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PHOSPHORUS IN THE SOLINA RESERVOIR ECOSYSTEM

The concentrations of mineral phosphorus and total phosphorus in the surface water as well as total phosphorus and organic matter in the bottom sediments of the Solina reservoir were determined. The load of total phosphorus in the tributaries of the reservoir and its retention in the reservoir were calculated. The reservoir loading with a total phosphorus and the retention of this element in the reservoir were significantly correlated.

1. INTRODUCTION

Phosphorus is accumulated in various components of the ecosystem, but first of all in the bottom sediments that play a fundamental and unquestionable role in its transformation and accumulation in water reservoirs [4], [5], [7], [15]. In a superficial 3 cm layer of sediment, the content of this element ranges from 72 to 80% of its total amount in aquatic ecosystem regardless of a reservoir character (area, depth, trophic characteristics) [6].

Phosphorus limits a primary production to a much higher degree than other elements. The seemingly slight increase in the phosphorus content in the water that may result in mass algae blooms causes a chain of negative effects for the whole ecosystem [16].

The cost of preventing waters from eutrophication are very high. They are, however, incomparably lower than the expenditure on a remedy for europhication [2].

The aim of investigation was to estimate the phosphorus content in the water and in the bottom sediments of a mountainous dam reservoir and to evaluate the reservoir loading with total phosphorus coming from tributaries.

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2. EXPERIMENTAL

The Solina reservoir was built in 1968 as a result of damming the San River by a concrete dam, being constructed at a distance of 325.4 km from the river spring [9], [12]. It is the biggest dam reservoir in Poland in terms of volume (502 mln m^3) and also the deepest one (max. 60 m, 22 m on an average). The basin occupies the area of approx. 22 km^2. The frequency of water exchange is approx. 1.5 times a year [10]. Overall drainage basin, including all its tributaries, occupies the area of 1174.5 km^2, however, the area of direct drainage basin, adjacent to the basin coastline, is 83.9 km^2 [9], [11].

The samples were collected as follows:

• surface water: 4 times from July to October 2000 and 3 times from July to October 2001,

• bottom sediments: in August and October 2000 and in July and October 2001.

The samples were taken at six measuring points, i.e.:

1. "Zapora", an average depth of approx. 60 m,
2. "Nelson", an average depth of approx. 13 m,
3. "Centralny", an average depth of approx. 45 m,
4. "Skalista", an average depth of approx. 25 m,
5. "Brama", an average depth of approx. 15 m [3].

The samples were also taken from the catchment area:

• surface water from seven reservoir tributaries and its outflow [1]: frequency of sampling – once a month from June to November 2000 and from June to November 2001.

The concentrations of phosphate phosphorus (P_{PO4}) and total phosphorus ($P_{tot.}$) in the water as well as total phosphorus in the bottom sediments (after their mineralisation in the mixture of concentrated HCl and HNO_3) were determined colorimetrically [14].

The organic matter (OM) in the bottom sediments was determined by roasting the samples at the temperature of 550 °C. The flow measurements necessary for calculating the loads were obtained from the water-gauge recordings and the IMWM data.

3. RESULTS

3.1. PHOSPHORUS IN RESERVOIR WATERS

The content of mineral phosphorus in the surface water of the reservoir during the period of investigation ranged from 0.007 to 0.064 mg dm^{-3} (figure 1). This range of phosphorus concentration in water allowed us to classify it into the first class of purity [13]. The proportion of mineral phosphorus to total phosphorus in the water expressed in per cents was on an average 41% and varied from 24% to 60%. Total phosphorus concentration ranged from 0.02 to 0.24 mg dm^{-3} and was 7 times higher compared to its concentrations in the water of the first class purity (figure 2). The phosphorus content was rather diversified; however, it did not exhibit any seasonal regularities. Such a variation of concentrations indicates that in summer in spite of an increased demand for phosphorus compounds and probably more intensive phosphorus sedimentation, its concentration in the reservoir water increases due to greater external loads [12]. The phosphorus content in the surface water of shallow and deep parts of the reservoir was not differentiated which could have been caused by an intense mixing of water by reversing turbines in its central part and in the vicinity of the dam. Based on an average total content of phosphorus in the water, the reservoir should be classified as eutrophic (Vollenveider and OECD [2]).

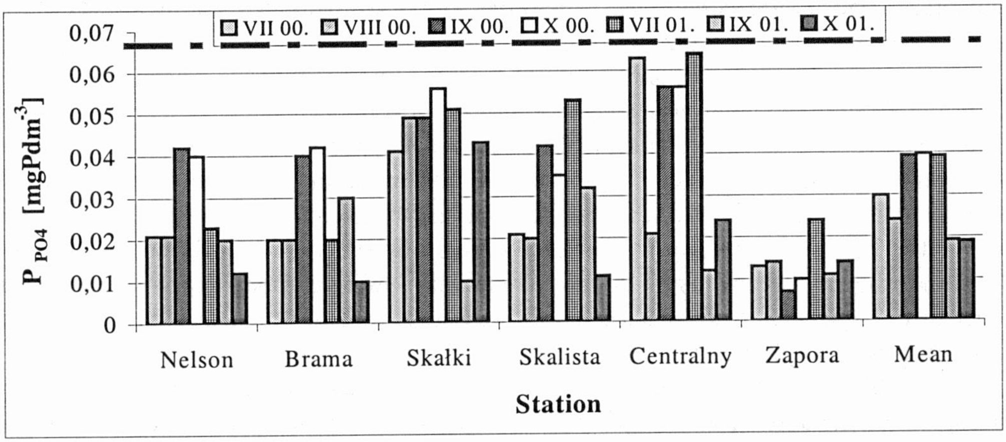

Fig. 1. Concentrations of P_{PO_4} [mg P dm^{-3}] in superficial water of the Solina reservoir (the level of the first class purity was marked [13])

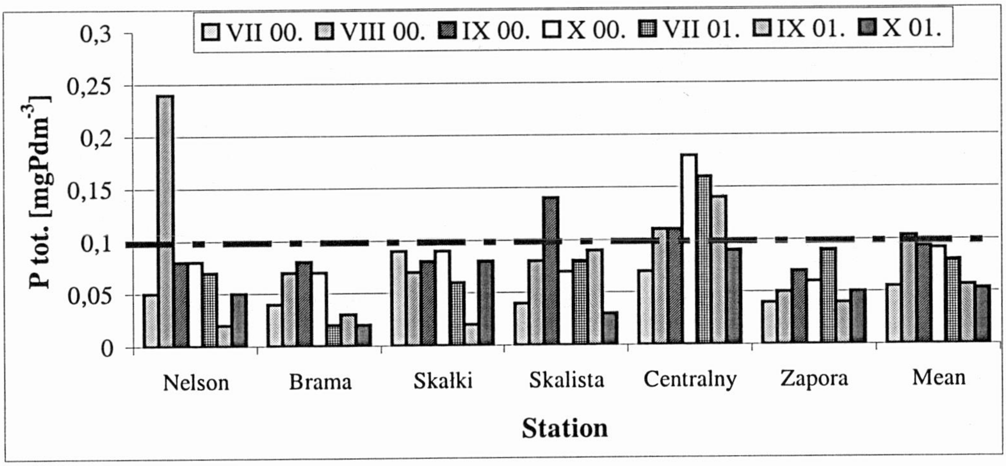

Fig. 2. Concentrations of total phosphorus ($P_{tot.}$) [mg P dm^{-3}] in superficial water of the Solina reservoir (the level of the first class purity was marked [13])

3.2. PHOSPHORUS AND ORGANIC MATTER IN BOTTOM SEDIMENTS

An average total content of phosphorus in the bottom sediments of the reservoir ranged from 0.572 to 0.659 mg $g^{-1}$of d.w. The phosphorus concentration in a surface layer of the sediment was changing slightly (figure 3). The sequence of the measuring stations presented in figures was arranged from the shallowest to the deepest. The sediments collected from the shallower parts of the reservoir (stations: Nelson, Brama and Skałki) in August 2000 and July 2001 (at the height of vegetation period) showed a lower phosphorus content, and in October 2000 and 2001 a higher one. At Skalista station with an average depth being close to an average depth of the reservoir, the variations in the phosphorus content were the same. Presumably, in the shallower parts of the reservoir in summer, phosphorus is released from the sediments, which is supported additionally by resuspension, and prevails over sedimentation. In the deeper parts of the reservoir (Centralny and Zapora stations), a total phosphorus concentration continuously increases. Probably, sedimentation is primarily responsible for the phosphorus cycle. In an aquatic ecosystem, the excess of nutrients in the water and its fast eutrophication are disadvantageous, therefore a considerable amount of nutrients sediments and is accumulated in bottom sediments [6]. Generally, it can be stated that total phosphorus content in the bottom sediments of Solina is relatively low in comparison to its content in other reservoirs, e.g., in the sediments of the Włocławski reservoir and the Zegrzyński reservoir, the phosphorus concentrations reach 5.1 and 5.9 mg $g^{-1}$of d.w., respectively, [5], [8], [16]. However, these are reservoirs that are loaded with much higher load of pollutants of the anthropogenic origin; moreover, the areas of their drainage basins are much larger in comparison to the Solina drainage basin.

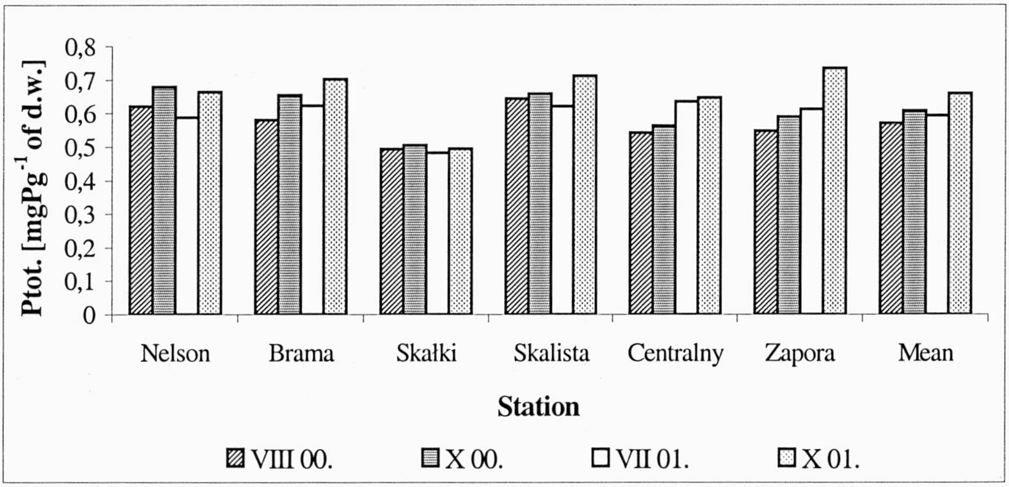

Fig. 3. Concentrations of total phosphorus [mg P g^{-1} of d.w.] in bottom sediments of the Solina reservoir

An average content of organic matter in the reservoir sediments ranged from 8.58% to 10.46% (figure 4). For the sake of comparison, the Włocławski reservoir (max. depth only 15 m) contained 16–19% of organic matter in its sediments [8]. The extent of mineralisation of the sediments is greater in deep reservoirs, where the time of sedimentation is long [7]. At the stations in deep parts of the reservoir, the organic matter content decreases together with an increase in the phosphorus content in the bottom sediments. This may suggest that the contribution of the organic compounds with phosphorus to nutrients can be decreased in favour of its mineral compounds. A significant negative relationship between phosphorus and organic matter in the sediments for the Centralny and Zapora stations is presented in figure 5. This relationship is also valid for the average values.

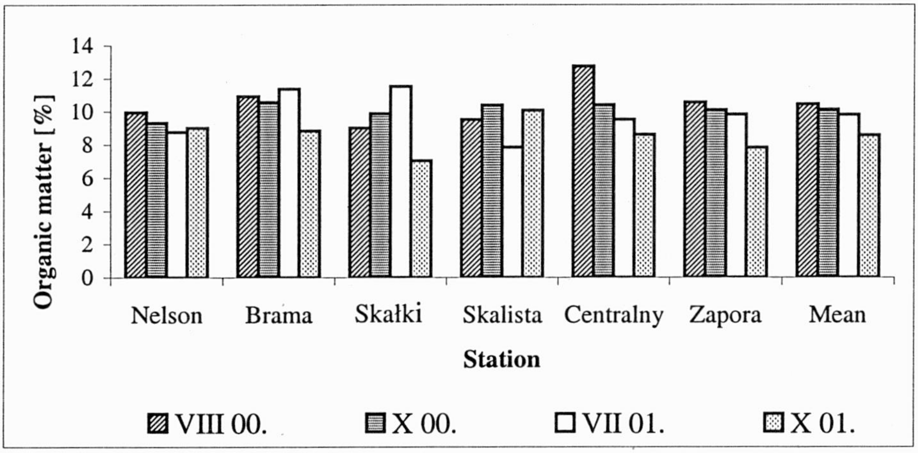

Fig. 4. Organic matter contents [%] in bottom sediments of the Solina reservoir

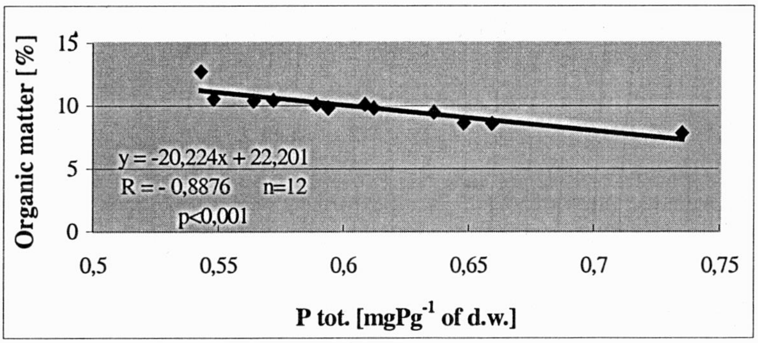

Fig. 5. Relationship between the content of total phosphorus and organic matter in bottom sediments at the sampling stations: Zapora and Centralny. It is also valid for average values

3.3. PHOSPHORUS IN TRIBUTARIES AND ITS RETENTION IN THE RESERVOIR

The quality of water in the dam basins, including the phosphorus concentration, is effectively controlled by surface tributaries [16]. A total phosphorus load introduced into the reservoir by surface tributaries was estimated at 16.1 t per month in the period from June to November 2000 and 7.3 t per month in the period from June to November 2001. Each square meter of the reservoir was loaded on an average with 24.35 mg P d^{-1} in the first investigation period (2000) and with 10.95 mg P d^{-1} in the second one (2001). These loads were clearly higher (even in the second investigation period) than the load considered to be critical (figure 6). According to Vollenweider in the reservoirs with an average depth of 22 m, a critical load exceeds 0.79 mg P $m^{-2}d^{-1}$ [6]. In

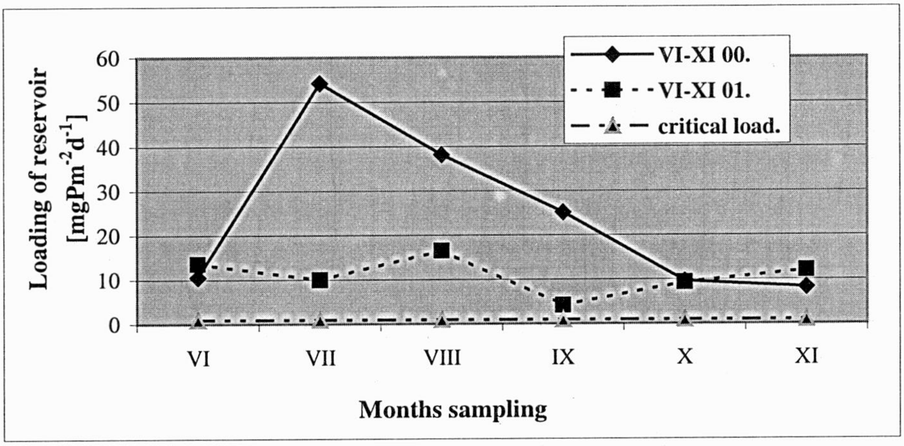

Fig. 6. The loading of the Solina reservoir with total phosphorus in particular investigation periods (critical loading according to Vollenweider [6] was marked)

most of the reservoirs in Poland, particularly in the lowland reservoirs, the loads of phosphorus are higher than loads considered to be critical [16]. The retention measured in the first period of investigation ranged from –6.03 to 44.97 mg P $m^{-2}d^{-1}$ (an average of 10.0 mg P $m^{-2}d^{-1}$), an in the second period, from –11.83 to 10.08 mg P $m^{-2}d^{-1}$ (an average of 0.33 mg P $m^{-2}d^{-1}$). A very significant correlation was found between the retention and the total phosphorus load introduced into the reservoir (figure 8). Similarity between the curves of retention and the curves of loading is very distinct (figures 6 and 7). This proves that retention of phosphorus in the reservoir depends upon its external load introduced into the reservoir first and foremost in the whole summer period. From September (when the vegetation period ends) to November presumably the process of surface water enrichment with phosphorus from hypolimnion takes place due to autumn circulation and decomposition of water organisms.

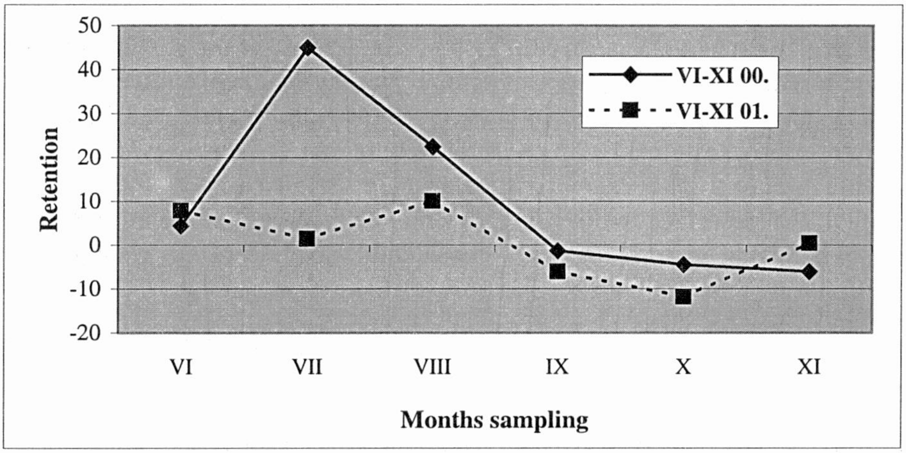

Fig. 7. Changes of total phosphorus retention [mg P $m^{-2}d^{-1}$] in particular investigation periods

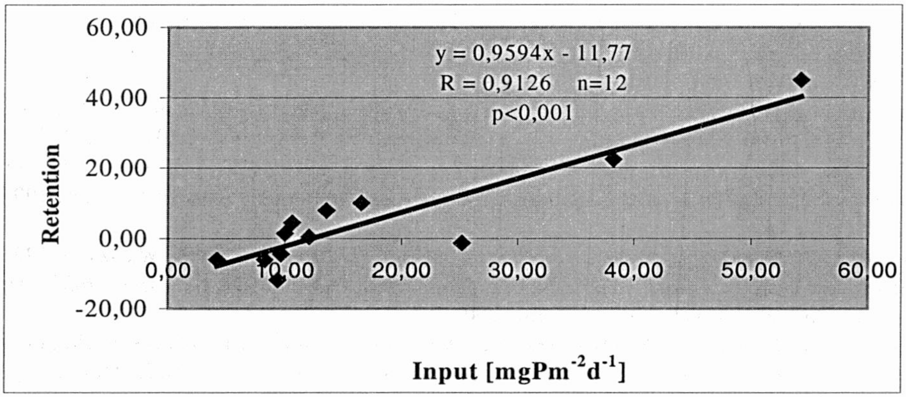

Fig. 8. Relationship between total phosphorus retention [mg P $m^{-2}d^{-1}$] in the Solina reservoir and input of total phosphorus [mg P $m^{-2}d^{-1}$]

4. CONCLUSIONS

1. A total phosphorus content in the Solina reservoir water was diversified; however, it did not exhibit any seasonal regularities. No differentiation was observed between shallow and deep parts of the reservoir. The concentration of total phosphorus exceeded several times the concentrations characteristics of the water of the first-class purity.

2. A lower total phosphorus content in the bottom sediments of the Solina reservoir in comparison to other reservoirs is explained by much smaller load of the pollutants of anthropogenic origin and a smaller area of the drainage basin.

3. The lower values of total phosphorus content in the sediments of the shallower reservoir parts in the summer period may be due to the prevalence of the phosphorus release from sediments, which was supported by resuspension, over sedimentation.

4. Phosphorus load introduced into the reservoir from the drainage basin in summer is significantly correlated with phosphorus retention in the reservoir.

5. Evaluation of trophic characteristics of the reservoir based on the classification according to Vollenweider and OECD [2] cannot be fully applied because there are no indications allowing us to recognize a considerable loading of the reservoir surface with phosphorus (found in both periods of investigation) as critical.

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FOSFOR W EKOSYSTEMIE ZBIORNIKA SOLIŃSKIEGO

Oznaczono zawartość fosforu mineralnego i całkowitego w wodzie powierzchniowej oraz fosforu całkowitego i materii organicznej w osadach dennych zbiornika solińskiego w okresie 2000–2001 r. Obliczono ładunek fosforu całkowitego pochodzącego z dopływów i jego retencję w zbiorniku. Stwierdzono istotną korelację między obciążeniem zbiornika fosforem całkowitym a zachodzącą w nim retencją tego pierwiastka.