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OCCURRENCE OF SOME HEAVY METALS IN BOTTOM SEDIMENTS OF LOBELIA LAKES

WYSTĘPOWANIE WYBRANYCH METALI CIĘŻKICH W OSADACH DENNYCH JEZIOR LOBELIOWYCH

Abstract: The paper presents the occurrence of zinc (Zn), copper (Cu) and manganese (Mn) in bottom sediments of selected Lobelia lakes which are specific and unique aquatic reservoirs. The lake sediments were sampled in summer stagnation in the surface layer at two stands in each lake: in littoral zone and in profundal zone at maximum depth of the lake.

Results of the investigations show that Zn, Cu and Mn contents in the investigated bottom sediments were low and ranged within geochemical background limits or slightly exceeded them. Presence of the metals in the sediments was spatially differential. Zn, Cu and Mn contents were significantly higher in most cases in the profundal zone of each investigated lake than they were in the litoral zone. Another factor which significantly differs the heavy metals content was level of thermal stratification.

Keywords: heavy metals, bottom sediments, Lobelia lakes

Bottom sediments are an important element of water ecosystems useful for control of quality of the environment. Bottom sediments are produced as a result of sedimentation of mineral and organic matter coming from erosion and the elements precipitated from water. Bottom sediments are also produced by the material carried with industrial and municipal sewage into surface waters.

Production and properties of lake bottom sediments depend on a number of factors including geological structure, character and use of the basin, thermal conditions and mixing of the lake waters as well as oxygenation or vegetation type etc. [1].

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Bottom sediments are irreplaceable archives, which reflect climate and environmental change being the same a valuable source of paleo-environmental information. Bottom sediments are a kind of trap for quite a lot of material carried into the lake. Lake sediments accumulate most potentially hazardous heavy metals and other organic compounds [2]. The heavy metals content may be a substantial indicator and a source of information on the impact of anthropopresion on the water environment [3, 4].

Heavy metals in sediments have attracted much attention recently because of their toxic nature [5]. They are brought in the environment as a result of natural processes occurring in the nature as well as a result of agriculture and industrial activity. Heavy metals are deposited in bottom sediments where they are temporarily immobilized and in this way they may be a source of secondary pollution. In favourable conditions the heavy metals may be released from the bottom into water but this process depends on the form in which given metal occurs in the sediments, as well as pH and redox conditions of the environment [6, 7].

This paper is an initial stage of research related to the overall assessment of sediment quality in Lobelia lakes for contamination by heavy metals. Lobelia lakes are specific and unique aquatic reservoirs on a global scale.

The main aim of this work is to determine the total content and stowage of heavy metals such as zinc (Zn), copper (Cu) and manganese (Mn) in bottom sediments from selected Lobelia lakes.

Material and methods

The material of this study was samples of bottom sediments from the chosen Lobelia lakes. In EU Lobelia lakes are declared to be endangered ecosystems of European importance. In Poland there are about 170 Lobelia lakes, mainly situated on the West Pomeranian Region. There are four lakes, namely Jelonek, Morskie Oko, Wielkie Oczko and Ciemino selected for investigations (as shown in Fig. 1). These lakes differ in morphometric structure, use of basin, trophy and thermal conditions of waters.

The Jelonek Lake is a small aquatic reservoir surrounded by poor sandy fields – arable land is only 78 %. The lake belongs to aquatic reservoirs of dystrophic type. In summertime it has deficient thermal stratification. There is abundant vegetation characteristic for lobelia lakes.

The Morskie Oko Lake is a small round aquatic reservoir. It is deep and it has full thermal stratification. It is surrounded by mixes coniferous forests. Kraska [8] 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 of Pomeranian beech. There is occasional *Lobelia dortmanna* and plentiful *Myriophyllum alterniflorum.* In summertime the lake has not got full thermal stratification. It is a balanced lake in danger. It is also recommended for protection.

The Ciemino Lake is a big and deep aquatic reservoir. It has very diversified shoreline. In summer stagnation it has full thermal stratification. A basin of the lake in

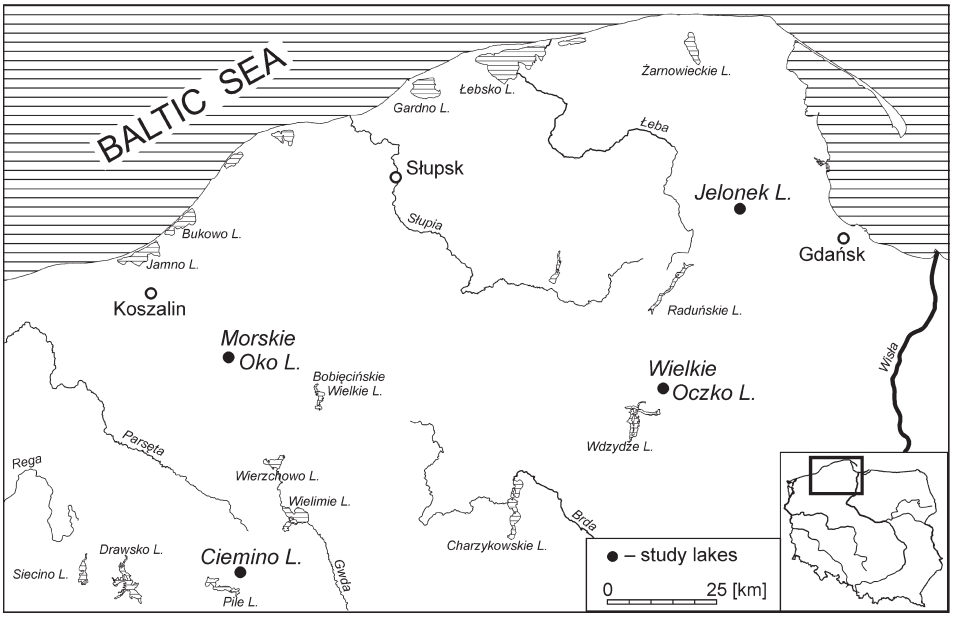

Fig. 1. Map showing location the studied lakes

50 % consists of forests, mainly deciduous ones with Pomeranian beech. The lake belongs to eutrophic reservoirs. Observed degradation of the lake is caused by village buildings situated in the immediate vicinity of the lake, slurry coming into the lake and liming which is an element of fishing farming. In the lake there is occasional *Myriophyllum alterniflorum*.

All of the studied lakes are not-flow reservoirs. In Table 1 are presented the selected morphometric and hydrochemical parameters of the lakes.

Table 1

The selected morphometric and hydrological parameters of the studied lakes

Parameter	Jelonek	Wielkie Oczko	Morskie Oko	Ciemino
Longitude	54°26.8′	54°03′30″	54°04′30″	53°38′
Latitude	18°15′	18°00′20″	16°28′40″	16°34′
Maximum depth [m]	3.5	10.0	19.2	13.4
Area [ha]*	9.0	3.6	4.9	241.7
pH	5.8	7.6	7.1	8.1
Secchi disc visibility [m]	3.5	3.0	5.6	2.8
Thermal stratification	incomplet	incomplet	full	full
Use of catchment	72 % of arable land	100 % pine forests and acid beech Pomeranian	100 % mixed forests	52 % deciduous forests and acid beech Pomeranian

* Area lakes by Choinski [9].

The water and sediments were sampled in summer stagnation. The samples of sediments were taken in the surface layer up to 20 cm with the aid of Kajak's device. The randomly chosen 4–6 samples taken at one sampling stand were mixed and they were treated as a cumulative sample. Bottom sediments were sampled at two stands in each lake:

– in the coastal zone (samples A),

– in profundal zone at maximum depth of the lake (samples B).

In dried and crushed samples were examined organic carbon ($C_{org.}$), Cu, Zn and Mn. Organic carbon content was determined with Orlov and Grindel method [10]. The heavy metals were determined by *atomic absorption spectrophotometer* (AAS), after previous mineralization of samples in *aqua regia* [11].

Statistical analysis was performed in order to verify the significance of differences between the analyzed parameters. Tukey's test was performed. Also the Pearson correlation coefficient was applied in order to determine the significance of relationships between Cu, Zn, Mn and C_{org}.

Results and discussion

The analytical results are summarized in Table 2.

Table 2

Organic carbon and selected heavy metals contents

Lake	Zone	$C_{org.}$ [%]	Cu	Zn	Mn
			[mg · kg^{-1}]		
Lake of the incomplete thermal stratification of water					
Jelonek	A*	21.0^{c}	7.9^{c}	92.3^{d}	105.3^{d}
	B	21.1^{c}	8.9^{d}	108.3^{e}	89.4^{c}
Wielkie Oczko	A	20.8^{c}	6.9^{b}	67.7^{c}	261.5^{g}
	B	20.3^{c}	10.9^{e}	92.4^{d}	165.3^{f}
Lake of the full thermal stratification of water					
Morskie Oko	A	0.4^{a}	0.4^{a}	2.3^{a}	5.1^{a}
	B	29.5^{d}	19.3^{g}	150.5^{g}	124.8^{e}
Ciemino	A	0.7^{a}	1.01^{a}	12.5^{b}	31.6^{b}
	B	13.0^{b}	11.9^{f}	138.3^{f}	428.7^{h}

*A – samples of sediments from litoral zone; B – samples of sediments from profundal zone; means marked by the same letters did not differ significantly at $p < 0.05$.

Results obtained in the analysis of bottom sediments sampled in the investigated lakes show that the sediments may be described as not polluted with zinc, copper and manganese as in most reservoirs content of these metals corresponds to a level of geochemical background or only slightly exceeds the level [12].

It was observed significant differences in content of the investigated metals between the studied lakes. These differences arise from, *inter alia* trophy character of the

reservoirs, and the use of their basins. The factors, which determine setting of the investigated metals in bottom sediments the most strongly is the place of deposit sediments in the lake basin and level of thermal stratification.

In the bottom sediments deposited at the maximum depth of the lake concentration of Cu and Zn was significantly statistically higher than it was in the bottom sediments deposited in the litoral zone. In the bottom sediments in a profundal zone Zn and Cu content reaches higher values than the range of geochemical background. The overall elevated concentrations of the elements at these lakes may be attributed to multiple factors. Both Zn and Cu may be introduced into the lakes with surface wash and municipal sewage. In particular, this situation may occur in lakes Ciemino and Jelonek. On the other hand, the source of elevated concentration of Cu and Zn can be precipitation.

However, values of Cu and Zn are close to the limit between the geochemical background and the I class and should not constitute a greater threat to the purity of the studied lakes.

Another factor which significantly differs Cu and Zn content is level of thermal stratification. In bottom sediments of the lakes (Jelonek Lake and Wielkie Oczko Lake) where the thermal stratification is not full, Zn and Cu content is almost the same in both the litoral zone.

The lakes Jelonek and Wielkie Oczko are shallow reservoirs. These lakes operate differently than deep lakes [13], due to the different dynamics of water masses, and therefore other circulation of matter. Evenly arrangement of Cu and Zn in sediments of these lakes may be due to resedimentation induced on resuspension or the result of bioturbation [14].

Furthermore in the lakes in which during summer stagnation there is not hypolimnion that is a kind of a trap for different types of pollution including heavy metals, the metals are not cumulated in the bottom sediments but they may be released and they include in the circulation in the whole aquatic reservoir.

In the lakes with full thermal stratification Zn and Cu content in the litoral zone waters is below the range of geochemical background and in profundal zone waters the content exceeds the range of geochemical background. Enrichment of profundal sediments with heavy metals may be caused by less intensive water mixing and water erosion due to which some sediments are carried on the slope of a lake basin from shallow parts of the lake towards the deeper layers [14, 15].

Due to the large number of factors influencing the processes of depositing sediment in lakes, only a broader survey will answer what causes the different distribution of metals in the sediments of lakes.

The milder hydrochemical processes in the deepest parts of a lake, especially that where the thermal stratification is full, cause that deposited in the profundal zone sediments contain more organic matter which is reflected in organic carbon content. In analysed sediments Zn and Cu content significantly correlates with organic C content (Cu: $r = 0.93$, Zn: $r = 0.87$). High contents of Zn and Cu are recorded in samples with high content of organic matter. Similar relations were obtained also by other researchers

[16–19]. It confirms the important role of organic matter in distribution processes of heavy metals in the aquatic system [20, 21].

Manganese content in bottom sediments is also diversified and the factor of high importance is here water mixing and the place of setting of the metal in the lake basin. However, tendency of changes is unlike Cu and Zn. There is observed characteristic tendency of changes in concentration of manganese in connection with different mixing of a lake. In bottom sediments of lakes with full thermal stratification small contents of manganese occur in the litoral zone and its concentration instantly increases in the profundal zone. In profundal sediments of the Ciemino Lake where degradation of the reservoir is noticeable Mn content reaches maximum value of 428.7 mg · kg^{-1} dry matter. In bottom sediments without full thermal stratification tendency of the changes in Mn content is reverse. In the litoral zone Mn content is higher than in sediments deposited in profundal zone. Full mixing of the lake waters in autumn and spring circulation allows the mineral substances to be distributed in the whole lake and it leads to saturation of all water layers with oxygen coming from the air. That may affect the changes in chemical properties of polyvalent elements like manganese.

There was non-significant correlation between C_{org} content and the Mn content in the sediments of studied lakes (Table 3).

Table 3

The Pearson correlation matrix for organic carbon and heavy metals

Parameter	$C_{org.}$	Cu	Zn
Cu	0.95*	—	
Zn	0.82*	0.94*	—
Mn	0.30	0.45	0.59

* Correlation coefficient is significant at the 0.05 level.

Similar poor associations of Mn with other trace metals in sediments were also noticed by Alagarsamy [19] for Mandovi estuary, west coast of India and by Chatterjee et al [20] for the lower stretch of Hugli (Ganges) estuary, northeast coast of Bay of Bengal.

Conclusions

Results of the investigations show that Zn, Cu and Mn contents in bottom sediments in the investigated were low and ranged within geochemical background limits or slightly exceeded them.

Presence of the metals in the sediments was spatially differential. The spatial distributions of trace elements in lakes sediments are influenced by so many factors and hence it is difficult to find the principal one. But to a large extent the observed differences in the contents of Zn, Cu and Mn are associated with different conditions of sedimentation in a given zone of a lake as well as with different content of organic matter, which plays an important role in depositing of the metals in bottom sediments.

Moreover, the observed spatial distribution of heavy metals is related to the basin's nature, appears to play a great importance for the observed differences.

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WYSTĘPOWANIE WYBRANYCH METALI CIĘŻKICH W OSADACH DENNYCH JEZIOR LOBELIOWYCH

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Abstrakt: W pracy przedstawiono występowanie cynku, miedzi i manganu w osadach dennych wybranych jezior lobeliowych, stanowiących specyficzną grupę jezior. Osady jezior pobierano w okresie stagnacji letniej z warstwy powierzchniowej, z dwóch miejsc: strefy brzegowej i w miejscu maksymalnej głębokości zbiornika.

Wyniki badań zawartości cynku, miedzi i manganu w osadach badanych jezior wskazują, że stężenia tych pierwiastków były niskie i mieściły się w granicach tła geochemicznego lub nieznacznie je przekraczały. Obecność analizowanych metali w osadach była zróżnicowana przestrzennie. W większości przypadków zawartość cynku, miedzi i manganu była istotnie większa w osadach deponowanych w miejscu maksymalnej głębokości każdego jeziora w porównaniu z zawartością tych metali w osadach strefy litoralu. Czynnikiem, który istotnie różnicował zawartość analizowanych metali, była wykształcona w pełni stratyfikacja termiczna wód lub jej brak.

Słowa kluczowe: metale ciężkie, osady denne, jeziora lobeliowe