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MAGNESIUM CONCENTRATIONS IN THE WATERS OF RE-NATURISED RESERVOIRS IN RURAL AREAS*

Józef Koc, Katarzyna Sobczyńska-Wójcik, Andrzej Skwierawski

Chair of Land Reclamation and Management University of Warmia and Mazury in Olsztyn

Abstract

The objective of the study has been to determine magnesium concentrations and their seasonal changes in waters of re-naturised reservoirs situated in a rural area, 25 years after their re-creation. The study included 3 small, non-flow-through reservoirs, situated close to the village of Sętal, in the commune of Dywity. Water samples for analysis were collected once a month in 2005 and 2006. They were examined in respect of the magnesium level and such physicochemical parameters as temperature, pH, oxygenation, dissolved oxygen, electrolyte conduction and water depth.

The results prove that the environment of the surface waters in this area is poor in magnesium (5.2 $mg \cdot dm^{-3}$ - 6.6 $mg \cdot dm^{-3}$ on average), which is characteristic for postglacial regions. The re-created water reservoirs can be listed in water quality class I in terms of their magnesium content.

The waters of these small re-created lakes were characterised by huge seasonal changes of magnesium concentrations. However, the fluctuations of Mg^{+2} concentrations were often larger within particular sites than between the examined reservoirs. The highest average seasonal magnesium concentration of 6.6 $mg \cdot dm^{-3}$, varying from 3.9 $mg \cdot dm^{-3}$ to 10.0 $mg \cdot dm^{-3}$, was determined in the waters of a reservoir whose whole catchment had for many years been used for agriculture.

The lowest magnesium concentrations in the waters of the reservoirs occurred in springtime, with a slight increase in early summer and an equally slight decline afterwards. No significant increase in magnesium amounts was found until autumn, before they reached their peaks in wintertime. Such a course of fluctuations was caused by the maximum magnesium biosorption in spring and releasing internal reserves (green matter and

prof. dr hab. Józef Koc, Chair of Land Reclamation and Management, University of Warmia and Mazury, pl. Łódzki 2, 10-730 Olsztyn, Poland, e-mail katemel@uwm.edu.pl

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bottom deposits) of the reservoirs in autumn and winter. Decrease and increase in the Mg^{+2} ion concentration in the waters of the reservoirs occurred in two 'pulses': in the springtime and wintertime, respectively.

Key words: re-naturisation of water reservoirs, magnesium concentrations, non-flow-through reservoirs.

STĘŻENIA MAGNEZU W WODACH ZBIORNIKÓW ZRENATURYZOWANYCH NA OBSZARACH WIEJSKICH

Abstrakt

Celem pracy było określenie stężenia magnezu oraz jego sezonowych zmian w wodach zrenaturyzowanych zbiorników wodnych zlokalizowanych na terenach wiejskich, po 25 latach od ich odtworzenia. Badaniami objęto 3 małe bezodpływowe zbiorniki wodne, położone w sąsiedztwie miejscowości Sętal, w gminie Dywity. Próbki wody do analiz laboratoryjnych pobierano 1 raz w miesiącu w latach 2005-2006 i oznaczano w nich magnez oraz parametry fizykochemiczne: temperaturę, pH, nasycenie tlenem, tlen rozpuszczony, przewodnictwo elektrolityczne oraz głębokość wód.

Wykazano, że środowisko występowania wód powierzchniowych na tym obszarze jest ubogie w magnez (średnio 5,2 $mg \cdot dm^{-3}$ - 6,6 $mg \cdot dm^{-3}$), co jest charakterystyczne dla terenów polodowcowych. Odtworzone zbiorniki wodne pod względem zawartości magnezu można zaliczyć do I klasy jakości wód.

W wodzie niewielkich, odtworzonych jezior objętych badaniami stwierdzono dużą sezonową zmienność stężeń magnezu. Jednak wahania stężeń Mg^{+2} często były większe w obrębie poszczególnych obiektów niż między obiektami badań. Najwyższe średnie sezonowe stężenie magnezu – 6,6 $mg \cdot dm^{-3}$, z wahaniami od 3,9 $mg \cdot dm^{-3}$ do 10,0 $mg \cdot dm^{-3}$, odnotowano w wodach zbiornika, którego zlewnia w całości jest użytkowana rolniczo od wielu lat.

Najniższe stężenia magnezu w wodach zbiorników występowały wiosną, niewielki ich wzrost obserwowano na początku lata, a następnie niewielki spadek. Wyraźny przyrost ilości magnezu stwierdzono dopiero jesienią, aż do osiągnięcia maksimum zimą. Taki przebieg był spowodowany maksymalną biosorpcją magnezu wiosną i uruchamianiem jesienią oraz zimą z zasobów wewnętrznych zbiorników (masa roślinna i osady denne). Spadek oraz wzrost stężenia jonów Mg^{+2} w wodach zbiorników odbywał się więc w postaci dwóch „pulsów" odpowiednio wiosną i jesienią.

Słowa kluczowe: renaturyzacja zbiorników wodnych, stężenia magnezu, zbiorniki bezodpływowe.

INTRODUCTION

Field water reservoirs play many roles in ecology and economy, primarily because they are an important element in the water balance of micro-catchments and, secondly, they are of some influence on water relations in soils (DRWAL, LANGE 1985). Organic and mineral substances flowing in water enter biological cycling and become accumulated in small ponds and their shore zones (SZYPEREK 2005). However, such reservoirs continually collect organic and mineral residues, which diminishes them and finally causes their disappearance (OSTENDORP et al. 1995, PIEŃKOWSKI 1996, MITRAKI et al. 2004). Water reservoirs play various functions in the environment, some of which are impossible to replace, therefore it is sometimes necessary to re-cultivate or re-naturise natural water bodies, depending on the direction and progress of changes they undergo.

In the recent years, as a result of the new economic and social conditions in Poland, it has become quite common to abandon farming in some areas of the country. This, in combination with the staggering water management, has made such areas vulnerable to rapid changes. Neglected drainage systems gradually fail to operate properly. Setting aside fallows initiates the growth of weeds and brambles. One possible way to use former farmland rationally re-naturisation, which in terms of water bodies means re-creating water reservoirs. Re-naturisation deserves particular attention because rural areas often hold some enclaves of natural hydrophilic flora and clumps of trees, which may serve as a source of propagating local species native of a given area (JĘDRYKA, KAMIŃSKA 2003).

Calcium and magnesium concentrations in water depend mostly on their influx from a catchment area and on sedimentation processes. High levels of these elements in surface waters result from their intensive leaching from soils, which is a natural and inevitable process (KAJAK 2001, GLIŃSKA-LEWCZUK 2005).

The objective of the present study was to analyse magnesium concentrations and their seasonal changes in the waters of small field water reservoirs, situated in the areas used for agriculture, 25 years after they had been re-created. Our attention was paid to magnesium because it is one of the elements essential for the proper development of plants and animals, and its circulation in the environment depends on the processes which occur in water reservoirs.

MATERIAL AND METHODS

The three water reservoirs we examined are located near the village Sętal in the commune of Dywity, which lies in the central part of the Olsztyn Lake District (Pojezierze Olsztyńskie) – Figure 1. Geologically, the commune is situated in the Mazovian Basin (Niecka Mazowiecka), which lies on Cretaceous formations (LEWICKA, TOMKIEWICZ 1994). The dominant earth types are clays, glacial gravels, and sands together with fluvioglacial formations, mostly covered with forests and forest-like plant assemblages. The landscape is highly diverse, with characteristic erratic blocks, moraine uplands and hills, typical of a postglacial area. The area of the commune we examined only slightly forested, mostly occupied by farmland and dominated by brown soils (GUS 2003).

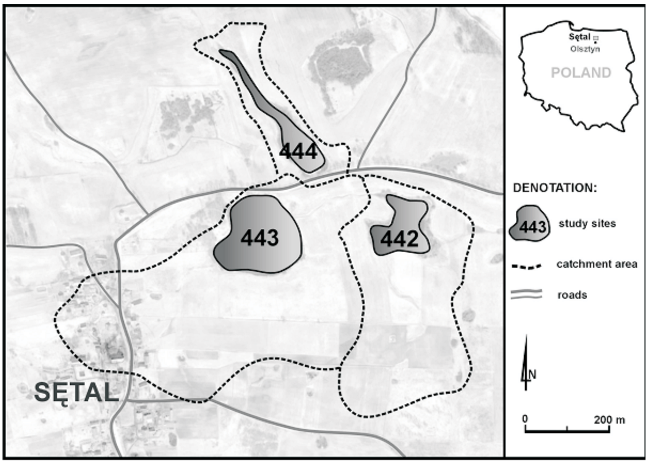

Fig. 1. Location of the study area and sites

The study has included three small, non-flow-through water reservoirs marked as nos 442, 443 and 444, of the maximum depth of 2.5 m. Reservoir 442 has the smallest area of 1.49 ha. Until 2004, only the western part of the catchment covering 16.7 ha was used for agriculture whereas the land in the east was fallow. It was reintroduced to farming in 2005. Reservoir 443, of an area of 3.61 ha, has the largest catchment among the three study sites: 29.2 ha, of which 60% is arable land and the remaining land consists of wastelands and bushes. The area of Reservoir 444 is 1.65 ha and its catchment is the smallest one, just 4.9 ha, all of which is used for agricultural purposes. The arable lands in all these catchments were used for plantations of rape in 2005 and winter triticale in 2006.

The above reservoirs were dried out in the late 19^{th} century by a complex drainage system. end of the 19^{th} century. In 1980, following some regulation of the water conditions in this area, Reservoir 443 was re-created and a few years later the other two ponds spontaneously filled with water as a result of an elevated groundwater level in the catchment.

The following physical and chemical parameters were recorded: temperature – using a thermometer integrated with oxygen probe, oxygen and oxygenation – using a WTW Multiline P3 meter, electrolytic conductivity – using a Hanna conductometer, and pH reaction – with a potentiometer. The water depth was measured once a month based on the watermark readings. Water samples for laboratory analyses were collected once a month in 2005 and 2006, from the central depth of every reservoir. Their magnesium concentration was determined colorimetrically with titanium yellow (HERMANOWICZ et al. 1999). Species composition of the flora was identified in the filed using the key by RUTKOWSKI (1998).

Monthly means of total precipitation were calculated from the data interpolated from the meteorological stations in Lidzbark Warmiński and in Olsztyn – Dajtki, which were obtained from the Institute of Meteorology and Water Management.

Statistical calculations of the results were performed with Statistica 7 programme, and the coefficient of variation was calculated according to the formula: standard deviation/arithmetic mean x 100%. Seasonal changes in the magnesium concentration in water were calculated according to the following groups of samples: winter (January – March), spring (April – June), summer (July – September), autumn (October – December). This division was created on the basis of the air and water temperatures during the sample collection.

RESULTS AND DISCUSSION

Chemical composition of water is very complex and closely related to its migration and the environment it originates from. Chemical properties of waters in agricultural and forested areas are dependent on soil's physical, chemical and biological properties as well as on the method of land management, intensity of agronomic practices, draining processes and climatic conditions (BOROWIEC, PIEŃKOWSKI 1993, KOC, SZYMCZYK 2003).

Our results (low concentrations of Mg^{+2}) indicate that the water environment in the study area is poor in magnesium, which is characteristic for postglacial areas (MACIOSZCZYK 1987). The re-created water reservoirs can be listed in water quality class I in respect of their magnesium content (*Rozporządzenie MŚ* 2004).

The three sites we have examined are classified as polytrophic reservoirs with richly developed rush flora. In the reservoirs, significant changes of physical and chemical properties were observed (Table 1). The changes in the Mg^{+2} concentration were influenced by meteorological conditions (the seasons). In the summertime, over-oxygenation was noticed, caused by an intensive flora growth. Electrolytic conductivity of the waters, which indicates water-dissolved ions, also changed significantly. The waters of the small, re-created lakes subjected to our study were characterised by huge seasonal changes of magnesium concentrations (Figures 2 and 3). However, the fluctuations were often larger within the particular sites than between them.

Slightly different meteorological conditions in the time of the study (2005 and 2006) triggered various trends in magnesium fluctuations in the analysed waters. For each site, the highest concentrations were noticed in the winter months (January – March), particularly in 2006, when the reservoirs had a 30-centimetre-thick ice cover. At that time, the amount of oxygen dissolved in the waters was at its lowest, and the electrolyte conduction was the highest for whole study period. Such conditions favoured a release of mineral components, including magnesium, from the bottom deposits (Table 1).

Seasonal changes of Mg^{+2} concentrations were characterised by a decrease in springtime, which was connected with an intensive absorption of this element by the developing rush flora (reed canary grass, common

Table 1

Seasonal changes of physical and chemical parameters in the waters of the reservoirs

Parameter	Season*	Study site (Reservoir)					
		442		443		444	
		2005	2006	2005	2006	2005	2006
Dissolved oxygen ($mg\ O_2 \cdot dm^{-3}$)	WI	4.6	2.9	4.9	5.5	4.8	2.6
	SP	10.4	12.0	7.8	9.0	9.7	8.5
	SU	10.2	11.1	11.8	9.1	9.5	9.2
	AU	12.2	8.6	11.7	9.3	13.1	8.1
	YM	9.3	8.6	9.0	8.2	9.3	7.1
Oxygenation (%)	WI	34.5	20.1	37.1	36.9	36.6	17.6
	SP	105.8	126.8	80.6	91.9	99.8	90.7
	SU	122.6	123.8	141.6	107.3	116.3	149.1
	AU	97.1	76.0	90.8	80.1	100.8	69.4
	YM	90.0	86.7	87.5	79.0	84.6	81.7
Temperature (°C)	WI	1.56	0.3	1.4	0.3	1.7	0.1
	SP	15.9	17.5	16.1	17.0	15.9	17.6
	SU	24.2	23.0	23.2	24.1	23.9	23.7
	AU	4.8	6.4	5.0	6.4	4.8	5.4
	YM	11.6	11.8	11.4	11.9	11.6	11.7
pH	WI	8.9	7.3	8.1	7.3	8.1	7.2
	SP	7.8	7.7	7.9	7.7	7.7	7.6
	SU	8.5	8.2	8.7	8.2	8.2	7.8
	AU	8.3	7.8	7.9	7.9	8.0	7.8
	YM	8.4	7.7	8.2	7.8	8.0	7.6
Conduction ($\mu S \cdot cm^{-1}$)	WI	250	522	283	375	246	406
	SP	209	200	299	256	307	266
	SU	206	268	328	268	322	251
	AU	222	260	308	267	299	265
	YM	222	313	251	292	294	297
Water depth (cm)	WI	205	140	166	161	173	164
	SP	211	148	165	159	174	164
	SU	185	117	155	156	142	142
	AU	134	122	152	160	130	176
	YM	184	132	160	159	155	162

* WI – winter; SP – spring; SU – summer; AU – autumn; YM – yearly mean

reed, water horsetail, broadleaf cattail), the event which is also confirmed by SZYPEREK (2003). The lowest Mg^{+2} concentration (1.6 mg·dm^{-3}) during the two years was noticed in Reservoir 442 in June 2005. The results support the opinion that low magnesium concentrations in spring are characteristic for small non-flow-through ponds with intensively developed flora (KOC 1999). When compared to spring, slight increases in the magnesium concentrations were noticed in summer, apart from Reservoir 443 in 2006, in which the Mg^{+2} concentration continued to decrease. The increased amount of Mg^{+2} may originate from its production in the processes of mineral and organic matter decomposition as well as its release from bottom deposits. Movements of plants (caused by waving generated by winds), thermal circulation and activities of organisms disturb and disperse bottom deposits, which accelerates their decomposition (SKONIECZEK et al. 2004, SKORBIŁOWICZ 2005). In summertime, the water level was lowered by evapotranspiration, which additionally increased magnesium concentrations (Table 1 and Figure 2.).

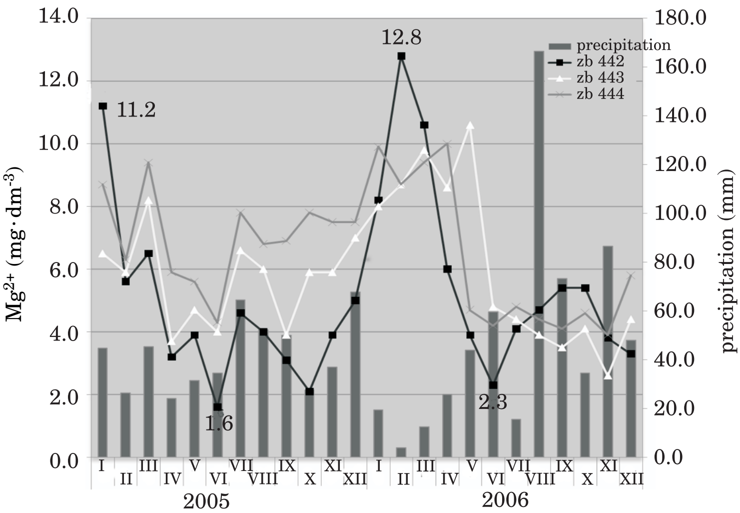

Fig. 2. Seasonal changes of magnesium concentrations (mg·dm^{-3}) in the waters of the reservoirs in 2005 and 2006 in relation with the meteorological conditions

A distinct increase in the Mg^{+2} concentrations in the waters of all the reservoirs was observed from autumn 2005. This trend lasted in Reservoir 442 until the winter 2005, and in Reservoirs 443 and 444 until the early spring of the following year. It could have been caused the atmospheric precipitations occurring outside the growing season (limited phytosorption) which may have caused extraction of Mg^{+2} from arable lands (SZYMCZYK, CYMES 2005) as well as its release from the deposits (Figure 2).

When analysing the dynamics of Mg^{+2} concentrations in the waters of the reservoirs, it should be noticed that the biggest fluctuations occurred in Reservoir 442: from 1.6 to 11.2 mg·dm^{-3} (CV = 56.5%, SD = 2.6) in 2005 and from 2.3 to 12.8 mg·dm^{-3} (CV = 55%, SD = 3.3) in 2006. Most likely, it was the effect of the most disadvantageous ratio of the catchment to the reservoir area (16.7 ha : 1.49 ha) as compared to the other basins (Table 2 and Figure 1). Such substantial fluctuations may have also been the result of reintroducing farming in the eastern part of the catchment, thus accelerating the release of Mg^{+2} ions from the soils. The increase in magnesium concentration observed from autumn to winter in the water of this basin may have been caused by a large influx of groundwater, rich in magnesium. In these two seasons of the year, the leaching of elements from soil is facilitated by ploughing and temporary absence of plant cover (FALKOWSKI et al. 1996).

Table 2

Magnesium concentrations in the waters of the reservoirs in 2005 and 2006

Study site	2005			2006		
	mean X / range of values	SD	CV (%)	mean X / range of values	SD	CV (%)
442	4.6 / 1.6 - 11.2	2.6	56.5	5.9 / 2.3 - 12.8	3.3	55.0
443	5.6 / 3.7 - 8.2	1.4	24.5	6.1 / 2.6 - 10.2	2.8	44.4
444	7.1 / 4.3 - 9.4	1.5	21.1	6.2 / 3.9 - 10.0	2.5	39.6

SD – standard deviation, CV – coefficient of variation

A large increase in the concentration of this element was also highly dependent on the water level fluctuations. Diminishing water volume in the reservoirs in spring accelerated the heating of the whole system, including its deposits, and this in turn accelerated the changes which occurred in the system. Additionally, exposition of some part of the deposits as well as their transformations under aerobic conditions and higher temperatures may have speeded up mineralisation to the simplest forms. Autumn atmospheric precipitations made magnesium return to the reservoir's waters (Table 1). Smaller fluctuations of magnesium concentrations were observed in Reservoirs 443 (CV = 24.5, SD = 1.4) and 444 (CV = 21.1, SD = 1.5) in 2005 and higher in 2006, when the coefficient of variation and the standard deviation were almost two-fold higher (Table 2). This could have been caused by different atmospheric conditions, suggesting that the dynamics of magnesium concentrations in the waters of the reservoirs was influenced more by the anaerobic decomposition of their deposits under the ice cover (in 2006) than by the mixing of ice-free waters by wind.

An analysis of correlations between magnesium concentration and physicochemical parameters of the waters in the reservoirs has shown statistically significant correlations (at $p \geq 0.05$) between the above parameters occurred only in Reservoir 442 (Table 3). The concentration of magnesium

Table 3

Magnesium concentrations in the waters of the reservoirs in 2005 and 2006

Reservoir number \ Physical parameters	Temperature	pH	Conductivity	Oxygenation
442	- 0.57*	-0.46*	0.73*	-0.66*
443	-0.39*	-0.25	0.24	-0.23
444	-0.53*	-0.06	0.11	-0.47*

*correlations significant at $p \leq 0.05$

positively correlated with conductivity (r = 0.75). As for thethe other relationships, the correlation coefficients were negative: temperature (r = -0.57), pH (r = -0.46), oxygenation (r = -0.66). However, in Reservoir 444, the Mg^{+2} concentration was significantly correlated only with temperature and oxygenation, and in Reservoir 443 it was significantly correlated, with the correlation coefficients being negative. This suggests that the Mg^{+2} concentration in waters of small reservoirs is highly variable and depend on a wider range of parameters than those analysed in this study.

In the two years of the study, in all the lakes the seasonal means for magnesium concentrations were at their highest in the wintertime (Fig. 3). The magnesium concentrations began to rise as early as autumn, which to some extent was caused by the presence of flora, which participates not only in accumulation of elements but also in their release. This phenomenon generally happens in two ‘pulses’ – in summer and in winter (Wojciechowska, Solis 1999).

The study has proved that during the analysed time average magnesium concentrations in the reservoirs were varied: from 5.2 mg□dm^{-3} (lake no 442), 5.8 mg·dm^{-3} (443) to 6.6 mg·dm^{-3} (444) – Figure 3. Thus, the variability ranged from from 10% to 26%. The highest average magnesium concen-

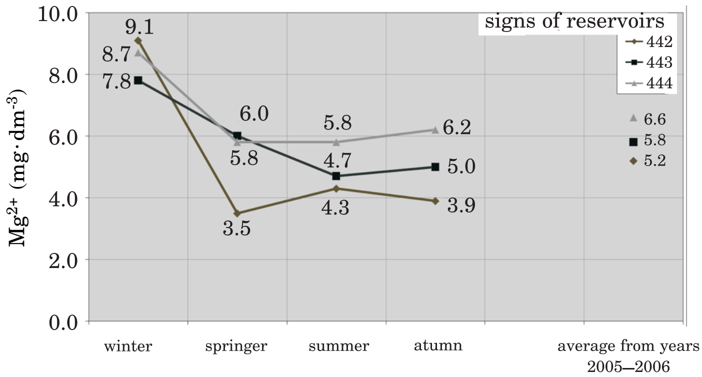

Fig. 3. Average seasonal magnesium concentrations (mg·dm^{-3}) in 2005 and 2006 in the waters of the reservoirs

tration in the water of Reservoir 444 was closely related to the agricultural character of its catchment, which for many years had been used agriculturally. The influx of elements from the catchment is mostly conditioned by the landscape features, its flora, soil compactness, intensity of agricultural production and type of land use (KOC et al. 2002, BANACH, SZCZUROWSKA 2007). The results of our study clearly demonstrate that reservoirs situated on arable lands are most vulnerable to contamination with substances flowing out of their catchments (e.g. excess of unused mineral fertilizers).

CONCLUSIONS

1. The water reservoirs re-created 25 years before our study were characterised by low values of average magnesium concentrations (from 5.2 mg·dm^{-3} to 6,6 mg·dm^{-3}), which is characteristic for postglacial areas, such as the area where the study sites are situated.

2. The highest average seasonal magnesium concentration of 6.6 mg·dm^{-3} oscillating from 3.9 mg·dm^{-3} to 10.0 mg·dm^{-3} was noticed in the water of the reservoir whose whole catchment had been used for agriculture for many years.

3. The seasonal changes of Mg^{+2} concentrations were evidently influenced by meteorological conditions, which affect the circulation of substances in the catchments. The reservoirs displayed a distinctly cyclic nature of magnesium concentration changes connected with a decrease in magnesium levels in spring (when magnesium is intensively absorbed by plants) and its increase in autumn and winter due to depressed or absent bioaccumulation of Mg^{+2} released from the catchments and deposits of the lakes.

4. The highest amplitude of Mg^{+2} ionic concentrations in water was noticed in winter, and the lowest one – in spring, in the reservoir whose catchment was partly covered by fallows. Reintroducing the fallow land into farming, in addition to the disadvantageous ratio of the catchment to the lake's surface area and depth resulted in such a high coefficient of magnesium fluctuations.

5. The analysis of the changes in magnesium concentrations and their relationship with the physical and chemical parameters of the water has proved that in small water bodies magnesium levels are a highly variable feature, only partly connected with other properties of water. Magnesium concentrations negatively correlate with the water temperature and oxygenation.

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