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# OCCURRENCE OF CALCIUM, MAGNESIUM AND IRON IN BOTTOM SEDIMENTS OF LOBELIA LAKES*

## WYSTĘPOWANIE WAPNIA, MAGNEZU I ŻELAZA W OSADACH DENNYCH JEZIOR LOBELIOWYCH

**Summary.** Lobelia lakes are the ecosystems which needs special attention due to their specific and unique character. There are about 170 lobelia lakes in Poland. Increased degradation of this kind of lakes has been observed recently. To prevent degradation of the lobelia lakes it is necessary to introduce proper standards which bring limitation of anthropopression of these very valuable natural reservoirs. The aim of the research was to determine and compare the contents of lithophilus elements (Mg, Ca and Fe) in bottom sediments from selected lobelia lakes. The lake sediments were sampled during summer stagnation in the surface layer of the thickness of about to 20 cm. The samples were collected at two stands: (i) in the littoral zone and (ii) at the maximum depth of the basin. The investigated sediments were characterised with the low concentration of Ca, Mg, Fe. The total mean concentration of the metals was Fe > Mg > Ca (11 136 > 1.626 > 0.798 $g \cdot kg^{-1}$). In the lakes characterised with big depth in relationship to their surface (a big slope) substantial differences in properties of the bottom sediments in the litoral zone and profundal zone were observed. In the lakes of small depth the substantial differences in the properties of the investigated bottom sediments were not observed in the whole basin. The obtained differences in chemical properties of the investigated sediments result from individual characteristics of each lake such as: geological structure, character and use of the basin, as well as thermal conditions and mixing of the lake waters or its degree of oxidation.

**Key words:** lobelia lakes, bottom sediments, calcium, magnesium, iron

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## Introduction

Due to rapid acceleration of civilization, development protection of environment is an essential aspect of economic growth. Taking actions on environmental protection is necessary to conserve some ecosystems and species, especially those endangered with anthropopression because of their specific ecological requirements and conditions of existence. Lobelia lakes represent this kind of ecosystem which needs special attention due to its specific and unique character. In Poland there are about 170 lobelia lakes (SZMEJA 1997, KRASKA and PIOTROWICZ 2000). Polish lobelia lakes are situated on the south-west boundary of their covering area in Europe. Polish lobelia lakes are located on plateau areas of the frontal moraine belt, partly on sandurs mainly in Western Pomerania.

Lobelia lakes are disharmonic aquatic reservoirs. Due to their limnological character they are not a unified whole. Low contents of calcium, iron and phosphorus are the hydrochemical parameters which characterise them. They are also characterised with a high water transparency. Lobelia lakes are mainly distrophic reservoirs partly close to mesotrophic ones. Even those lakes which indicate clear symptoms of eutrophication substantially differ from typical eutrophic reservoirs (KRASKA et al. 1997, KRASKA and PIOTROWICZ 2000).

Flora of lobelia lakes includes mainly relict species from Boreal and Atlantic Periods such as *Lobelia dortmanna, Isoetes lacustris* and *Litorella uniflora.* Narrow range of tolerance as an effect of physiological conditions in which the plants may exist allows them to vegetate only in this kind of waters. Changes in trophy or pH waters cause atrophy or even extinction of the species. *Myriophyum alternifolium* that also occurs in lobelia lakes is much less demanding than the other three and during degradation of lake disappears as the last one.

Due to their rather small areas and depth, lobelia lakes are very sensitive to all kinds of anthropopression. Increased degradation of this kind of lakes has been observed recently. Within the serious threats for the lakes there are inflows which carry products of agricultural activity, intensive deforestation or excessive use of the lakes for recreation and fishing farming. Disturbing the relations between land and lake ecosystems leads to changes in trophic and biocoenotic systems in the lakes. In consequence the trophic status of a lake changes and primary species of flora disappear. Depending on the direction of anthropopression it leads to distrophication or eutrophication (KRASKA et AL. 1999, 2006).

To prevent further devastation and degradation of the lobelia lakes it is necessary to introduce proper standards which bring limiting of anthropopression of these very valuable natural reservoirs.

In EU lobelia lakes are declared to be endangered ecosystems of European importance. They are included into I Habitats Directive that means the lobelia lakes are a subject of protection on the areas of Natura 2000 Network.

The aim of the research was to determine and compare the contents of lithophilus elements (Mg, Ca and Fe) in bottom sediments from selected lobelia lakes.

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## Material and methods

There are four lobelia lakes focused on for the investigations. The lakes differ in morphometric structure, and use of basin and trophy waters (Table 1). They are located on Western Pomerania (Fig. 1).

Table 1. Selected morphometric and hydrological parameters of the studied lakes
Tabela 1. Wybrane parametry morfometryczne i hydrologiczne badanych jezior

| Lake<br>Jezioro | Maximum depth<br>Głębokość maksymalna (m) | Area<br>Powierzchnia (ha) | pH | Secchi disc visibility<br>Widzialność krążka Secchiego (m) | Use of catchment<br>Zagospodarowanie zlewni |
|---|---|---|---|---|---|
| Jelonek | 3.5 | 9.0 | 5.8 | 3.5 | 72% of arable land<br>72% użytków rolnych |
| Kociołek | 16.3 | 2.6 | 5.7 | 3.0 | 100% deciduous forests<br>100% lasów liściastych |
| Morskie Oko | 19.2 | 4.9 | 7.1 | 5.6 | 100% mixed forests<br>100% lasów mieszanych |
| Wielkie Oczko | 10.0 | 3.6 | 7.6 | 3.0 | 100% pine forests and acid Pomeranian beech<br>100% lasów sosnowych i kwaśnych buczyn pomorskich |

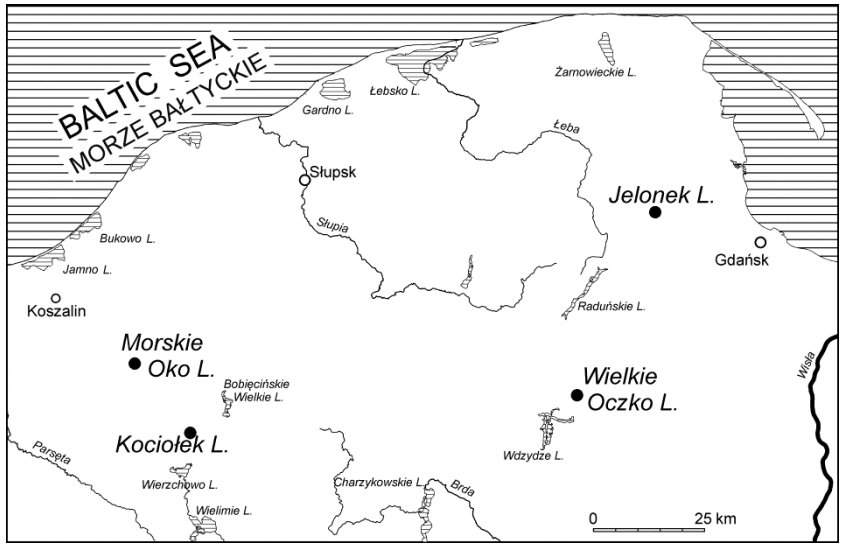


Fig. 1. Map showing the location of the studied lakes
Rys. 1. Mapa przedstawiająca położenia badanych jezior

The **Jelonek Lake** is a small aquatic reservoir surrounded by poor sandy fields – arable land is only 78%. According to classification introduced by KRASKA et AL. (1999) it belongs to reservoirs of distrophic-polyhumic character. In summertime it shows deficient thermal stratification. It is abundant in vegetation characteristic for lobelia lakes.

The **Lake Kociołek** is a very small but quite deep aquatic reservoir. It is round in shape and located in steep slope trough. During summer stagnation the lake shows full thermal stratification. Basin of the lake consists of deciduous forest in 100%. According to 1950's literature, flora species characteristic for lobelia lakes used to live there but today none of them is found. Lake Kociołek is classified into distrophic, polyhumic aquatic reservoirs.

The **Morskie Oko Lake** is a small round aquatic reservoir. It is deep and it has full thermal stratification. It is surrounded by mixed coniferous forests. KRASKA et AL. (2006) classifies the lake as well-balanced lake. The lake is plentiful of species typical for lobelia lakes. The lake is recommended for strict protection.

The **Wielkie Oczko Lake** is a small round quite shallow aquatic reservoir. It is surrounded by forest mainly pinewood with some Pomeranian beech. There is occasional *Lobelia dortmanna* and plentiful of *Myriophyllum alterniflorum.* In summertime the lake has not got full thermal stratification. It is a balanced lake in danger of degradation. It is also recommended for protection.

The lake sediments were sampled during summer stagnation. The surface layer of the thickness of about to 20 cm was taken with the aid of Kajak's device (KAJAK et AL. 1965). Then randomly chosen four-six samples taken at one sampling stand were mixed and were treated as a cumulative sample. The samples were collected from: (i) the coastal area in the littoral zone (samples designated L) and (ii) at the maximum depth of the basin in the profundal zone (samples designated P).

In dried and crushed sediments the following were determined: calcium (Ca) content, by atomic emission spectrometry, as well as magnesium (Mg) and iron (Fe) content by atomic absorption spectrophotometry. To describe the physicochemical conditions on the bottom of a lake, the properties of the organic matter are a very important factor. Therefore, in the examined sediments the organic carbon ($C_{org}$) content with the Orlov and Grindel method (ORLOV et AL. 1969), and total nitrogen ($N_{tot}$) content with Kiejdahl method were determined. The value of the ratio $C_{org}/N_{tot}$ was also calculated which gives indicative information about the concentration and quality of organic matter and conditions of its decomposition (TWICHELL and MEYERS 2002, MEYERS 2003, MIELNIK et AL. 2009). Pearson correlation coefficients are calculated for the determined parameters.

## Results and discussion

Results of physicochemical properties of the examined sediments are presented in Table 2.

The content of $C_{org}$ is the basic indicator to describe the content of organic matter in bottom sediments. From the literature it is known that the lake organic matter contains even up to 50% of organic carbon (ISHIWATARI 1985).

Table 2. Values of the analysed elements in the bottom sediments of the studied lakes
Tabela 2. Wartości analizowanych pierwiastków w osadach dennych badanych jezior

| Lake<br>Jezioro | Zone<br>Strefa | $C_{org}$<br>(%) | $N_{tot}$<br>(%) | Ca<br>($g \cdot kg^{-1}$) | Mg<br>($g \cdot kg^{-1}$) | Fe<br>($g \cdot kg^{-1}$) |
|---|---|---|---|---|---|---|
| Jelonek | L | 21.0 | 1.76 | 1.18 | 1.98 | 13.47 |
| | P | 21.1 | 1.78 | 0.75 | 2.19 | 11.30 |
| Kociołek | L | 2.4 | 0.10 | 0.15 | 0.63 | 2.36 |
| | P | 22.0 | 1.61 | 0.83 | 2.92 | 27.30 |
| Morskie Oko | L | 0.4 | 0.03 | 0.05 | 0.18 | 0.17 |
| | P | 29.5 | 3.13 | 1.06 | 1.53 | 4.59 |
| Wielkie Oczko | L | 20.8 | 1.50 | 1.23 | 1.19 | 19.80 |
| | P | 20.3 | 1.60 | 1.14 | 2.39 | 10.10 |

L – sediments from the littoral zone, P – sediments from the profundal zone.
L – osady ze strefy litoralu, P – osady ze strefy profundalu.

The biggest share of organic carbon was observed in profundal bottom sediments of Lake Morskie Oko (29.5%) and the smallest one was recorded in bottom sediments sampled at the coastal zone of the same lake (0.4%). The highest concentration of organic matter occurs mostly in the sediments sampled at the biggest depth and the least concentration is observed in the sediments sampled at the coastal zone (TROJANOWSKI and ANTONOWICZ 2005). This tendency is observed in the lakes Kwisno and Morskie Oko. They are aquatic reservoirs of small areas but quite deep (a big slope) so it may cause intensive movement of sediments along the lake basin slope and transport of important components into the deep parts of the lake. In bottom sediments samples from the lakes Jelonek and Wielkie Oczko the same content of organic matter ($C_{org}$ from 20.1 to 21.0%) is found in both litoral and profundal zones.

The investigated sediments were characterised with low content of nitrogen. The sediments contained from 0.03 to 1.78% of nitrogen (mean 1.20%) depending on the sampling site. Only in typical organic sediments in profundal zone sampled from the Lake Morskie Oko did the content of nitrogen increase up to 3.13%. In comparison, in lobelia lakes sediments located in the Zaborski Landscape Park investigated by GONET et AL. (1994), the nitrogen content was higher and ranged from 0.52 to 3.39% (mean 1.83%).

The trend of changeability of nitrogen content in the investigated sediments of lobelia lakes was related to the changes in carbon content.

The value of $C_{org} : N_{tot}$ (Table 3) in sediments is often used as an indicator of time changes in organic matter cycles in water ecosystems (KAMALELDIN et AL. 1997, MEYERS and LALLIER-VERGÈS 1999). $C_{org} : N_{tot}$ ratio in the investigated sediments ranged from 9.4 to 13.9 (mean 12.0) that means organic matter in the sediments coming from the investigated lake. The coastal zone sediments of the Lake Kociołek were an exception where the relatively high ratio $C_{org} : N_{tot} = 23.4$ was recorded.

Table 3. Values of the analysed ratios for the bottom sediments sampled from the studied lakes
Tabela 3. Wartości analizowanych współczynników dla osadów dennych pobranych z badanych jezior

| Lake<br>Jezioro | Zone<br>Strefa | $C_{org}$ : $N_{tot}$ | Ca : Mg | Fe : Ca |
|---|---|---|---|---|
| Jelonek | L | 11.9 | 0.60 | 11.40 |
| | P | 11.3 | 0.34 | 15.15 |
| Kociołek | L | 23.4 | 0.23 | 15.95 |
| | P | 13.7 | 0.28 | 32.97 |
| Morskie Oko | L | 13.3 | 0.25 | 3.78 |
| | P | 9.4 | 0.69 | 4.35 |
| Wielkie Oczko | L | 13.9 | 1.04 | 16.06 |
| | P | 12.7 | 0.48 | 8.87 |

L – sediments from the littoral zone, P – sediments from the profundal zone.
L – osady ze strefy litoralu, P – osady ze strefy profundalu.

The lithophilus elements (such as Mg, Ca and Fe) which naturally occur in the Earth's crust usually reflect normal changes in transport of mineral material from the lake basin (KINDER et AL. 2008). The mean concentration of investigated elements was Fe > Mg > Ca (11 136 > 1.626 > 0.798 $g \cdot kg^{-1}$).

Calcium is one of the basic elements occurring in the bottom sediments of lakes. It is the element which leads to fast mineralization of organic compounds contained in bottom sediments. Plankton, calcareous alga, detritus and skeletons as well as shells of benthic organisms are the source of calcium in the bottom sediments.

The investigated sediments showed small calcium contents which ranged from 0.05 to 1.23 $g \cdot kg^{-1}$. It is important for vegetation of *Isoëto-Lobelietum dortmannae* (Koch 1926) in the investigated ecosystems. Magnesium content was also relatively small and ranged from 0.18 to 2.92 $g \cdot kg^{-1}$. Iron in the investigated sediments is a result of leaching of rocks and soils. Its content ranged from 0.17 to 27.3 $g \cdot kg^{-1}$.

The tendency of changes in the content of the investigated elements in bottom sediments depends on the place of deposition of sediments in a given reservoir. Mg content at sites of the maximum depth was bigger than sediments sampled at the coastal zone. Very low concentration of Mg was recorded in litoral sediments characterised with the biggest depth i.e. lakes Kociołek and Morskie Oko. The tendency of changes in Ca and Fe contents is different. In the bottom sediments sampled from the lakes where there is no full thermal stratification (Jelonek Lake and Wielkie Oczko Lake) bigger Ca and Fe contents were recorded in the littoral sediments where as in the lakes with full thermal stratification (Kociołek Lake and Morskie Oko Lake) bigger Ca and Fe contents were observed at the maximum depth. Moreover, littoral sediments of both reservoirs are characterised with very small Ca (0.15 and 0.05 $g \cdot kg^{-1}$, respectively) and Fe (2.36 and 0.17 $g \cdot kg^{-1}$, respectively) contents.

The ratio Fe : Ca is an eutrophication indicator and it is used to assess the trophic conditions in a lake (BORÓWKA 2007). The highest Fe : Ca ratio was recorded in the lakes Jelonek and Kociołek, which, for their hydrochemical properties, are classified into distrophic-plyhumic aquatic reservoirs (KRASKA and PIOTROWICZ 2000). The mean ratio Fe : Ca in the bottom sediments from the Lake Wielkie Oczko is also relatively high and it is 12.45. Probably it results from possible eutrophication in the lake. Kraska classifies the lake into balanced lakes in danger (KRASKA et AL. 1999). Low Fe : Ca ratio in the bottom sediments of the Lake Morskie Oko (mean 4.07) indicates the oligotrophic character of the aquatic reservoir.

WOJCIECHOWSKI (2000) obtained a very good correlation between Fe : Ca and Fe : Mn indicators. Indicator Fe : Mn illustrates the changes in oxidation-reduction thus the author takes that Fe : Ca ratio may reflect the changes connected with a degree of oxidation in bottom waters.

From the research carried out by KRASKA and PIOTROWICZ (2000) it results that waters of hypolimnion in the Lake Morskie Oko where in the sediments was observed the lowest Fe : Ca ratio are characterised with trace amount of oxygen. The authors observed oxygen depletion in the nearbottom waters in the lakes Kociołek and Jelonek. In the bottom sediments of the lakes Fe : Ca ratio reaches the highest values (11.40-32.97).

Figure 2 shows an excellent positive correlation between Ca and Mg concentrations and $C_{org}$ content for the lakes sediment samples. This correlation can be represented mathematically by the linear regression equations:

$$Ca = 0.0979 + 0.004\ C_{org} \qquad r = 0.89^*$$

and

$$Mg = 0{,}4931 + 0{,}007\ C_{org} \qquad r = 0.73^*$$

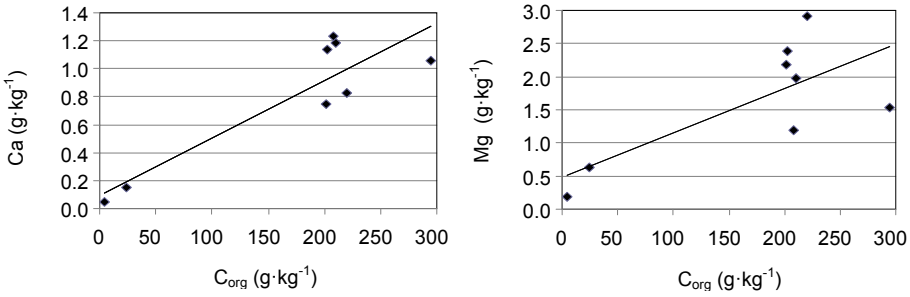


Fig. 2. Relationships between the content of Ca and $C_{org}$, and Mg and $C_{org}$ in the bottom sediments of the studied lakes

Rys. 2. Zależności między zawartością Ca i $C_{org}$ oraz Mg i $C_{org}$ w osadach dennych badanych jezior

This may indicate the role of organic matter in binding of these compounds. However, there was no significant correlation between the contents of $C_{org}$ and the concentration of Fe.

## Conclusions

The investigated bottom sediments were characterised with the low concentration of Ca, Mg, Fe. The total mean concentration of the metals was Fe > Mg > Ca (11 136 > 1.626 > 0.798 $g \cdot kg^{-1}$).

The presented above run of changes in concentration of the analysed elements ($C_{org}$, $N_{tot}$, and Ca, Mg, Fe) in the bottom sediments of lobelia lakes reflects the processes of natural migration of organic and mineral matter which is connected with, among others, diversified affinity with accumulating bottom sediments.

The obtained differences in chemical properties of the investigated sediments result from individual characteristics of each lake such as: geological structure, character and use of the basin, as well as thermal conditions, and mixing of the lake waters or degree of its oxidation.

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## WYSTĘPOWANIE WAPNIA, MAGNEZU I ŻELAZA W OSADACH DENNYCH JEZIOR LOBELIOWYCH

**Streszczenie.** Jeziora lobeliowe stanowią specyficzną i unikatową grupę zbiorników wodnych. Liczba tego typu jezior w Polsce wynosi około 170. W ostatnich latach obserwuje się wzmożone procesy ich degradacji. W celu zapobieżenia dalszej dewastacji jezior lobeliowych powinny zostać wprowadzone odpowiednie normy postępowania prowadzące do ograniczenia antropopresji tych cennych przyrodniczo zbiorników. Celem przeprowadzonych badań było określenie i porównanie zawartości pierwiastków litofilnych (Mg, Ca oraz Fe) w osadach dennych wybranych jezior lobeliowych. Próby osadów przeznaczonych do badań pobierano w okresie stagnacji letniej z około 20-centymetrowej warstwy powierzchniowej. Osady pobierano z dwóch miejsc: (i) w strefie litoralu oraz (ii) w miejscu maksymalnej głębokości jeziora. Badane osady charakteryzowały się małą koncentracją Ca, Mg i Fe. Ogólna średnia zawartość metali wynosiła: Fe > Mg > Ca (11 136 > 1,626 > 0,798 $g \cdot kg^{-1}$). Uzyskane różnice we właściwościach chemicznych badanych osadów wynikają z indywidualnych cech każdego jeziora, m.in. budowy geologicznej, charakteru i użytkowania zlewni, jak również z termiki i miksji wód jeziornych oraz stopnia ich natlenienia.

**Słowa kluczowe:** jeziora lobeliowe, osady denne, wapń, magnez, żelazo

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