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Na, K, Ca AND Mg CONCENTRATIONS IN EFFLUENT WATER DRAINED FROM AGRICULTURAL CATCHMENT BASINS IN LOWER SILESIA

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Abstract

This paper contains the results of research of the content Na, K, Ca and Mg in waters drained from three agricultural river basins in Lower Silesia. The investigations covered two objects situated close to Wrocław and one in the border region between the Bolków-Wałbrzych Plateau and the Wałbrzych Mountains. The effect of the agricultural use of the land on changes in the concentrations of the analyzed macroelements in the water flowing from the river basins has been assessed. Between 58 and 91 samples of waters for chemical analyses were taken once a month.

Our analysis has shown that the concentrations of the analyzed elements were considerably different, both in the water flowing into and from the basins. The effluent water from the river basins was characterized by an elevated content of calcium and low concentrations of potassium. However, the content of magnesium was typical for the conditions in Poland.

The content of magnesium in waters drained from all the river basins was higher than in the water flowing into the basins and the correlation coefficients for the concentrations in both of these cross-sections ranged from 0.7846 to 0.8603. Likewise, for sodium, calcium and potassium, dependences were found between the concentrations of these elements above and below the analyzed objects but the correlation coefficients were lower. Distinctly lower values of the correlation coefficients were obtained for the village of Samotwór. The agricultural use of the river basin area contributed to a higher magnesium and calcium content in waters and an insignificantly raised content of sodium. These changes were accompanied by a decrease in the concentration of potassium.

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It has been found out that differences in the Na : K : Ca : Mg ratio between the seasons of the year (early spring, late summer) are connected with the dynamics of the calcium concentration. The growth in the concentration of this element caused evident differences in the Ca : Mg ratio, reaching 0.7 to 1.2. An increase in the value of the Ca : Mg ratio in late summer reduces the outflow of potassium in most cases. Agricultural practice does not show any direct influence on seasonal changes of the Ca : Mg ratio and its effect on the value of this ratio is not unambiguous.

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

STĘŻENIE Na, K, Ca I Mg W WODACH ODPŁYWAJĄCYCH ZE ZLEWNI UŻYTKOWANYCH ROLNICZO NA DOLNYM ŚLĄSKU

Abstrakt

W pracy przedstawiono wyniki badań zawartości: Na, K, Ca i Mg w wodach odpływających z trzech zlewni użytkowanych rolniczo na Dolnym Śląsku. Badania realizowano na dwóch obiektach położonych w pobliżu Wrocławia i jednym na pograniczu Pogórza Bolkowsko-Wałbrzyskiego i Gór Wałbrzyskich. Ocenie poddano wpływ sposobu rolniczego użytkowania gleb na zmiany stężenia analizowanych makroelementów w wodzie odpływającej ze zlewni. Próbki wody do analiz chemicznych pobierane były raz w miesiącu, ich liczba wynosiła od 58 do 91.

Analiza wykazała że stężenia tych składników, zarówno w wodzie dopływającej, jak i odpływającej z tych obiektów, istotnie się różnią. Woda odpływająca ze zlewni miała podwyższoną zawartość wapnia i niskie stężenie potasu. Natomiast zawartość magnezu była typowa dla warunków polskich.

Zawartość magnezu w wodach odpływających ze wszystkich zlewni była wyższa niż w wodzie dopływającej, współczynnik korelacji między stężeniami w obu tych przekrojach wynosił od 0,7846 do 0,8603. Dla sodu, wapnia i potasu również uzyskano istotne zależności między stężeniem powyżej i poniżej obiektu, ale współczynniki korelacji były niższe. Zdecydowanie niższe wartości współczynnika korelacji uzyskano dla Samotworu. Rolnicze użytkowanie zlewni sprzyjało zwiększeniu w wodach zawartości magnezu, wapnia i w niewielkim stopniu sodu oraz obniżeniu koncentracji potasu.

Stwierdzono, że zróżnicowanie stosunku Na : K : Ca : Mg w poszczególnych okresach (przedwiośnie, późne lato) jest związane z dynamiką stężenia wapnia. Wzrost stężenia tego pierwiastka spowodował widoczne różnice w stosunku stężeń Ca:Mg, wynoszące od 0,7 do 1,2. Wzrost wartości stosunku Ca : Mg w okresie późnego lata sprzyja w większości przypadków ograniczeniu odpływu potasu w tym okresie. Działalność rolnicza nie wykazuje bezpośredniego wpływu na sezonowe zmiany stosunku Ca : Mg, również jej oddziaływanie na wartość tego stosunku nie jest jednoznaczne.

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

INTRODUCTION

Protection of water resources is one of the major challenges for the contemporary society. Assurance of suitable quantity and quality of water determines further development of civilization on our planet. The crucial role in this process is performed by agriculture because arable lands often make up a large percentage of the area of many countries. This makes the water outflow from parts of river basins used for agriculture affect significantly the water quality in watercourses and water bodies. It is important to provide a suitable quantity of water for agriculture as the competition on behalf of other water users is growing stronger (De Fraiture, Wichelns 2010). With the food demand on the increase, the water balance can be improved by using low-grade water (De Fraiture et al. 2010), implementing economic irrigation systems (Pokladek, Nyc 2005) and changing people's eating habits. Production of vegetarian food requires just about 40% of the water used up for production of food for a diet based on beef (Renault, Wallender 2000).

Water is a very good solvent, which enables plants to obtain substances essential for their growth. Any excess of water in soil, however, causes an undesirable outflow of nutrients. The mass of nutrients removed with water depends mainly on the volume of water discharged from a given area (Pulikowski 2004). Most of this mass is composed of macronutrients and alkaline elements (Orzepowski, Pulikowski 2008). These elements are highly important for the physiology of plants and their content in water is essential when using water for the purposes connected with the supply of human population and industry.

The content of elements in water drained from river basins used agriculturally depends on the kind of soils and on the land management (Cymes, Szymczyk 2005). Irrigation and drainage also play a crucial role. Irrational use of irrigation, for example, can cause some accumulation of magnesium (Karaimov et al. 2009) whereas a depressed Ca : Mg ratio favours the release of potassium (Jalali 2008). Drainage elevates the outflow indicator and consequently depletes soil from macronutrients. Drainage systems can be used for soil desalination (Kelleners et al. 2000).

The purpose of this work has been to assess the influence of agricultural use of land on changes in concentrations of several macronutrients in water flowing from river basins situated in Lower Silesia and used agriculturally.

MATERIAL AND METHODS

This study was conducted in 1996-2008 and comprised analyses of selected elements in water sampled at three locations: Bogaczowice, Miękinia and Samowtór.

Bogaczowice is situated on the border between the Bolków-Wałbrzych Plateau and the Wałbrzych Mountains, in the region of the Central Sudetes. The research included the basin of a ditch, covering a total area of 29 hectares, within the B-II section. This ditch basin is located at an altitude of 400-500 meters above sea level, on northern and north-eastern slopes. The slopes are very steep, of the gradient from 52 to 84‰. About 50% of the area of this basin is covered by fields drained by a drainage system. In the upper part of the B-II section, an area of 6.6 hectares was distinguished and marked as the B-I section. This basin covers a cultivated field which is not drained. Between sections B-I and B-II, there is an outflow of water from a drainage system which drains 14.47 hectares of arable land. Samples of water for chemical analyses were taken from sections B-I and B-II.

In the Bogaczowice object, there are pseudo-podsolic soils of the grain size composition of medium and heavy clays with a large content of the skeleton. Soil profiles are shallow, reaching 1.2 m deep, and rest on rocky rubble. The main crops are cereals such as barley, wheat and maize.

The second object (Miękinia) is a compact, 720-hectare complex of drained cropland and forest areas situated in a small basin of a watercourse called the Zdrojek, which flows into the Jeziorka River. The Zdrojek runs through the centre of the object, along a distance of about 3 kilometres, and locally is the main water source. At the turn of 1980/90, the object was drained by regulating the main section of the watercourse, developing regular water gates on the watercourse and reconstructing an irregular network of single ditches carrying water into the Zdrojek. This pattern of ditches and water gates on the Zdrojek River, located centrally in relation to the borders of the object, ensures effective influence of the water heads. Over the recent years, there have been some changes in the use of the land within the basin of the Zdrojek River. At present, cropland makes 54% and forests cover 20%, including approx. 3%of new forests; the remaining 26% of the land is occupied by industrial or residential areas as well as some land left for future investment projects.

The soils in the object are permeable mineral (52%) and organic (48%) deposits, lying mostly on weak loamy sands and loose sands. Permanent grasslands cover mainly muck and mineral soils as well as some local low peats. Arable lands most often lie on degraded black soils and pseudo-podsolic soils of different soil classes and good hydraulic conduction.

The fall of the ground surface is mostly within 3.0-6.0‰, and locally up to15 ‰. Samples of waters for chemical analyses were taken in section M-I (above the object) and M-II (below the object).

The village of Samotwór, the third of the examined objects, is situated 20 kilometres west of the centre of Wrocław, in the lower part of the Bystrzyca River basin. This is a 100-hectare complex of arable fields, which constitutes a closed, local hydrological basin. The drainage system consists of the main ditch A with its tributary. These ditches receive waters from drainage

outlets. In the lower part of the object, on the main ditch A, there is a water gate used for annual regulation of the water outflow. The fall of the ground surface is within 1-5‰, and locally 0.5-1‰. In the past, the object was used as cropland but at present above 50% of this area is wasteland. Distances between hydrometric sections on the main water flow (S-I and S-II), at which the quality of inflowing and outflowing water was assessed, are about 600 meters. This is a typical object irrigated by water from own retention and dependent on atmospheric precipitation. It is only some periodic excess of rainfall that is drained outside the system.

The soils of the object are shallow and medium deep deposits, moderately permeable and permeable, of the grain size composition of heavy loamy sand and also light sandy loam. They lie on permeable sandy or sand and gravel deposits. These are mainly brown soils, and in the valley of the Bystrzyca River, there are also fen soils, classified as good and very good rye complex as well as good rye soils.

Samples of water for chemical analyses were taken once a month. The content of magnesium and calcium was determined with the versenate method, whereas concentrations sodium and potassium were assayed using flame photometry. All the determinations were carried out at the Laboratory of Water and Sewage of the Institute of the Environmental Development and Protection of the Wrocław University of Environmental and Life Sciences. Each series consisted of 58 to 91 of samples. The evaluation of differences in the average composition of water originating from different measuring sections was performed based on a one-way analysis of variance (the F test) at the significance level equal p=0.05. The significance of the linear correlation between concentrations in inflowing and effluent water was tested at the significance level p=0.05. For statistical calculations, a Statistica software package was applied.

RESULTS AND DISCUSSION

The results of our tests deal with the objects differentiated in respect of the landscape, soils and water management. Our analysis of the Na, K, Ca and Mg concentrations showed that waters flowing to these objects differed significantly in the content of sodium, potassium, calcium and magnesium (Figure 1).

An analogous situation occurred in reference to the water flowing away from these objects (Figure 2). The average concentrations of sodium, potassium and calcium were highly varied. Magnesium was an exception in that that its average concentration was from 18.2 mg Mg dm^{-3} in Samotwór to 25.3 mg Mg dm^{-3} in Bogaczowice. These concentrations are higher than determined in agricultural river basins in north-eastern Poland (GLIŃSKA-

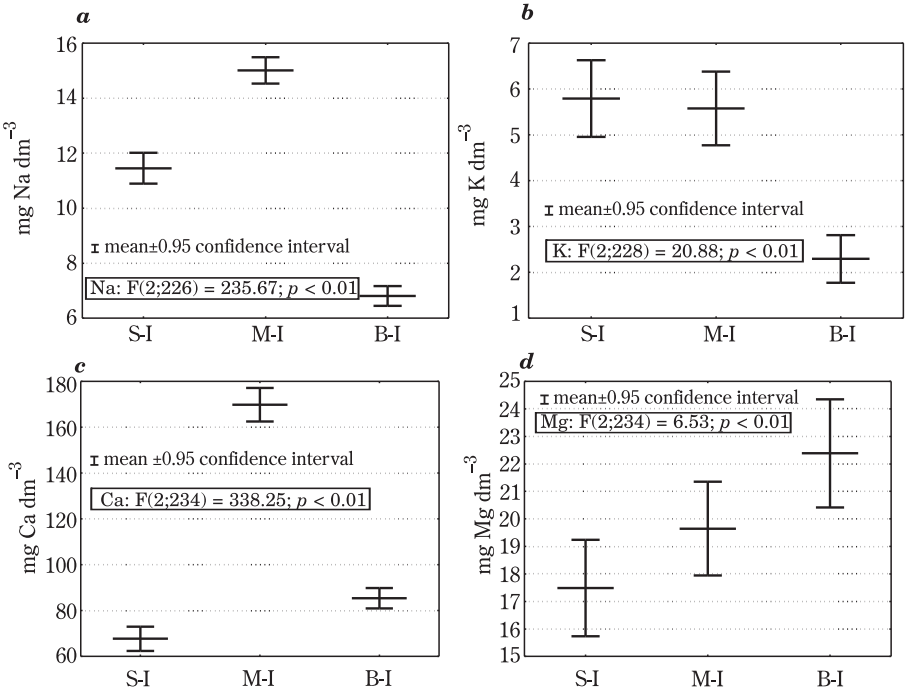

Fig. 1. Concentrations of elements in inflowing waters:
a – sodium, *b* – potassium, *c* – calcium, *d* – magnesium

-Lewczuk, Kobus 2005) but lower than reported by Terelak and Pondel (1990) for the Lubartów Plain. Notable is the high concentration of calcium in both inflow and effluent water from Miękinia – it is significantly higher than determined at the remaining objects or given in literature (Glińska--Lewczuk, Kobus 2005, Koc, Duda 2009). A very high Ca : Mg ratio, i.e. 3.6:1 in Samotwór up to 9.1:1 in Miękinia, does not favour the leaching of potassium (Jalali 2008). The determined concentrations of potassium are significantly lower than given by Durkowski, Woroniecki (2001) and Durkowski (2005).

For a number of reasons, and particularly for the physiology of plants, it is not only essential to have proper concentrations of elements but also to secure proper ratios between these elements in water available to plants. This study involved an analysis of the Na : K : Ca : Mg ratio as well as a detailed Ca : Mg ratio over a year relation and during two characteristic seasons of the year, namely early spring and late summer (Table 1).

It was demonstrated that the differentiation of the above ratios in the analyzed seasons of the year (early spring, late summer) was connected with the dynamics of the calcium concentration. Concentrations of this element were significantly higher in summer, at a smaller outflow of water from the

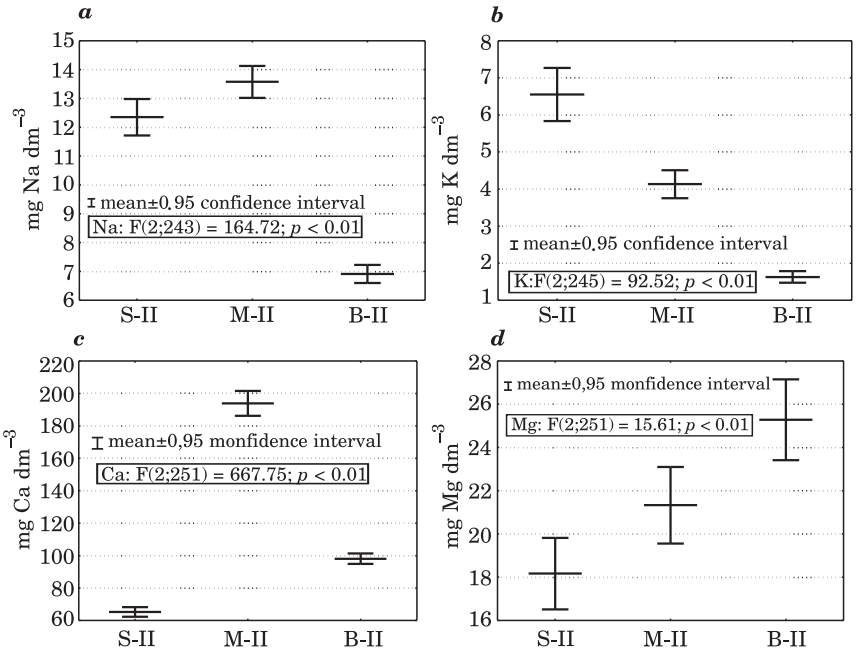

Fig. 2. Concentrations of elements in effluent waters:
a – sodium, *b* – potassium, *c* – calcium, *d* – magnesium

objects Considering the fact that this element is easily leached, one ought to suppose that the amount of leached calcium was analogous to that leached in, which obviously corresponded to higher concentrations of calcium. This caused visible differences in the Ca : Mg ratio, which ranged from 0.7 to 1.2. An increase of the value of the Ca : Mg ratio in late summer limits the outflow of potassium; concentrations of this element late summer tended to be lower. In Bogaczowice, the Ca : Mg ratios in inflow and effluent water were almost identical, although in the other two objects this ratio was variable. In Miękinia, for example, this ratio increased by about 0.4 ÷ 0.5 below the object (in this cross-section, a significant growth in the concentration of calcium in the water flowing to to the object was determined. In Samotwór, the value of this ratio below the object was lower by about 0.3÷0.4. However, seasonal changes did not show any connected with the agricultural activity because they were almost identical in sections above and below the objects.

Another analyzed dependence was the concentration of the macronutrients in effluent water versus their concentration in inflow water. The correlation coefficients for this dependence are presented in Table 2. All the correlations were significant at $p = 0.05$. For sodium, calcium and potassium, the correlation coefficients for each object were similar, with significantly smaller values obtained in Samotwór (Table 2). In all the objects, the maxi-

Table 1

Ratios of selected macroelements in early spring (Feb-April), late summer (Aug-Oct) and all year

Bogaczowice				
Season	inflow		effluent	
	Na : K : Ca : Mg	Ca : Mg	Na : K : Ca : Mg	Ca : Mg
P*	3.0:1.0:34.5:9.6	3.6	4.1:1.0:53.8:14.8	3.6
L*	2.6:1.0:34.2:8.0	4.3	4.1:1.0:65.5:15.4	4.3
Year	3.0:1.0:37.3:9.8	3.8	4.2:1.0:60.2:15.5	3.9
Miękinia				
Season	inflow		effluent	
	Na : K : Ca : Mg	Ca : Mg	Na : K : Ca : Mg	Ca : Mg
P	2.6:1.0:26.3:3.3	8.0	3.2:1.0:40.3:4.8	8.4
L	2.8:1.0:33.4:3.6	9.2	3.4:1.0:51.5:5.4	9.6
Year	2.7:1.0:30.5:3.5	8.6	3.3:1.0:48.0:5.3	9.1
Samotwór				
Season	inflow		effluent	
	Na : K : Ca : Mg	Ca : Mg	Na : K : Ca : Mg	Ca : Mg
P	2.2:1.0:12.7:3.5	3.7	1.5:1.0:8.0:2.4	3.3
L	1.9:1.0:11.2:2.5	4.5	2.0:1.0:10.5:2.6	4.1
Year	2.0:1.0:11.8:3.1	3.9	1.9:1.0:10.0:2.8	3.6

*early spring
**late summer

Table 2

Correlation coefficients between inflow and effluent water from the river basins

Element	Bogaczowice	Miękinia	Samotwór
Sodium	0.6802	0.6433	0.2332
Potassium	0.5181	0.6686	0.3601
Calcium	0.6758	0.7072	0.3136
Magnesium	0.7846	0.8064	0.8603

mum values of the correlation coefficients were calculated for magnesium, and the maximum value for this element, in contrast to the other ones, appeared (Figure 3). From the above analysis, it can be concluded that the concentration of magnesium in water flowing from a basin area used agriculturally is to a small extent relative to the type of water management.

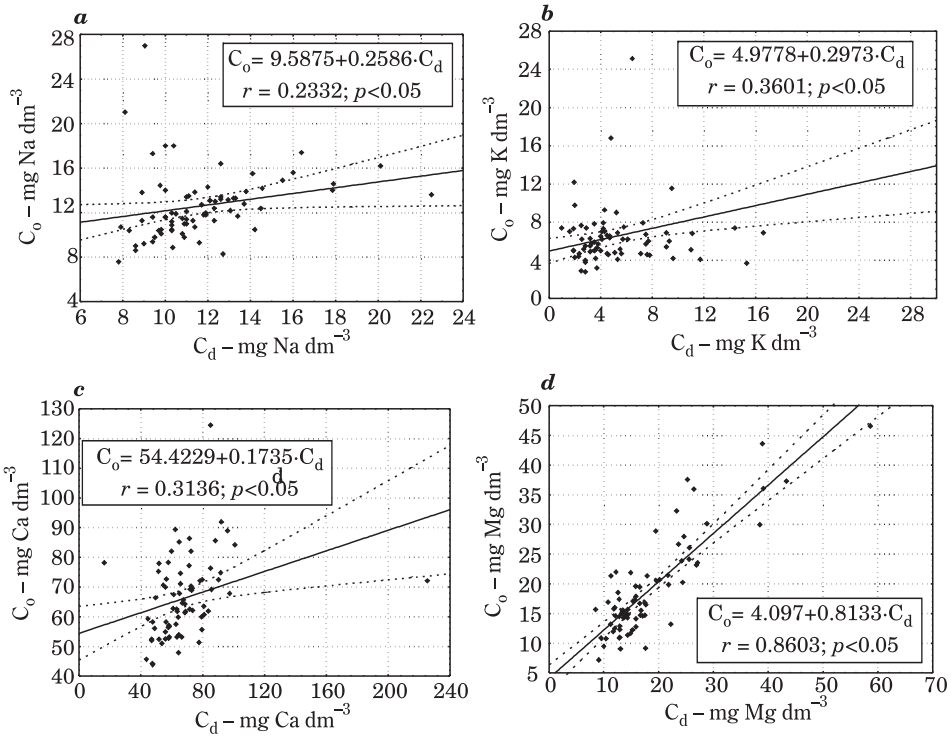

Fig. 3. Relations between concentrations of elements in inflow (Cd) and effluent (Co) water in Samotwór: *a* – sodium, *b* – potassium, *c* – calcium, *d* – magnesium

Finally, differences between concentrations of elements in inflow and effluent water from the objects were analyzed. For sodium, it was evident that drainage affects the leaching of this element as its concentration was higher in water from both drained objects, although these differences were not always significant. In the water flowing away from Miękinia, the concentration of sodium was actually smaller than its concentration above the object (Figure 4). The concentrations of potassium in the outflow water were actually smaller in Bogaczowice and Miękinia, whereas in Samotwór a somewhat higher value was determined in the water below the object, although the difference was not significant. In Bogaczowice and Miękinia, a higher concentration of calcium was found below the objects, which can suggest the leaching of this element from the river basin. Such a situation did not appear in Samotwór. Unambiguous results were obtained only for magnesium (Figure 5), whose concentration rose in the water flowing away from all the objects, but it was only in Bogaczowice that this difference was significant at the assumed level of significance of $p = 0.05$.

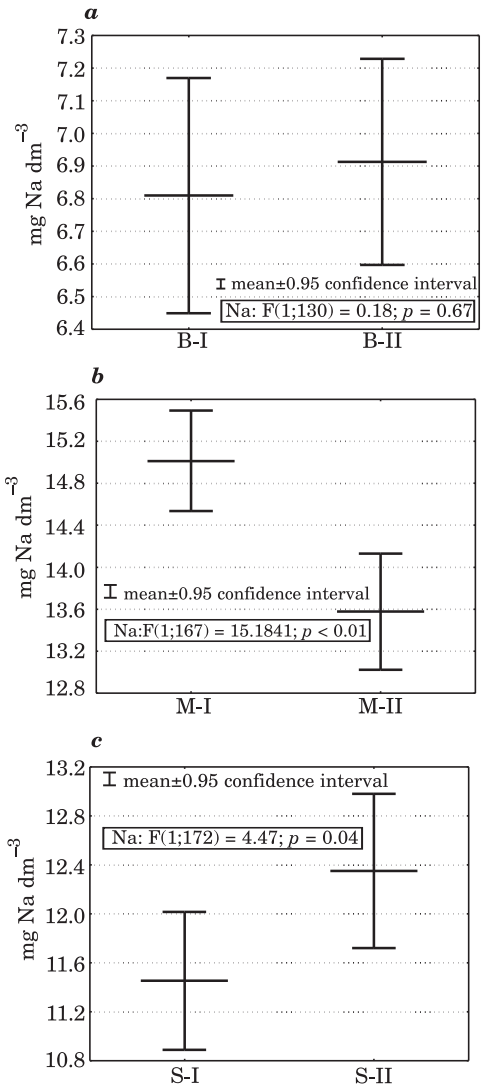

Fig. 4. Concentration of sodium in inflow and effluent waters in:
a – Bogaczowice, *b* – Miękinia, *c* – Samotwór

It can be concluded that the agricultural use of the river basins favoured an increase in the concentration of magnesium, calcium and, slightly, sodium but depressed the concentration of potassium.

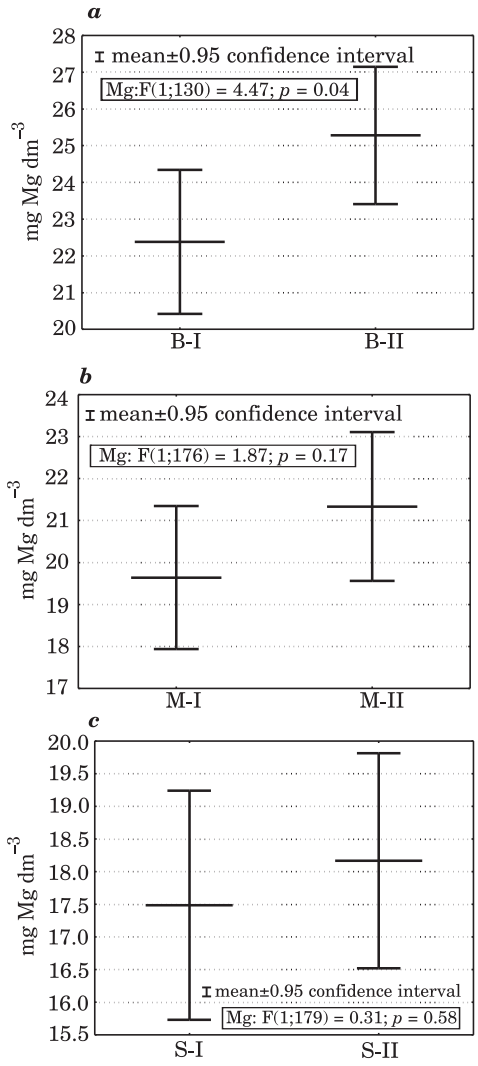

Fig. 5. Concentration of magnesium in inflow and effluent waters in: *a* – Bogaczowice, *b* – Miękinia, *c* – Samotwór – Samotwór

CONCLUSIONS

1. The magnesium content in effluent waters from all the river basins was higher than in the inflow water, with the correlation coefficients for the concentrations of the element in both sections varying from 0.7846 to 0.8603. As or the remaining elements, significant dependences were found between

their the concentrations above and below the objects, but the correlation coefficients were lower than for magnesium.

2. The differentiation of the Na : K : Ca : Mg ratio in particular seasons of the year (early spring, late summer) is connected with the dynamics of the calcium concentration. Concentrations of this element were significantly higher in summer.

3. An increase in the in value of the Ca : Mg ratio during late summer reduces the leaching of potassium; concentrations of this element tended to be lower during this season.

4. Agricultural activity does not show any direct influence on seasonal changes of the Ca : Mg ratio. Likewise, its effect on the value of this ratio is not univocal.

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