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Nitrates in drinking water as a factor of a health risk to the Platerow commune inhabitants (Mazovian province)

Azotany w wodzie do picia jako czynnik ryzyka zdrowotnego mieszkańców gminy Platerów (województwo mazowieckie)

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Słowa kluczowe: studnie kopane i wiercone, woda wodociągowa, azotany, ryzyko zdrowotne

Abstract
Well and piped water quality was examined out in the area of the Platerow Commune in 2008. The study examined water from 18 household wells used as a source of water for consumption and household purposes, and piped water which is abstracted from two deep wells in Platerow. Water samples for testing were taken five times. The concentrations of physical and chemical parameters such as NO_3^-, PO_4^{3-}, Cl^-, Ca^{2+}, Mg^{2+}, total hardness and pH, EC were determined. Health risk due to the presence of NO_3^- ions in drinking water consumed by people was estimated in this paper. The Platerow Commune population consuming piped water abstracted from the well located in Platerow take in nitrates in the amounts which are within the low limit of safety margin (ADI : EDI = 6.76) although their concentration in water does not exceed the standard level. People drinking water from 78% examined wells ingest excess quantities of nitrates (safety margin <1), which, in the case of long-term exposure, can be harmful particularly for infants and pregnant women. Statistical analysis revealed negative correlation of nitrate concentration in well water with well depth and water pH, which indicates that there was an influx of NO_3^- ions to shallow groundwater.

Streszczenie
Jakość wody pitnej na terenie gminy Platerów badano w roku 2008. W próbkach wody pobranych pięciokrotnie z 18 studni (kopanych i wierconych) oraz w wodzie wodociągowej ujmowanej dwoma studniami głębinowymi w Platerowie oznaczono następujące wskaźniki: NO_3^-, PO_4^{3-}, Cl^-, Ca^{2+}, Mg^{2+}, twardość ogólną oraz pH i przewodność elektrolityczną właściwą. W pracy oszacowano ryzyko zdrowotne związane z obecnością jonów NO_3^- w wodzie pitnej. Mieszkańcy gminy pijący wodę pochodzącą z sieci wodociągowej zasilanej przez ujęcie w Platerowie pobierają azotany w zakresie niskiego marginesu bezpieczeństwa (ADI : EDI = 6.76) chociaż występują w wodzie w stężeniu poniżej wartości normatywnej. Ludność pijąca wodę z 78% badanych studni pobiera azotany w nadmiernej ilości (margines bezpieczeństwa <1), co przy długotrwałości tego stanu może być niebezpieczne dla zdrowia niemowląt, kobiet w ciąży. Analiza statystyczna udowodniła ujemną korelację pomiędzy stężeniem azotanów w wodzie studziennej a głębokością studni i pH, co wskazuje na dopływ jonów NO_3^- do płytkich wód gruntowych.

1. INTRODUCTION

Nitrate contamination in agricultural areas is one of the most widespread groundwater problems worldwide and in Poland posing environment hazard [Bonton et.al. 2010; D'Alessandro et.al. 2012; Igras and Jadczyszyn 2008; Jaszczyński et.al. 2006; Raczuk 2006; Sapek 1995; Thorburn et.al. 2003]. Nitrate in groundwater may come from point sources such livestock facilities, sewage disposal systems, including septic tanks and non-point sources such as fertilized cropland, or naturally occurring sources of nitrogen [Sapek 2004; Sądej and Przekwas 2006; WHO 2008].
Unlike water from deep wells located in rural areas which is supplied by distribution systems, water in household wells is particularly prone to NO_3^- pollution [Caballero-Mesa et.al. 2003; Grygorczuk-Peterson 2008; Raczuk 2010; Radzka et.al. 2008]. According to Central Statistical Office (GUS) [Ochrona… 2011], in 2008−2010 water supplied by 18.0−10.8% pipe networks did not meet sanitary requirements.
High nitrate concentration in drinking water causes a few harmful health problems such as methemoglobinemia (so-called "blue baby syndrome") in infants, thyroid disorders, spontaneous abortions, and birth defects [Gupta at.al. 2008; Knobeloch et.al. 2000].
The toxicity of nitrate (NO_3^-) to humans is mainly attributable to its reduction by bacteria in the upper alimentary tract to harmful nitrite (NO_2^-). Nitrite ions are precursors of potent carcinogenic N-nitrosamines [Nowak and Libudzisz 2008].
The purpose of the study was to assess the risk to human health due to nitrates occurring in both piped and well water consumed by inhabitants of the Platerow Commune located in the Mazovian Province.

2. MATERIALS AND METHODS

2.1. Study area and sampling collection

Platerow is a typical agricultural commune located in the northern part of the Losice County which is situated at the eastern edge of the Mazovian Province. Agricultural land is 71.7% and forested area is 23.7% of the commune's area [Statystyczne… 2012]. The community has a water supply system which is 106.3 km long and fed with water from Quaternary resources abstracted from deep wells located in Platerow, Czuchow, Hruszniew and

Mezenin. The water has to be treated for iron removal and periodically disinfected with chlorine. The percentage of population using water supply and sewage systems in the Platerow Commune in 2008−2011 ranged from 81.9 to 82.1% and 27.6 to 43.3%, respectively [Statystyczne… 2012]. However, there are some households in the commune with no access to the water distribution system which still use domestic wells. It is sometimes because of economic reasons but usually due to their location in a sparsely build-up area where the water pipe network has not been installed or the households have deep-drilled wells.

The study examined water from 18 household wells used as a source of water for consumption and household purposes, and piped water which is abstracted from two deep wells in Platerow. The household wells are situated in Platerow, Nowodomki and Kisielew where there is also a water distribution system using water abstracted from Platerow wells. Seventeen of the wells examined are dug wells, 4 to 25 m deep (wells no 1−17) and one drilled well (no 18) which is 40 m deep. Wells no 1−3, 10 and 11 are situated is sparsely build-up area surrounded by cultivated fields, meadows, orchards and forests. The remaining wells are located in densely build-up areas.

2.2. Analytical procedure

Water samples for testing were taken five times: in April, May, July, September and October 2008. Water samples for physical and chemical analysis were collected in polyethylene bottles and taken to the laboratory. Analyses were carried out immediately. The pH and electrical conductivity EC values were measured immediately after collection with the help of a portable pH-meter and conductivity-meter. The concentration of nitrates (NO_3^-) was determined by the modified Griess method, and PO_4^{3-} was determined by the colorimetric molybdenum blue method [Marczenko and Balcerzak 2001]. Total hardness, Ca and Mg were determined by the complexometric titration with EDTA and chloride (Cl^-) was determined by the argentometric method with silver nitrate solution [Hermanowicz et.al.1999]. All analyses were repeated three times for the same sample.

2.3. Evaluation of a health risk

The presence of nitrates (NO_3^-) in drinking water is dangerous for human health, therefore their daily intake is limited. The Acceptable Daily Intake (ADI) for nitrates is up to 5 mg $NaNO_3 \cdot kg^{-1}$ body weight$\cdot day^{-1}$ [FAO/WHO 2003], which corresponds to maximum 3.65 mg $NO_3^- \cdot kg^{-1}$ b. w.$\cdot day^{-1}$. Health hazards associated with nitrate-contaminated drinking water were assessed by comparing Acceptable Daily Intake (ADI = 0.365 mg $NO_3^- \cdot kg^{-1}$ b. w. $\cdot day^{-1}$ which is 10% of the total value ADI) with Estimated Daily Intake (EDI) [Szczerbiński et.al. 2006]. Estimated Daily Intake (EDI) was calculated according to the following formula:

$$EDI = F \cdot R,$$

where:

F − average daily water consumption − 2 $l \cdot person^{-1} \cdot day^{-1}$,

R − concentration of nitrates in drinking water − $mg \cdot l^{-1}$.

The safety margin = ADI : ED; the higher index value, the lower health risk. In the present work, calculations were performed for an assumed human body weight of 70 kg.

2.4. Statistical analysis

Kolmogorov−Smirnov test was first used to check the normality of the data. Because the data were non-normally distributed ($p<0.05$), Spearman's rank order correlation was utilized to study the associations between variables. The differences between concentrations of nitrate coming from various water samples collected at different time intervals, were estimated by the nonparametric Kruskal−Wallis test. Statistical analysis was conducted using Statsoft Statistica 10.0 computer programme.

3. RESULTS AND DISCUSSION

The results established that nitrate concentration in piped water samples ranged from 0.8 to 3.1 $mg \cdot l^{-1}$ and met the standard set at 50 mg $NO_3^- \cdot l^{-1}$ (Tab.1) [Rozporządzenie….2007; WHO 2008]. The nitrate concentrations in water were within the limit of hydrogeochemical background which is defined at 0−5 mg $NO_3^- \cdot l^{-1}$ [Rozporządzenie… 2008]. Piped water can have various nitrate concentrations which may even exceed the standard values as reported by Radzka et. al. [2008], who analyzed piped water in the Siedlce County.

Nitrate concentrations in the samples of water from household wells ranged between 0.5 and 145.0 $mg \cdot l^{-1}$ with the median value of 37.4 $mg \cdot l^{-1}$ (Tabs.1−2). The highest concentration, 121.0−145.0 $mg \cdot l^{-1}$, was determined in the water from well no 5 situated in Nowodomki. It is a dug well 8 m deep located in a densely build-up area. Such a high concentration was probably due to the presence of a leaking septic tank situated at the distance of 8 m from the well and nearby cultivated fields. Excessive nitrate concentrations were detected in the water of dug wells no 4, 7, 13 and 14 which are inappropriately located and too shallow (4−10 m). Wells no 13 and 14 were situated in a sparsely build-up area in the proximity of ploughed land, meadows and an orchard. A high nitrate concentration indicates that there was an excess of nitrates leaching into ground waters from the household sources as well as from nearby cultivated fields. The lowest nitrate concentration, which did not exceed 10 $mg \cdot l^{-1}$, was determined in water sampled from dug wells no 16 and 17 which are 22−25 m deep, and from drilled well no 18, situated in Kisielew, which is 40 m deep. The good quality of water from wells no 16 and 17 was also due to their location in a forested area. A low concentration of mineral nitrogen and phosphorus compounds in groundwater is most likely the result of an intensive uptake of these compounds by forest vegetation. Trees absorb large quantities of biogenic nutrients from the soil, which reduces the amount of these elements leaching into groundwaters. Lower groundwater contents of nitrates and phosphates under forests have been reported by Groffman et.al. [1992]. It is worth noting that well no 8, which was 8 m deep, was cleaned in the study year. Water sampled from this well had the nitrate levels of 17.3−35.0 $mg \cdot l^{-1}$ (Tab.1).

Assessment of threat to human health indicated that water consumed from 78% household wells examined had excessive nitrate levels which exceeded acceptable daily intake (ADI), that is far below the safety margin (ADI : EDI <1) (Tab.1). The greatest hazard to health is when daily water consumption from well no 5 is 2 l (ADI : EDI = 0.11). Nitrate intake with drinking water characterized by a low safety margin was determined for people drinking piped water (ADI : EDI = 6.76) as well as water from wells no 1, 16, 17 and 18 (ADI : EDI = 2.24−3.35) (Tab.1). It should be stressed that no water from the sources studied had nitrate concentrations within the range of medium (10−20) or high (20−30) and very high (> 30) safety margin. In their study, Szczerbiński et al. [2006] have found that rural inhabitants consumed piped water whose nitrate levels were below the safety margin in 10 counties of the Podlasie Province, the highest percentage, 22.46%, reported for the Grajewo County.

Prolonged consumption of water which has got critical (>150 $mg \cdot l^{-1}$), unacceptable (100–150 $mg \cdot l^{-1}$) and undesired nitrate concentrations (50−100 $mg \cdot l^{-1}$) [Świetlik et.al.1999] may pose a threat to health particularly of babies under 6 months of age as well as pregnant women [Knobeloch et. al. 2000; Gupta et.al. 2008].

The present work demonstrated that, compared with water from shallow dug wells, piped water and water from deep dug wells or drilled wells consumed by the inhabitants of the Platerow Commune represented a lower risk to health due to nitrates.

Statistical analysis revealed a negative correlation between nitrate concentration and well depth (rs = −0.482, p<0.05). It indicates that shallow dug wells are most likely to be nitrate contaminated. Significant relationship between depth and nitrate concentration was confirmed by other authors, too [Jaszczyński et. al. 2006; Nas and Berktay 2006].

Nitrate concentration in well water was negatively associated with water pH (rs = −0.405, p<0.05), which indicates that nitrates reduce the value of this parameter. In her study, Sapek [1995] has demonstrated that increased groundwater nitrates cause water acidification. A statistically significant correlation was found between nitrate concentration and phosphate concentration (rs = 0.326, p<0.05) as well as nitrate concentration and well water specific electrolytic conductivity (rs = 0.580, p<0.05).

Phosphate concentrations in piped water, water from deep dug wells and drilled wells ranged between 0.10 and 0.31 mg·l^{-1} (Tab.2) and was within the limits of the hydrogeochemical background which is 0.01−1.00 mg PO_4^{3-}·l^{-1} [Rozporządzenie... 2008]. The water in the remaining wells had higher phosphate concentrations of even 5.00 mg·l^{-1} (well no 18).

Table 1. Estimated daily intake EDI and safety margin for nitrates taken with drinking water

Locality and well number	Concentration mg NO_3^-·l^{-1}		EDI mg NO_3^-·pers.$^{-1}$·day^{-1}	Safety margin ADI : EDI
	range	median	median	median
Platerow				
1	10.0−13.3	10.5	11.0	2.32
2	6.5−25.0	13.6	27.2	0.94
3	42.0−53.0	47.0	94.0	0.27
Nowodomki				
4	66.0−85.0	76.0	152	0.17
5	121.0−145.0	140	240	0.11
Kisielew				
6	8.3−38.0	25.0	50.0	0.51
7	41.5−76.0	70.0	140.0	0.18
8	17.3−35.0	26.3	52.6	0.49
9	28.0−45.0	40.5	81.0	0.32
10	30.0−42.0	34.0	68.0	0.38
11	37.0−63.0	45.5	91.0	0.28
12	34.0−38.0	34.0	68.0	0.38
13	53.0−98.0	70.0	140.0	0.18
14	42.0−93.0	53.0	106.0	0.24
15	37.0−74.5	49.0	98.0	0.26
16	4.1−7.2	4.6	9.2	2.79
17	4.9−9.4	5.7	11.4	2.24
18	0.5−4.9	3.8	7.6	3.35
Platerow Piped water	0.8−3.1	1.9	3.8	6.76

ADI− Acceptable Daily Intake; EDI− Estimated Daily Intake

Table 2. Some physical and chemical indexes of piped and wells water

Indexes	Piped water		Wells water	
	range	median	range	median
NO_3^- (mg·l^{-1})	0.5−3.1	1.9	0.5−145.0	37.4
PO_4^{3-} (mg·l^{-1})	0.10−0.31	0.21	0.10−5.00	0.30
Cl^- (mg·l^{-1})	10.0−10.0	10.0	7.0−54.0	21.0
$CaCO_3$ (mg·l^{-1})	238−260	250	70−440	246
Ca^{2+} (mg·l^{-1})	72.2−81.8	78.6	16.0−125.0	82.2
Mg^{2+} (mg·l^{-1})	11.2−15.6	14.0	2.4−23.3	10.9
pH	6.7−7.0	6.9	6.4−7.8	7.2
EC (μS·cm^{-1})	403−429	419	264−1247	556

Phosphorus infiltration into groundwater may be associated with soil fertilization and livestock production but it may be as well introduced into the soil with detergents [Sapek 2001].

The strongest significant relationship was determined between nitrate and chloride concentrations in well water (rs = 0.798, p<0.05). Chloride concentrations in samples of water from domestic wells ranged from 7.0 to 54.0 mg·l^{-1} the median being 21.0 mg·l^{-1} (Tab.2) and in no sample did it exceed the standard set at 250 mgCl·l^{-1} [Rozporządzenie.... 2007; WHO 2008]. In turn, chloride concentration in well water was within the limits of the hydrogeochemical background which are 2−60 mg·l^{-1} for groundwater in Poland [Rozporządzenie....2008]. According to Jaszczyński et al. [2006], livestock faeces and household waste are the main sources of chlorides in well water. Just like nitrates, chlorides are not bound by soil colloids and, according to Zahn and Grimm [1993], their presence may be indicative of water contamination. Similarly to nitrates, chloride concentration was significantly correlated with specific electrolytic conductivity (rs = 0.598, $p<0.05$).

Chloride concentration in piped water was 10.0 $mg \cdot l^{-1}$ and, throughout the whole study period, it did not differ from the average Cl^- concentration for piped water in rural areas reported by Sapek [2008]. The piped water in this study was moderately hard, with calcium and magnesium concentrations of 72.2−81.8 and 11.2−15.6 $mg \cdot l^{-1}$ (Tab. 2), respectively. Calcium concentration in the well water samples ranged from 16.0 to 125.0 $mg \cdot l^{-1}$ with the median value of 82.2 $mg \cdot l^{-1}$ (Tab. 2). Magnesium concentration in well water did not drop below the lower standard value of 30 $mg \cdot l^{-1}$ [Rozporządzenie… 2007], which is probably associated with the area's geological structure and low magnesium concentration in the Quaternary deposits. The hydrogeochemical background of calcium and magnesium concentrations in groundwater in Poland is 2−200 and 0.5−30 $mg \cdot l^{-1}$, relatively [Rozporządzenie… 2008].

No significant seasonal variation in water quality parameters was observed ($p>0.05$).

Monitoring of selected physical and chemical parameters of drinking water has demonstrated the need to increase the consciousness of rural inhabitants as to the quality of water which they drink, sources of its pollution and consumption effects.

4. CONCLUSIONS

1. The Platerow Commune population consuming piped water abstracted from the well located in Platerow take in nitrates in the amounts which are within the low limit of safety margin (ADI : EDI = 6.76) although their concentration in water does not exceed the standard level.
2. In the Platerow Commune, water from 28% household wells examined had nitrate concentrations which did not meet standard requirements, which probably resulted from inappropriate well depth and location as well as insufficient insulation to prevent leakage of contaminants.
3. People drinking water from 78% examined wells ingest excess quantities of nitrates (safety margin <1), which, in the case of long-term exposure, can be harmful particularly for infants and pregnant women.
4. Statistical analysis revealed negative correlation of nitrate concentration in well water with well depth and water pH, which indicates that there was an influx of NO_3^- ions to shallow groundwater.

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