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THE BOTTOM SEDIMENTS OF THE URBAN LAKE IN THE CONTEXT OF THE NEED AND POSSIBILITY OF ITS RESTORATION

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ABSTRACT

Lake Sajmino (26.1 ha, 7.8 m) situated in the Mazurian Lake District, NE Poland, due to advantageous localisation and still good water quality is readily used for active leisure by the inhabitants of its surroundings. The lake is fed with four surface tributaries, relatively constant in flow over the year. They bring in high loadings of nitrogen (1,589.7 kg N/year) and phosphorus (112.0 kg P/year). The conducted physico-chemical analyses have revealed that the lake is entering the phase of accelerated eutrophication. Composition of the bottom sediments from the lake was examined on 5 locations. The main component is silica (55.04 – 75.19 % DW). Organic matter comprises from 9.13 to 15.62 % and is correlated with P-tot (r=0.9949), the Al-P fraction (r=0.9229) and N (r=0.9423) Phosphorus in the sediments occurs mainly in durable bonds with calcium (0.567 – 1.550 mg P/g DW) and aluminium (0.121 – 0.205 mg P/g DW). No correlation has been found between Fe-P, and P-min and P-tot. The fraction with aluminium is responsible for phosphorus release from the solid phase to the interstitial water (r = - 0.9375). In order to preserve the good quality of the lake water some definite protective measures have to be implemented. The high sorption ability of the bottom sediments is the property that offers good prospects to the proposed method of phosphorus inactivation meant firstly to remove the excessive phosphorus from the water column and then to immobilize it in the sediment.

Keywords: catchment, external load, internal load, lake protection, renovation.

INTRODUCTION

Urban lakes and other located nearby settlements play an important role in recreation and active leisure of the local inhabitants. Although lakes undergo the transformation process of eutrophication which is natural, they remain very vulnerable to increasing loadings of organic and mineral pollutants coming from the developing drainage basins. In the past decades the process has been observed to accelerate, mostly due to an input of different types of waste water, i.e., urban, industrial, and agricultural. The practical results are, among others, intensified primary production, deteriorated aesthetics and hygienic conditions, increased difficulty and cost of water treatment, and eventually the lake's elimination from recreation and fisheries. Now and again, the changes caused by nutrients input are so apparent and posing danger to the economic use of the water that they raise social anxiety.

Lake Sajmino is located on the periphery of the town. The lake has a high natural value and is used for recreation and angling, but its organoleptic properties have been observed to deteriorate. Algal blooms occur. The Halls of the Town and the Community have decided to take up a preventive action including the recognition of the lake's present condition, needed to identify the possible remedial measures.

MATERIALS AND METHODS

Description of the lake: Lake Sajmino (22º21'34.2" E, 53º49'08.8" N) is situated in NE Poland, in the Mazurian Lake District, south-east of the Ostróda town (Fig. 1). Own measurements revealed that the surface area is 26.1 ha, the max depth 7.8 m, and the mean depth 3.1 m. The lake is elongated in shape (elongation 5.0) and spreads from the north-west to the south-east.

The lake is fed by four surface inflows which are characterised as relatively stable hydrologically over the year. Two of the inflows carry storm water from the near village and its surroundings and two other are small streams draining the south-western part of the drainage basin.

Operating periodically are the storm water interceptors draining the junction of the national roads. Part of the north-western shore is used as a bathing beach.

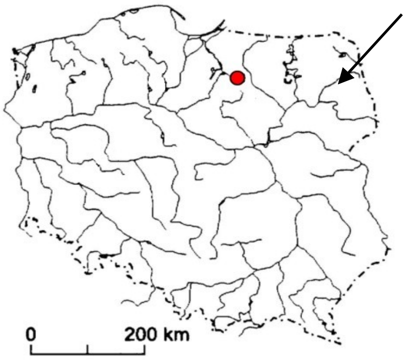


Fig. 1. Dislocation of lake Sajmino, NE Poland, The Mazurian Lake District

Due to diverse development of the drainage basin the lake receives pollutants also from area sources (surface run off from the main drainage basin) and atmospheric deposition. Additional sources of pollution are angling baits and bathing people (Tandyrak *et al.*, 2010).

The samples of bottom sediments were collected from 5 sites (location determined with a GPS): site I - at the deepest spot in the lake (7.8 m deep), site II - nearby the national road (3.5 m), site III - near the island of reeds (4.5 m), site IV - nearby the closed military training ground (3.5 m), site V - near the bathing beach (6.0 m).

Sediment samples were collected 5 times with the use of Kajak apparatus, 52 mm in diameter, 0.5 m long. The 10-cm layer of water over the sediment was regarded as the near-bottom water. The 10-cm top layer was cut off the collected undisturbed sediments cores and transported to the laboratory. Interstitial waters was obtained from a sediment sample centrifuged at 3,000 RPM for 20 minutes. The near-bottom and interstitial waters, after filtration through paper filter, were subjected to the chemical examinations in accordance with the methods applied in surface waters analyses (Hermanowicz *et al.,* 1999).

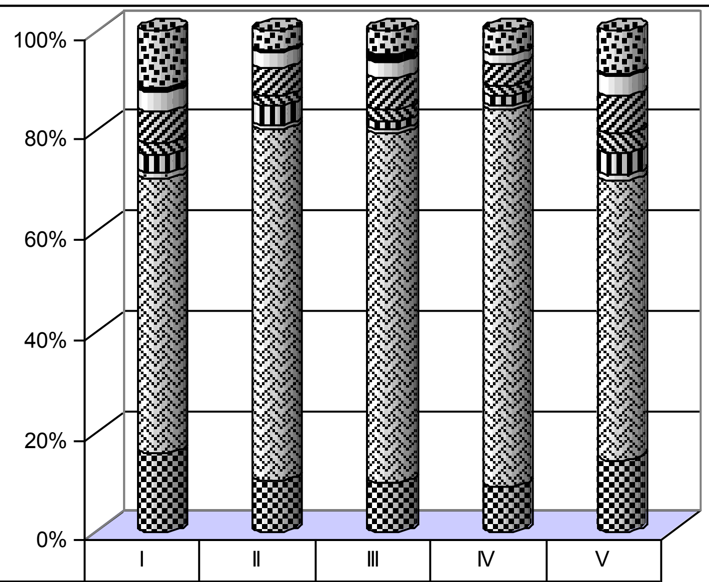
Centrifuged bottom sediments were dried at room temperature and grinded in a porcelain mortar into homogenous powder. Next, they were subjected to the chemical analyses in accordance with the methods by Januszkiewicz (1978). The content of phosphorus and its fractions were determined in accordance with the methods by Golachowska (1977 a, b, c).

The obtained data have been processed statistically. With the help of Excel spreadsheet the Pearson coefficient was calculated at $\alpha=0.05$ for the relationships between the selected components of the sediments.

RESULTS AND DISCUSSION

The observed chemical composition of the bottom sediments in Lake Sajmino near Ostróda was relatively uniform (Fig. 2). The content of organic matter was correlated with total phosphorus (r = 0.9949) and nitrogen (r = 0.9423) and confirm the hypothesis on the close relationship between these elements (Brzozowska *et al*. 2007, Kowalczewska-Madura *et al*., 2005).

The deposits from site I (the deepest one) and site V (near the bathing beach) contained the most total phosphorus (3.251 and 3.003 mg g^{-1} DW, respectively). The ability of this element to accumulate in bottom deposits is determined by the sorption complex (Forsberg 1989, Lange 1993) whereas the durability of the accumulation and the rate of release by the type of chemical bonds. The dominant component of the sorption complex in the discussed lake was calcium (1.72 - 4.34 % DW). The fraction of phosphorus bound to calcium comprised from 40 to 84 % of the mineral phosphorus. It is also the most durable type of phosphorus bond in the bottom deposits (r = 0.9823). The highest content was observed at the deepest sampling site (1.633 mg g^{-1} DW) and near the bathing beach (1.550 mg g^{-1} DW). The second durable phosphorus bond, non-vulnerable to the redox changes (Golterman, 2001), was the fraction with aluminium. In Lake Sajmino it comprised from 9.1 to 16.4 % of the sum of all fractions, and from 5.6 to 7.7 % of P-tot. No correlation was found between phosphorus and its fraction with iron which implies that this component of the sorption complex plays no important role in phosphorus binding. The fraction of phosphorus of the highest availability is so-called labile phosphorus. In the Lake Sajmino sediments it was merely 0.7 to 1.3 % of all determined forms of the mineral phosphorus and the measured concentrations were noticeably lower than in the eutrophic Lake Licheńskie (Brzozowska *et al.* 2007) or in the hypertrophic Lake Swarzędzkie (Kowalczewska – Madura *et al.,* 2005)



	I	II	III	IV	V
other	11,52	3,8	4,88	4,61	8,46
MnO	0,6	0,43	1,36	0,26	0,43
Fe2O3	4,07	3,41	3,27	1,78	4,25
Al2O3	6,22	5,24	6,12	4,32	7,33
MgO	2,35	2,12	2,33	2,09	4,06
CaO	3,47	3,74	1,72	1,99	4,34
N og	1,11	0,74	0,72	0,63	0,87
% SiO2	55,04	70,37	69,7	75,19	55,9
% org. mat.	15,62	10,15	9,9	9,13	14,36

Fig. 2: Chemical composition of the surface layer of bottom sediments in lake Sajmino

but similar to those measured in Lake Starodworskie before the phosphorus inactivation (Tandyrak, 2002). Considering the concentration gradient between the interstitial and near-bottom waters in Lake Sajmino it can be concluded that phosphorus was transported by diffusion to the near-bottom waters however, in the summer, it was not released to the water column. In the interstitial water concentration of the phosphate ranged between 0.591 and 1.290 mg P·dm^{-3} and of the total phosphorus from 0.963 to 1.805 mg P·dm^{-3} (Tab. 1). It can be assumed that the release of mineral phosphorus to the interstitial water depends strongly on the content of phosphorus bound to aluminium. For Al-P and P-min in the interstitial water r equalled - 0.9375.

The deteriorating water quality observed in the study was caused by the excessive loadings of pollutants imported from the drainage basin. The total load of nutrients supplied in such way annually is 112.0 kg P and 1,589.7 kg N. Such loading, according to Vollenweider's criteria, indicates high overloading (approximately 4.3 times for phosphorus and 3.8 for nitrogen) and no doubt is the main reason for the advancing eutrophication of the lake (Tandyrak *et al.*, 2010). Taking into account the lake's high vulnerability to degradation, it can be concluded that in order to achieve and sustain its good ecological condition appropriate protection and restoration measures ought to be applied.

The proposed restoration technique has been selected after a thorough recognition of the morphometric and hydrologic properties, as well as the drainage basin characteristics. The hydrologic budget and the shape of the water bowl allow application of only one method, i.e., phosphorus inactivation with polyaluminium chloride (trade name PAX 18). The dose has been calculated as proposed by Rydin and Welch (1999) and set for

18.45 g Al per m^2 sediment (corresponding to 250 g PAX 18) which equals 53,515 kg of the coagulant. However, the results of the authors' (unpublished) studies and own experience indicate that the dose should be increased to 20.8 g Al per m^2 sediment (equiv. 60,330.0 kg PAX 18) because the coagulant is not only to immobilize phosphorus in the sediments but also to remove it from the water column. The restoration should be conducted in two phases, each time during the early spring turnover, i.e., soon after the ice melts but before the algae bloom. Such timing is optimal as the maximum amounts of phosphorus are available in the form of dissolved orthophosphate, yet unused by the phytoplankton (Klapper, 2003) This form of phosphorus is also the most effectively bound by the coagulant (Łopata and Gawrońska, 2006; 2008) and its elimination before the vegetation starts up is the major reason for spectacular water quality improvement observed yet in the year of the coagulant application. The second possible date for the coagulant implementation, i.e., autumn, offers no chance for equally positive results. Spreading of the restoration over the 2-year period is additionally recommended because of the necessity to intensify the protective measures within the drainage basin.

Table 1: Content of total and mineral phosphorus in the over – bottom, near-bottom and the interstitial waters of Lake Sajmino (mg P·dm^{-3})

Site	Waters	25.05.2009		09.07.2009		18.08.2009		29.10.2009	
		Tot.P	Min.P	Tot.P	Min.P	Tot.P	Min.P	Tot.P	Min.P
1	over-bottom	0.086	0.019	0.116	0.039	0.212	0.052	0.125	0.043
	near-botom	0.180	0.118	0.227	0.177	0.345	0.279	0.165	0.118
	interstitial	**1.237**	**0.909**	**1.321**	**0.903**	**1.442**	**0.982**	**1.340**	**0.897**
2	near-botom	0.083	0.050	0.088	0.047	0.138	0.074	0.094	0.053
	interstitial	**1.836**	**0.691**	**1.309**	**0.878**	**1.476**	**0.951**	**1.502**	**0.769**
3	near-botom	0.073	0.050	0.115	0.068	0.114	0.039	0.092	0.054
	interstitial	**1.264**	**0.812**	**1.805**	**1.290**	**1.502**	**1.036**	**1.563**	**0.818**
4	near-botom	0.098	0.059	0.107	0.077	0.103	0.044	0.095	0.085
	interstitial	**1.352**	**0.763**	**1.248**	**0.854**	**1.799**	**1.175**	**1.078**	**0.715**
5	near-botom	0.106	0.088	0.149	0.089	0.215	0.139	0.112	0.091
	interstitial	**1.145**	**0.935**	**0.924**	**0.591**	**1.018**	**0.606**	**0.963**	**0.660**

Most of the sediment-phosphorus in Lake Sajmino is bound with insoluble calcium and aluminium, which allows for the durable immobilization. However, the hitherto studies have revealed that bottom sediments have superior sorption ability which combined with a substantial reduction of phosphorus import from drainage basin make the sediment excellent phosphorus trap, even during summer. In Lake Sajmino, the main goal will be to eliminate excessive phosphorus from the water body, immobilize it in the bottom sediment, and increase the sediment sorption ability. On the other hand, less important will be to hinder the release of phosphorus from the previously deposited bottom sediments.

CONCLUSION

Lake Sajmino is a valuable water reservoir of a high natural and recreational value. The advantageous localisation and relatively good quality of the water make the lake a popular leisure spot for the inhabitants of the Ostróda town and the surrounding villages. The complex surveys comprising water from the lake and its tributaries as well as the lake bottom sediments have revealed that the lake is entering the phase of the accelerated eutrophication. Given the lack of any definite protective activities in the drainage basin or in the lake bowl, it can be concluded that the state of affairs, yet unfixed, will consolidate in the coming years in the visible form of turbid water.

The state-of-the-art in limnology indicates that an aquatic ecosystem transforms from the clear water condition into turbid water very quickly while the opposite process is slow and only the modification of the environmental conditions gives a chance for its acceleration. In the first row, the definite and radical protective activities should be applied, eliminating the phosphorus loadings from the drainage basin.

Bottom sediments are characterized by excellent sorption ability and can durably immobilize phosphorus in bounds with calcium and aluminium. Provided that the restoration method to be applied is the phosphorus inactivation technique, the main task will be to remove this element from the water body and immobilize it in the bottom sediments.

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