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TOTAL PHOSPHORUS CONTENT IN BOTTOM SEDIMENTS OF THE EUTROPHIC DAM RESERVOIR ZALEW ZEMBORZYCKI NEAR LUBLIN

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Summary. The total phosphorus (TP) content in bottom sediments of Zalew Zemborzycki, established in the valley of the River Bystrzyca near Lublin in 1974, was investigated. Sediments from 22 sites were sampled in autumn of 1999. TP was determined by ICP-EAS method after sample mineralization in concentrated HNO_3 and $HClO_4$. The highest TP content occurred in sediments of the area at the River Bystrzyca inflow and in the right-bank part of the reservoir. The spatial distribution of TP concentration intervals perpendicular to the dam was observed. The results indicate an increase in TP content in the majority of the reservoir area as compared with data from late 1970s.

Key words: dam reservoir, sediments, total phosphorus

INTRODUCTION

The main problem in the functioning of Zalew Zemborzycki reservoir is its bad water quality. There are many reasons for this state, including the loads of nutrients (particularly phosphorus and nitrogen) from the catchment.

Phosphorus is one of the most important factors affecting water quality and trophic state of storage reservoirs [Kajak 1994]. As opposed to nitrogen (which can be assimilated from the air by some water microorganisms, e.g. *Cyanobacteria*), it originates mainly from external (allochtonous) sources, i.e. from direct catchments and catchments of watercourses supplying reservoirs.

Phosphorus deposited in sediments is not permanently fixed there. It is excluded from biogeochemical cycles in reservoirs only temporarily. It can be mobilized into circulation when conditions are favourable. A great part of easily (biologically) available P is accumulated in the top layer of bottom sediments [Boström *et al.* 1988, Kajak 1994]. There are many mechanisms causing sediments resuspension, resulting in P migration from them and from interstitial water into a near-bottom water column, and then its inclusion to biological cycles [Nürnberg 1988].

The threat to a trophic state of water from a load of P flowing into a reservoir can be evaluated according to the Vollenweider index [1968]. In the case of Zalew Zemborzycki, the P load is great and exceeds the permissible values.

The main objective of the research was to determine the spatial distribution of the total phosphorus content in bottom sediments of Zalew Zemborzycki and to indicate parts of the reservoir with its greatest accumulation.

STUDY AREA, MATERIALS AND METHODS

The artificial reservoir called Zalew Zembrzycki was completed in 1974 on the River Bystrzyca to the south of Lublin (SE Poland, N 51°40', E 22°24') at the village of Zemborzyce. The main function of the reservoir is recreation (rest, aquatic sports, fishing), as well as flood control and regulation of water supply in the river in periods of drought. It also serves as a source of water for the 'Thermal Power Plant Wrotków'. The surface area of Zalew Zemborzycki is about 280 ha. The reservoir is classified as a shallow water body as its depth ranges from 1 to 4 meters at a normal level of water lifting.

Sediments were sampled in the autumn of 1999 by means of Kajak sediment core sampler. The material was collected in twenty sites (1-20) regularly distributed at the reservoir area, which divided it into four longitudinal (A-D) and five transverse (I-V) transects (Fig. 1). Additionally, sediments were taken from the places of water inflow to the reservoir (point 'in') and its outflow (point 'out').

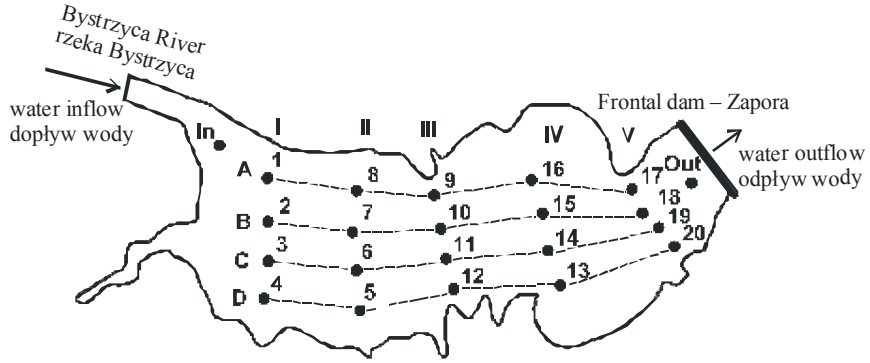

Fig. 1. Zalew Zemborzycki – distribution of sampling points (●)
Rys. 1. Zalew Zembrzycki – miejsca poboru próbek (●)

At each site, depending on the thickness of sediment strata, from several to about twenty cores of hydrated sediments were taken to obtain a sample of about 3 dm^3.The samples were dried on the air without separation of pore water. After homogenization, air dry material was ground in an agate mortar and then mineralized in a microwave oven in a concentrated HNO_3 and $HCLO_4$ mixture (1:1, v/v). The total content of P (TP) was measured by the ICP-EAS method (Lemans Inc. PS 950 instrument). The certified materials were the points of reference for the accuracy of analyses.

Three categories of total phosphorus (TP) content were assumed on the basis of central tendency measures – quartiles. The low concentration was attributed to sediment samples with TP content from the minimum to the lower quartile value (LQ = 679 mgP kg^{-1}), the mean concentration – to samples with TP amount in the range of the LQ to the upper quartile (UQ = 795 mgP kg^{-1}), and the high concentration – above the UQ value.

RESULTS AND DISCUSSION

The histogram of TP concentration (for the assumed intervals) indicates that the number of sediment samples with its lower values prevailed (Fig. 2). The median value of 737.5 mg P kg^{-1} was higher than the overall average (730 mg P kg^{-1}), which shows left-handed TP distribution. The mean content of TP in sediments of Zalew Zembrzycki was lower in comparison with data for other dam reservoirs, e.g. for Zegrzyński [Kajak 1990] or Siemianówka [Jekatierynczuk-Rudczyk 2006].

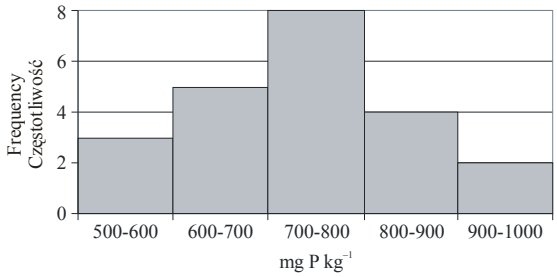

Fig. 2. Histogram of TP content in bottom sediments
Rys. 2. Histogram zawartości Pog. w osadach dennych

The comparison of results for transects parallel to the frontal dam of Zalew Zemborzycki showed that the lowest mean TP accumulation was observed in sediments in the middle part of the reservoir (transect III) and the highest in the area of the River Bystrzyca mouth (point 'in') (Tab. 1). The latter finding may indicate a major effect of the river on supplying the reservoir with allochtonous phosphorus. Such a suggestion can be also supported by by Misztal (unpublished data) on TP in water of this reservoir, measured in 2006. He stated that the concentrations of TP (in spring and in autumn) were higher in water at the inflow of the River Bystrzyca than in the other sampling sites of the reservoir.

Table 1. Content of TP in sediments of Zalew Zembrzycki (transects parallel to the frontal dam)
Tabela 1. Zawartość Pog. w osadach Zalewu Zemborzyckiego (transekty równoległe do zapory)

Point, transect Punkt, transekt	Min.	Max.	Mean – Średnia	RSD* %
		mg P kg^{-1}		
In	–	–	1000	–
I	675	822	746.5	8
II	678	870	767.5	13
III	526	691	591.8	13
IV	545	923	727.3	21
V	737	807	755.8	5
Out	–	–	760.0	–

* RSD – Relative Standard Deviation – współczynnik zmienności

The least variability in TP concentrations, as measured with RSD, was found in sediments from the upper (transect I) and lower (transect V) parts of the reservoir (Tab. 1). The TP content in sediments distributed in transects perpendicular to the frontal dam (A-D) was more differentiated than in the sediments along the parallel ones (Tab. 2).

The spatial distribution of TP concentrations, as shown in Fig. 3, suggests that its accumulation in sediments is fairly regular, i.e. perpendicular to the frontal dam. This

state has not changed since the reservoir began functioning and a similar pattern of elements distribution in its sediments was reported in earlier studies [Misztal and Smal 1980, Misztal *et al*. 1983/1984]. The stated pattern of the TP zonation in sediments is not typical for dam reservoirs. In general, a distribution parallel to frontal dams of reservoirs is reported in the literature. For example, Jekatierynczuk-Rudczyk [2006] stated, for Reservoir Siemianówka, that in the sediments from its current the P content increased while approaching the dam. The minimal values noted by the author occurred in the upper part, whereas maximal in the middle and lower part of that object.

Table 2. Content of TP in sediments of Zalew Zemborzycki (transects perpendicular to the frontal dam)
Tabela 2. Zawartość Pog. w osadach Zalewu Zembrzyckiego (transekty prostopadłe do zapory)

Transect – Transekt	Min.	Max.	Mean – Średnia	RSD*
	mg P kg^{-1}			%
A	526	1000	731.3	21
B	545	822	680.0	15
C	691	923	802.4	11
D	539	870	711.0	17

* explanations as in Table 1 – objaśnienia jak w Tabeli 1

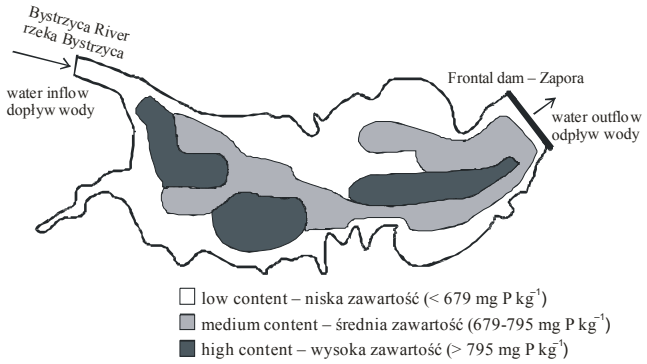

Fig. 3. Zone map of TP content in sediments of Zalew Zemborzycki
Rys. 3. Mapa stref zawartości $P_{og.}$ w osadach Zalewu Zembrzyckiego

The data available on P content in sediments of Zalew Zemborzycki from the late 1970s (when the reservoir began functioning), reported by Misztal and Smal [1980], allow to determine the tendency of its changes after about twenty years. A comparison is also possible because most of the sampling sites in both studies had the same location. Thus, it can be seen that the concentration of TP increased in sediments in the upper (the inflow of the River Bystrzyca) and lower (the area at the frontal dam) parts of the reservoir, whereas it decreased in the middle part of the reservoir.

CONCLUSIONS

1. The highest content of TP in sediments in the area at the River Bystrzyca inflow and in the right-bank part of Zalew Zemborzycki was observed. The spatial distribution of TP concentration intervals is perpendicular to the dam, which is different from data for most reservoirs.

2. Comparison of the data from the initial period of functioning of the reservoir and the present ones indicate permanent increase in TP concentrations in sediments of the majority of the reservoir sites.

3. The findings suggest that the increase in the phosphorus content in sediments results mainly from its load supplied with contaminated water of the River Bystrzyca. Thus, it seems that first of all proper water–waste management in its catchment would improve the sanitary and ecological state of Zalew Zemborzycki.

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ZAWARTOŚĆ FOSFORU CAŁKOWITEGO W OSADACH ZEUTROFIZOWANEGO ZBIORNIKA ZAPOROWEGO ZALEW ZEMBORZYCKI

Streszczenie: Badano zawartość P całkowitego w osadach dennych Zalewu Zembrzyckiego, utworzonego w dolinie rzeki Bystrzycy koło Lublina w 1974 r. Osady z 22 miejsc pobrano jesienią 1999 r. Fosfor oznaczono metodą ICP-EAS po mineralizacji próbek w mieszaninie stężonego HNO_3 i $HClO_4$. Najwyższe stężenie P_{calk} wystąpiło w osadach przy dopływie Bystrzycy oraz prawobrzeżnej części zbiornika. Zaobserwowano prostopadły do zapory rozkład stężeń fosforu. Wyniki wskazują na wzrost jego zawartości w osadach większej części zbiornika w porównaniu z danymi z końca lat 70. XX wieku.

Słowa kluczowe: zbiornik zaporowy, osady denne, fosfor całkowity