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MAGNESIUM, CALCIUM, POTASSIUM AND SODIUM CONTENT IN GROUNDWATER AND SURFACE WATER IN ARABLE LANDS IN THE COMMUNE (*GMINA*) OF KĄTY WROCŁAWSKIE

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Abstract

This paper discusses some aspects of the research conducted in the hydrological years 2000/2001-2002/2003 on arable areas around several small water bodies located on the outskirts of villages in the commune of Kąty Wrocławskie. The aim of the paper was to assess the content of selected chemical elements in the groundwater and small water bodies.

The water bodies included in the research appeared a few decades ago as a result of human activity; in Zybiszów and Bliż they are small post-mine water bodies, whereas in Smolec and Rybnica they are ponds filling former clay excavation sites. Their surface ranges widely between 0.05 and 2.2 ha, while the average depth reaches 1.2 to 3.5 m. Since no flows come to these water bodies, they are fed only by ground and rain water. In the research period the water level of the bodies fluctuated between 3 and 40 cm, while the maximum changes in the groundwater level were above 1 m.

The examined waters contained elevated levels of elements, the fact which is directly related to the kind of soils in the region. Another factor affecting the content of elements is whether or not soils are used agriculturally. It has been observed that arable areas are distinguished by positive correlation of magnesium, potassium and sodium concentrations in ground and surface waters. Increased content of these elements in Rybnica suggests that the waters receive pollutants from nearby houses.

In the groundwater examined the ratio of calcium and magnesium concentrations ranged from 2.7 to 6.9, whereas in the surface water it varied from 1.2 to 5.1. Values below

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3 were obtained for both types of water only in Rybnica, which proves the influx of sewage from households.

Key words: water, magnesium, calcium, potassium, sodium.

ZAWARTOŚĆ MAGNEZU, WAPNIA, POTASU I SODU W WODACH GRUNTOWYCH ORAZ POWIERZCHNIOWYCH NA UŻYTKACH ROLNYCH W GMINIE KĄTY WROCŁAWSKIE

Abstrakt

W pracy przedstawiono wybrane elementy badań prowadzonych w latach hydrologicznych 2000/2001-2002/2003 na użytkach rolnych wokół kilku niewielkich zbiorników wodnych zlokalizowanych na obrzeżach wsi w gminie Kąty Wrocławskie. Celem pracy była ocena zawartości wybranych pierwiastków w wodach gruntowych i małych zbiornikach wodnych.

Zbiorniki objęte badaniami powstały przed kilkudziesięciu laty w efekcie działalności człowieka – w Zybiszowie i Bliżu są to niewielkie zbiorniki kopane, natomiast w Smolcu i Rybnicy powstały w miejscach dawnych wyrobisk gliny. Ich powierzchnia jest zróżnicowana i wynosi od 0,05 do 2,2 ha, a średnia głębokość od 1,2 do 3,5 m. Nie dopływają do nich żadne cieki, a zasilanie następuje jedynie przez dopływ wód gruntowych oraz opadowych. W okresie badawczym położenie zwierciadła wody w tych zbiornikach zmieniało się w zakresie 3-40 cm, natomiast maksymalne zmiany położenia zwierciadła wody gruntowej przekraczały 1 m.

Badane wody zawiarają duże ilości pierwiastków, co ma bezpośredni związek z rodzajem gleb i użytkowaniem ich jako pola orne. Na terenach użytkowanych rolniczo obserwuje się dodatnie skorelowanie stężenia magnezu, potasu i sodu w wodach gruntowych i powierzchniowych. Podwyższone zawartości tych pierwiastków na obiekcie w Rybnicy wskazują na zanieczyszczenie wód spływem z terenów zabudowanych.

W analizowanych wodach gruntowych stosunek stężenia wapnia do magnezu wynosił od 2,7 do 6,9, natomiast w powierzchniowych od 1,2 do 5,1. Wartości mniejsze od 3, dla obu rodzajów wód, stwierdzono tylko na obiekcie w Rybnicy, co potwierdza hipotezę, że dopływają tam zanieczyszczenia z terenów zabudowanych.

Słowa kluczowe: woda, magnez, wapń, potas, sód.

INTRODUCTION

The composition and concentration of substances in ground and surface water is a resultant of two factors: the geological structure of the earth's crust, including the intensity with which it is leached, and anthropogenic activity associated with agriculture, industry and public utilities. As water travels through the soil's profile, various water-soluble substances are released (Pulikowski et al. 2006). Most of them are macroelements and alkali elements. Water acts as a solvent, enabling plants to absorb substances essential for their growth. Any excess of water content in soil causes an adverse outflow of nutrients. The actual mass of the components carried away

depends mostly on the amount of water leaving particular surface (PULIKOWSKI 2004). The amount of rainfall (SZYMCZYK, CYMES 2005), the type of soil and the manner in which it is used (CYMES, SZYMCZYK 2005) are indirectly responsible for the load of components carried away from the soil. Leaching calcium and magnesium is additionally made more intensive by draining devices (KOBUS, GLIŃSKA-LEWCZUK 2005). In the case of heavily salted soils, their profile is washed with clean water in order to reduce the concentration of, for instance, sodium (KELLENERS et al. 2000).

Calcium and magnesium are important macroelements, taken up by plants in considerable amounts. Magnesium is a constituent of chlorophyll and activates a number of enzymatic reactions. Calcium incrusts cell membranes, influences the accumulation of oxalates, regulates water supply and metabolic processes. It also favours the forming of cloddy structure, as it triggers off coagulation of soil colloids (DOBRZAŃSKI, ZAWADZKI 1981).

Alkali elements – sodium and potassium – also play a significant role in vital processes of plants. Potassium plays a major role in synthesis and respiration processes and, even more importantly, regulates the hydration of tissues. Sodium, on the other hand, influences the physicochemical properties of plasma and water supply. The uptake of these elements is strictly dependent on the relationship between their contents in soil (DOBRZAŃSKI, ZAWADZKI 1981).

The purpose of this paper was to assess the content of selected elements in groundwater and small water bodies in the commune (*gmina*) of Kąty Wrocławskie.

CHARACTERISTICS OF SUBJECTS AND METHODOLOGY OF RESEARCH

This paper discusses selected elements of the research conducted in the hydrological years 2000/2001-2002/2003 in the commune (*gmina*) of Kąty Wrocławskie on arable areas around several small water bodies located on the outskirts of the following villages: Bliż, Rybnica, Smolec and Zybiszów. The area included in the research is located in the region of Wrocław Plain (Równina Wrocławska) (KONDRACKI 1994), west of Wrocław. The surface of the plain is distinguished by minor denivelations. The arable lands there are mainly fertile black earth created mostly from silts and silty loams, sporadically lined with more permeable deposits.

The average long-term sum of rainfall in this area (on the basis of the data obtained from the meteorological point of the Experimental Station for Cultivar Testing in Zybiszów) was 568 mm, out of which 371 mm (*ca* 65%) fell during the vegetation period (April-September). Annual sums of rainfall

in the following years of the research period 2000/2001-2002/2003 were 644 mm, 577 mm and 488 mm, while the sums of rainfall recorded during the vegetation periods came to, respectively, 466 mm, 362 mm and 295 mm. The subsequent hydrological years of the research period were characterized as a wet year (2001), a normal year (2002) and a dry year (2003). Vegetation periods (April-September) of these years were described, respectively, as: medium wet, normal and medium dry. With regard to thermal conditions, the analyzed period can be considered relatively warm, with average air temperatures in summer semi-years (May-October) and winter semi-years (November-April) usually somewhat above average. Only in 2002/2003 the winter semi-year was cooler.

The water bodies included in the research has appeared a few decades ago due to human activity; in Zybiszów and Bliż they are small post-mine water bodies, whereas in Smolec and Rybnica they are ponds filling in former clay excavation sites. They differ in the surface area, with the largest pond in Smolec (Sb) – *ca* 2.2 ha. Much smaller are the water bodies in Rybnica (Rb) – *ca* 0.25 ha, in Zybiszów (Zb) – *ca* 0.06 ha and three bodies in Bliż, namely (Bb1), whose surface reaches 0.09 ha, Bb2 – 0.05 ha and Bb3 – 0.12 ha. The average depths of these bodies are: Sb – 3.5 m, Rb –1.4 m, Zb – 1.8 m, Bb1 – 1.8 m, Bb2 – 1.5 m and Bb3 – 1.2 m. Since no flows come to these water bodies, they are fed only by ground and rain water. The ponds in Bliż are connected and water flows from Bb1 through Bb2 to Bb3, with the excess of water from the latter pond carried away through a ditch to a small stream called the Kasina. Throughout the research period, the level of groundwater was systematically monitored by means of installed indicating devices. In piezometers situated on adjacent lands depths of the groundwater table were recorded. For the purpose of chemical analyses water samples were taken from all the bodies (Bz1, Bb2, Bb3, Rb, Sb, Zb) and piezometers: Bp (Bliż); Zp1, Zp2 (Zybiszów); Rp1, Rp2 (Rybnica) and Sp (Smolec).

Annual fluctuations in the water level of the particular bodies fell into the range from several to 40 cm at maximum. The water bodies were usually filled up to the maximum in spring or, briefly, after heavy summer rains. In the following years of the research, the water table levels were 24 cm, 14 cm and 30 cm in Rybnica; 31 cm, 33 cm and 40 cm in Smolec; and 34 cm, 32 cm and 36 cm in Zybiszów. The water table of the bodies in Bliż was generally very stable; small changes, oscillating around 3-15 cm, were due to the fact that these bodies form a mutually connected system, in which excess water can run freely to a nearby water flow.

The course of changes in the groundwater table in the piezometers located near the water bodies coincided broadly with the changes in the atmospheric conditions. The groundwater table was usually nearest the ground surface in spring after thaw. Later, the water level gradually decreased to reach its maximum depth in the second half of the hydrological year. Occa-

sionally, the groundwater table rose distinctly also after heavy summer rains, as it happened in the end of July and the beginning of August 2001.

The groundwater table in the piezometers at particular test subjects fluctuated within different ranges. In piezometer Rp1 the depth of the water table altered within 78 and 175 cm, while in Rp2 the minimum and maximum depths were 109 and 184 cm. The groundwater table in piezometer Sp in Smolec fluctuated during the research period from 97 to 210 cm. In piezometer Zp1 in Zybiszów the depths changed from 62 from 110 cm, whereas in Zp2 – from 185 to 234 cm. In Bliż in piezometer Bp the groundwater table changed in individual years from the minimum value of 95 cm beneath the ground level to the maximum level of 180 cm.

In order to conduct physicochemical analyses, water samples were taken once a month during the vegetation period (April-September). Calcium and magnesium contents were marked by the versene method while sodium and potassium were determined by flame photometry (HERMANOWICZ et al. 1999). The determinations were performed in the Water and Sewage Laboratory at the Institute of Environmental Development and Protection, University of Environmental and Life Sciences, Wrocław. The differences between average composition of the groundwater coming from various measuring points were estimated by means of unidirectional variance analysis (test F) at significance level p=0.05. Statistical calculations were performed with an aid of Statistica 7.1 software.

RESULTS AND DISCUSSION

The groundwaters were characterized by pH ranging from 6.5 do 8.4; a somewhat smaller range, from 7.2 to 8.3 pH, was observed for wells located near households. The surface waters had a slightly higher pH, which ranged from 7.3 to 8.8. On the whole, they are neutral or slightly alkaline waters.

The content of magnesium in the groundwaters was significantly different and it ranged from 25.0 mg $Mg \cdot dm^{-3}$ in the well in Bliż to 74.0 mg $Mg \cdot dm^{-3}$ in Rp1 in Rybnica (Figure 1). The values obtained in most of the subjects were approximate to those provided in the literature (PULIKOWSKI 2004, FIEDLER, OTHERS 2005). It is noteworthy that the values obtained at the piezometers in Rybnica were up to 2-3-fold higher than the remaining results. This is probably related to the local geological structure. The concentrations of magnesium in the surface waters were slightly depressed, indicating a direct relationship with the concentration of this element in the groundwater (Figure 2). The values obtained in our study are considerably high in comparison to those reported by KOC et al. (2001) for water bodies of similar dimensions located in Olsztyn Lake District (Pojezierze Olsztyńskie)

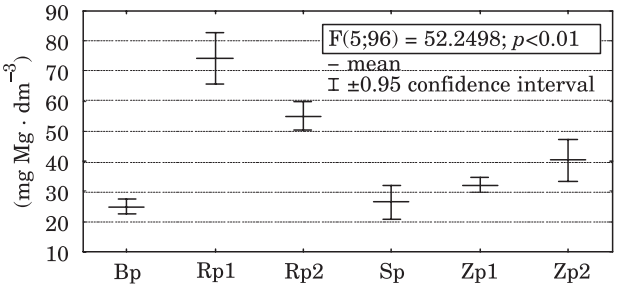

Fig. 1. Concentration of magnesium in groundwater

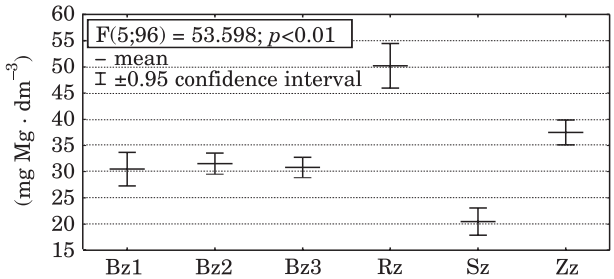

Fig. 2. Concentration of magnesium in surface waters

or MILER et al. (2001) in Wielkopolska Region. The area examined in the present research comprised black earth used as arable fields, thus the conditions are favourable for the leaching of magnesium and calcium (CYMES, SZYMCZYK 2005).

The concentration of calcium in the groundwater was characterized by significantly weaker changeability, with the exception of well Zp2, where an average concentration reached 280 mg $Ca \cdot dm^{-3}$, being evidently higher than in the other wells (Figure 3). In the case of calcium no direct relationship between the concentrations in ground and surface waters was discerned (Figure 4). It is the acidic pH that is crucial for the calcium content and this is why processes increasing the pH, such as acid rains or nitrification, increase the concentration of this element in water. (VAN LONN, DUFFY 2007). As for the bodies situated in Bliż, it may be presumed that the increased concentration of this element is related to the waters that flow there from the farmsteads and households (TANDYRAK et al. 2005).

In natural waters the content of calcium is 3-4-fold higher than that of magnesium, whereas waters which are more heavily salted, e.g. seawater, contain 3-4-fold more magnesium (GOMÓŁKA, SZAYNOK 1997). In the examined

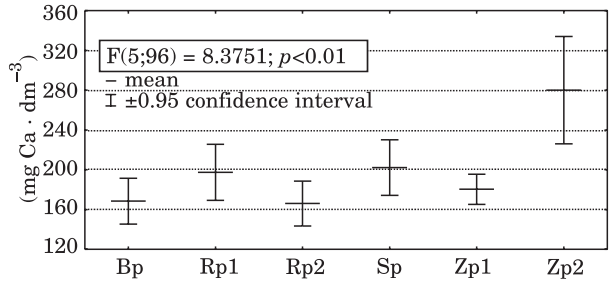

Fig. 3. Concentration of calcium in groundwater

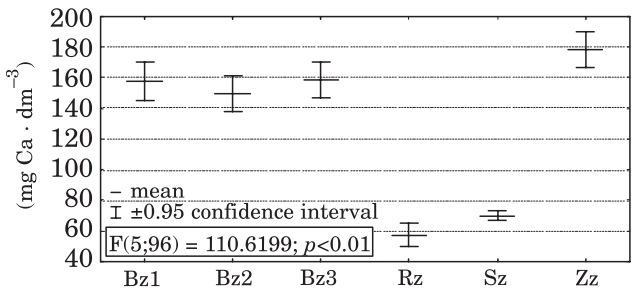

Fig. 4. Concentration of calcium in surface waters

groundwaters, calcium and magnesium concentrations were in the ratio from 2.7 to 6.9; in the surface waters the ratio was from 1.2 to 5.1. Values smaller than 3, for both types of water, were obtained only in Rybnica, which may indicate that these waters are polluted by an inflow coming from the local households.

Potassium content in the groundwaters varied substantially and ranged from 6.0 mg $K \cdot dm^{-3}$ in Bliż to 26.9 mg $K \cdot dm^{-3}$ in well Rp1 in Rybnica (Figure 5). Similar values were obtained in other studies (Miler et al. 2001, Durkowski 2005). An equally high potassium concentration occurred in surface waters coming from the subject in Rybnica, where it reached 65 mg $K \cdot dm^{-3}$. The research by Durkowski (2005) demonstrates that such high potassium concentrations occur in urban areas. An analogous situation was observed with respect to the surface waters (Figure 6); potassium concentration in body Rb was definitely higher than elsewhere and also diverged from the values noted in agricultural lands (Durkowski, Woroniecki 2001, Koc et al. 2001).

Also in the case of sodium the highest concentrations were obtained in the subject located in Rybnica, with the values of 109.7 mg $Na \cdot dm^{-3}$ for

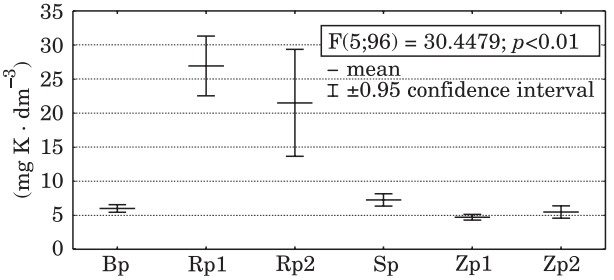

Fig. 5. Concentration of potassium in groundwater

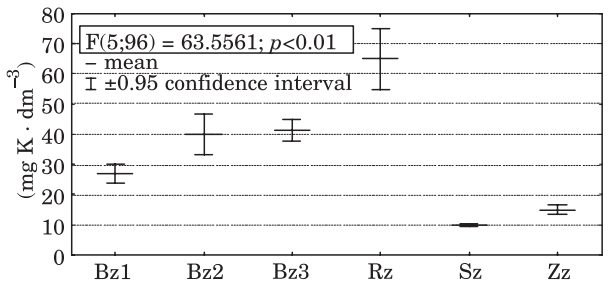

Fig. 6. Concentration of potassium surface waters

groundwaters and 59.6 mg $Na \cdot dm^{-3}$ for surface waters (Figures 7 and 8). Such high concentrations of this element do not occur on arable lands (MILER et al. 2001, PULIKOWSKI 2004), the fact which confirms the assumptions that the composition of water in this subject may be influenced by wastewater flowing to there from local households (ORZEPOWSKI et al. 2008).

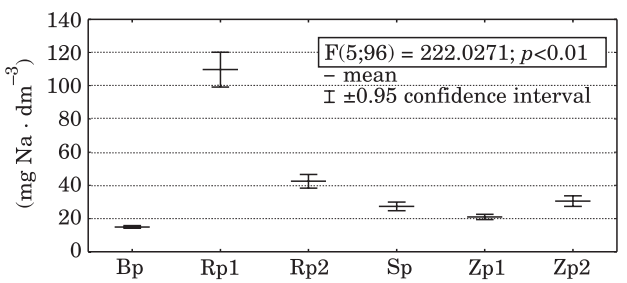

Fig. 7. Concentration of sodium in groundwater

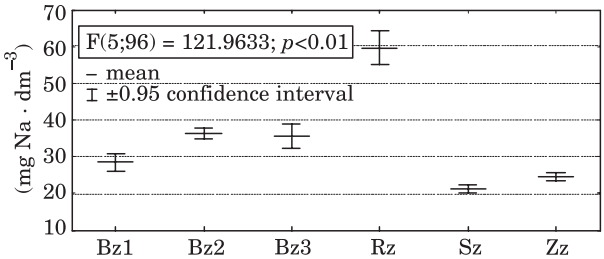

Fig. 8. Concentration of sodium in surface waters

CONCLUSIONS

1. The tested waters are characterized by a significant content of the examined elements, the finding which is directly related to the type of soils and their use as arable fields.

2. On arable areas a positive correlation of magnesium, potassium and sodium contents is observable, both in ground and surface waters.

3. Increased values of magnesium, potassium and sodium, as well as a low ratio of calcium to magnesium concentrations in the subject in Rybnica may be indicative of eutrophication of the waters in this area owing to an influx of pollutants from farmsteads and households nearby.

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