100
	2	8	15	50
	3	10	30	100
Topilec	1	6	5	100
	2	50	5	40
	3	6	5	150
Uhowo	1	0	3	200
	2	10	5	30
	3	20	3	50
Zawyki	1	0	20	150
	2	20	5	70
	3	15	30	30
Kaniuki	1	30	20	50
	2	3	20	30
	3	25	1	50
Ciełuszki	1	30	3	10
	2	30	15	50
	3	9	10	50
Narew	1	30	7	200
	2	17	5	200
	3	16	7	50
Sobótka	1	0	15	50
	2	35	8	50
	3	5	18	70

are grouped in sets called clusters that combine particular variables. The variables are more similar to one another when the distance between them is smaller.

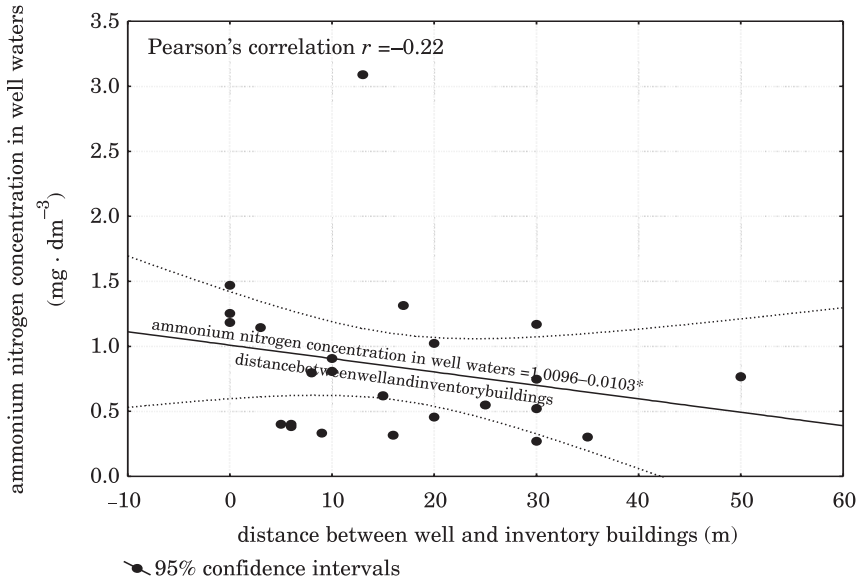


Fig. 2. Dependence of ammonia concentration in well waters on the distance between well and farm buildings

RESULTS AND DISCUSSION

The quality of the well waters we studied differed in particular villages. Most of the water samples were characterized by excessive content of ammonium nitrogen (according to the Decree of the Minister for Environment 2004), which indicates direct contact of water intake points with organic contaminants. They may originate not only from animal waste, but also from household sewage wrongly managed on a farm. The highest concentrations of ammonium nitrogen were found in the wells in Złotoria (1.6 mg·dm^{-3} – IV quality class for underground waters), while the lowest ones (0.52 mg·dm^{-3} – IV quality class) occurred in the wells in Topilec (Figure 3). Both values, nevertheless, exceeded norms regulating the quality of potable waters (0.39 N-NH_4 mg·dm^{-3}).

Ammonium nitrogen present in waters usually originates from biochemical decomposition of organic nitrogen compounds, which proves a direct contact of water intake point with organic contaminants (Błaszczyk 1993).

Sapek and Pietrzak (1996) as well as Urbaniak and Sapek (2003) claim that concentration of ammonia in water from piezometric wells localized on ploughed grounds is similar to that found on grasslands.

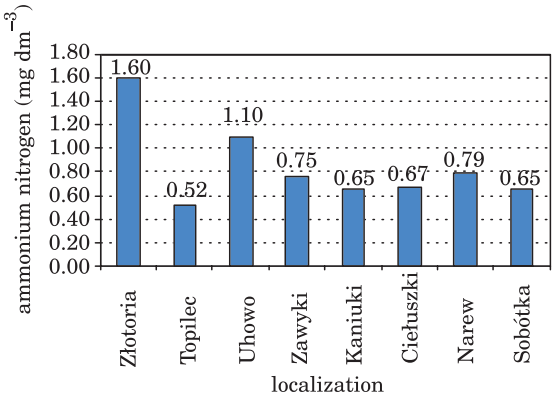


Fig. 3. Mean values of ammonium nitrogen

The highest level of nitrite nitrogen was recorded in the wells in Zawyki village (0.14 mg·dm^{-3} – out-of-class waters), whereas the lowest in Cieluszki (0.02 mg·dm^{-3} – III class of underground waters quality) – Figure 4. These values did not exceed permissible level (0.39 mg·dm^{-3}) set by the Minister for Health (DECREE of 2007).

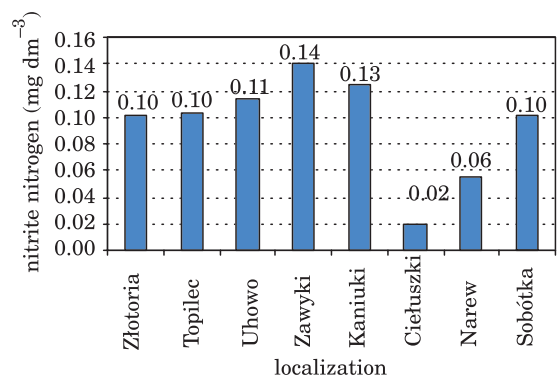


Fig. 4. Mean values of nitrite nitrogen

The highest content of nitrate nitrogen was recorded in waters from the wells localized in Zawyki (13.51 mg·dm^{-3} – IV quality class), while the lowest one in water samples collected in Uhowo (3.14 mg·dm^{-3} – II quality class for underground waters) – Figure 5. The concentration of nitrate nitrogen found in Zawyki village exceeded norms for potable waters (11.3 mg·dm^{-3}). The level of water saturation with nitrate nitrogen, which is the most common nitrogen compound in well waters, is one of the princi-

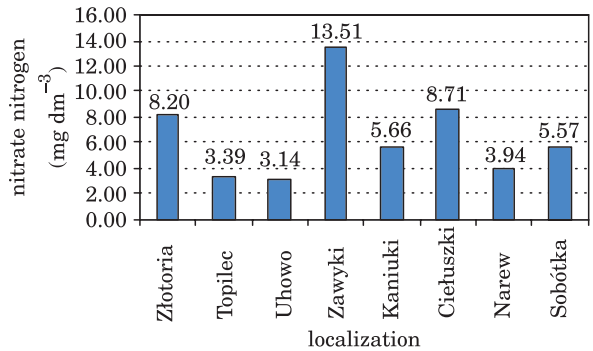


Fig. 5. Mean values of nitrate nitrogen

pal criteria for determination of well waters as potable waters (SĄDEJ, PRZEKWAS 2006). SKORBIŁOWICZ et al. (2001) observed that the well waters we analyzed were primarily affected by factors related to the agricultural and residential character of the villages, which largely contributed to the contamination of shallow waters supplied for consumption. Farmsteads and households are the main sources of contamination of well waters with nitrogen and phosphorus compounds.

ZAHN and GRIMM (1993) assumed that elevated concentration of chlorides in ground water is an indicator of the presence of nitrate nitrogen.

The highest phosphate concentration was recorded in well waters collected in Zawyki (3.07 mg·dm^{-3}– III quality class), whereas the lowest one appeared in water from Ciełuszki village (0.84 mg·dm^{-3} – II class of underground water quality) – Figure 6. The content of phosphates in potable water is not regulated by any decree.

Contamination of drinking water with nitrogen compounds is usually accompanied by phosphate contamination. As phosphates can stimulate biological life, it is accepted that its presence at levels higher than 0.5 mg·dm^{-3} is unwanted (DURKOWSKI et al. 1997). The elevated concentrations of phosphates in the well waters we studied, likewise increased ammonium nitrogen, may have been a result of wrong handling of household wastewater and sewage, which contained residues of detergents (WIATER, SKOWROŃSKA 2002).

SAPEK and SAPEK (2005) claim that toiletries used for personal hygiene on a farm habitants, detergents for washing clothes and dishes, other detergents used to clean houses and other farm buildings as well as veterinary preparations, including those used for milking and washing milk containers and tanks, are the main sources of farm and ground water contamination, mainly with sodium and phosphorus.

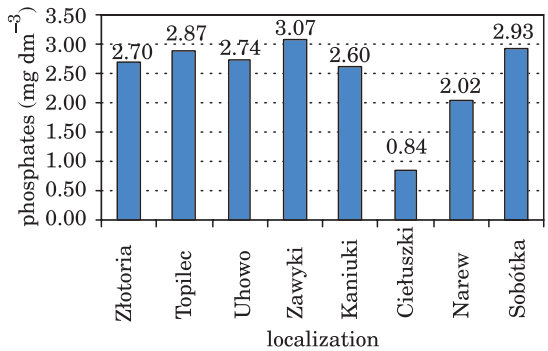
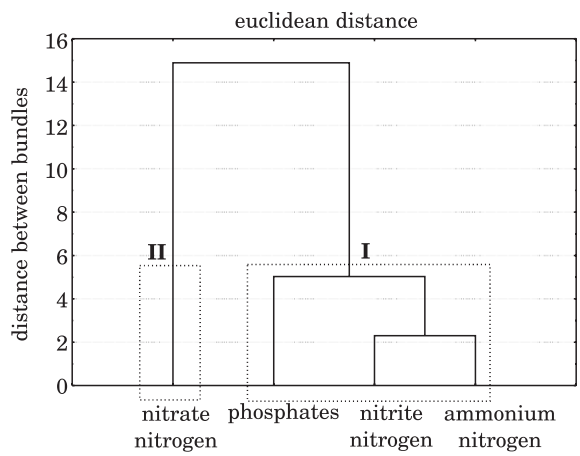


Fig. 6. Mean values of phosphates

A weak dependence of ammonia concentration in the well waters on the distance of a well from a nearby farmstead was discovered. It was manifested by the negative value of Pearson's coefficient r=-0.22 at p = 0.008. The mathematical model generated for this dependence, presented in Figure 2, makes it possible to predict the ammonium nitrogen concentration in well waters on a basis of a known distance of a well from a farm building.

The dendrogram (Figure 7), which includes the analyzed parameters, presents two arrangements: set I formed by phosphates, nitrite nitrogen, and ammonium nitrogen; set II consisting of a single indicator – nitrate nitrogen. The dendrogram illustrates a significant distance connecting set II with set I, which considerably differentiates both bundles. The bundle forming set II contains only one object called a separated point. The system presents the arrangement of nitrogen and phosphorus forms, which indi-



Fig, 7. Euclidean distances between parameters

cates that the occurrence of these components in waters from the wells we investigated results from the vicinity of organic contamination sources (ammonium nitrogen, nitrite nitrogen, and phosphates – set I). Set II (nitrate nitrogen) indicates that the concentration of this nitrogen form is determined by nitrification processes and its elution by runoffs from fields and farms.

CONCLUSIONS

1. The well waters examined did not meet standards for potable waters established by the Decree of Minister for Health because they exceeded permissible values of ammonium nitrogen and nitrate nitrogen concentrations.

2. The lowest quality waters were found in the wells in villages Złotoria and Zawyki.

3. The distance from a well to the nearest farm building had an influence on ammonium nitrogen concentration in the well water.

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