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LOADING OF THE RZESZÓW RESERVOIR WITH BIOGENIC ELEMENTS – MASS BALANCE

The results of experiments conducted in 1999–2000 in the ecosystem of the Rzeszów reservoir are presented. Our aim was to evaluate the nitrogen and phosphorus loadings introduced into the basin and to establish their influence on the progress in eutrophication of the reservoir water. The quality of water in the basin and its tributaries was being out of classification during almost whole sampling period. The concentrations of both biogenic elements considerably exceeded their admissible values and on average reached 3500 mg/m^2 of nitrogen per a day and 285 mg/m^2 of phosphorus per a day. 788 mg/m^2 of nitrogen compounds per a day and 30 mg/m^2 of phosphorus compounds per a day were both accumulated and underwent biochemical transformations. The maximum retention of both elements was observed during summer. An average N:P ratio, currently of 13:1, proves that phosphorus is more readily available, though earlier it has been the factor limiting eutrophication processes.

1. INTRODUCTION

The ecosystems of natural and man-made lakes seem to be similar in their structure and the mechanisms governing physical and biochemical processes. However, this similarity is apparent. Man-made lakes stand out for their much more frequent water exchange and large water fluctuations caused by the inflow and outflow variability. Water reservoirs, which are constructed by damming a freely flowing river, have also greater drainage area (KAJAK [3]). This feature is considered as a disadvantage of such systems. Great drainage area provides the reservoir with large amounts of impurities making adverse changes in the ecosystem, which consequently loses its self-purifying capability. This means enormous expansion of phytoplankton and also the changes in their qualitative composition, which is associated with the trophic alteration of a reservoir (JENSEN et al. [2], PŁUŻAŃSKI et al. [5], TOMASZEK and CZERWIENIEC [8], WRÓBEL [9]).

Nitrogen and phosphorus are the elements of a great importance in production processes taking place in water reservoirs. They both determine growth of often undesirable

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vegetation. In small reservoirs with short retention time, large amounts of nutrients are washed out of bottom sediments (GALICKA [1]). This decrement is compensated by external sources. Identification of the source of biogenic elements and assessment of their loads are crucial in terms of a water reservoir and a drainage area management.

2. RESEARCH AREA

The dam reservoir in Rzeszów was built by damming the River Wisłok at a distance of 64 km from its spring. The initial volume of the basin was 1.8 mln m^3. As a result of an intensive deposition of rock material drifted by reservoir tributaries – the Wisłok River and the Strug River – the basin area has been substantially decreased and after a partial reconstruction in 1996 it equals 1.18 km^2, whereas its volume is 1.1 mln m^3. Though the drainage area is of an agricultural character, many big industrial plants operate there, particularly in the Krosno district (glass-works, tanneries). The reservoir was built as a retention and recreational man-made lake and also as a drinking water basin. Despite the reconstruction trial in 1996, the reservoir utilization has been restricted due to its significant silting up and contamination (TOMASZEK [6]).

3. METHODS

The contents of both nitrogen and phosphorus compounds were determined from March 1999 to January 2001 in seven points localized in the estuaries of two tributaries, five points localized in the reservoir and one at the basin outflow from the reservoir (figure 1). Samples were being collected 1–2 times per month.

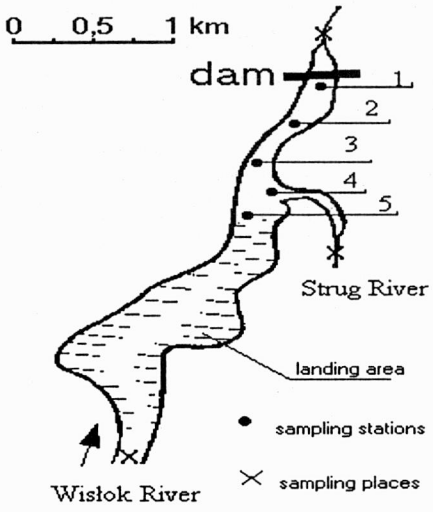

Fig. 1. The Rzeszów reservoir:
volume –1.1 mln m^3, area – 1.18 km^2,
maximum depth – 6 m, average depth – 0.5 m,
average hydraulic retention time – 2 days,
length along basin axis – 3.4 km,
number of tributaries – 2,
drainage area – 2050 km^2,
drainage area slope – 616 m

4. RESULTS AND DISCUSSION

Table 1 shows average, maximal and minimal concentrations of biogenic elements in the Rzeszów reservoir and in its inflows and outflow. In figures 1, 2 and 3, seasonal variations of the concentrations are presented. The concentrations of both phosphate phosphorus and nitrate and ammonia nitrogen in the reservoir and also its tributaries and the outflow usually fall into the first class of purity. However, the nitrite nitrogen concentration, often above 0.03 mg N/dm^3, allows us to include them in the second and sometimes in the third class of purity for nearly all sampling period. In spring time, nitrite concentrations

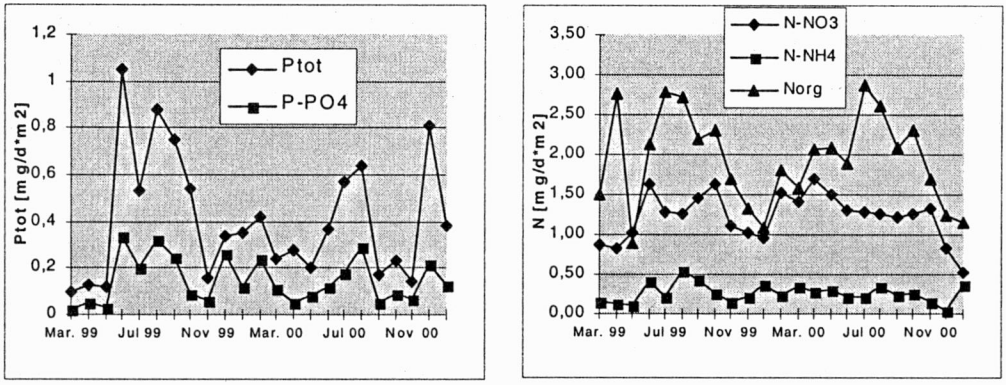

Fig. 2. Seasonal variations of the biogenic compound concentrations in the Strug River

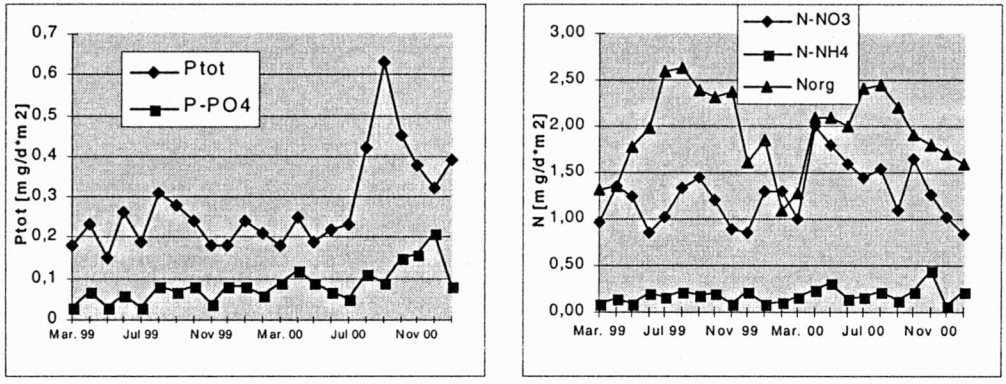

Fig. 3. Seasonal variations of the biogenic compound concentrations in the Wisłok River

exceed the value of 0.6 mg N/dm^3, which means that the water being analysed is out of classification. The total phosphorus concentration in the Strug River in summer makes its water also out of classification. Relatively high concentrations of organic nitrogen in the

Wisłok River and the Strug River water were measured during the sampling period. These concentrations often exceed 2 mg N/dm^3. The concentrations of such form of nitrogen in the reservoir water are found to decrease below 1 mg N/dm^3, and it is also valid for the outflow. The decrease in the average concentration of organic nitrogen from about 1.9 mg N/dm^3 in tributary rivers to nearly 1.0 mg N/dm^3 in outflow proves that a rapid mineralization of organic compounds in the reservoir takes place. The concentrations of organic nitrogen in the tributaries of the Rzeszów reservoir during winter months are similar to nitrate concentrations, but higher during the rest of a year. Any distinct seasonal variations both in nitrate nitrogen concentration and in ammonia nitrogen concentration are not observed (figure 3). The concentrations of both phosphorus and nitrogen in the reservoir are practically higher than those promoting algal bloom (0.3 mg $N–NO_3^-$ and 0.01 mg $P–PO_4^{3-}$) (TOMASZEK [6]). The bloom has been observed every year. The excessive growth of phytoplankton causes the water over-oxidation associated with photosynthesis in shallow and warm water of the basin (TOMASZEK and CZERWIENIEC [8]). Under such conditions the reservoir seems to be useless.

Table 1

Concentrations of biogenic compounds in the Rzeszów reservoir superficial water as well as its tributaries and the outflow

Concentrations [mg/dm^3]	Phosphate phosphorus	Total phosphorus	Nitrate nitrogen	Nitrite nitrogen	Ammonia nitrogen	Organic nitrogen	Total nitrogen
Superficial water – statistics on the basis of 130 measurements							
Average	0.11	0.25	1.08	0.022	0.49	0.40	1.99
Maximum	0.26	0.34	1.62	0.071	0.89	0.81	2.88
Minimum	0.03	0.1	0.14	0.011	0.15	0.11	0.78
SD	0.15	0.13	0.26	0.012	0.10	0.14	0.40
The Wisłok River – statistics on the basis of 27 measurements							
Average	0.068	0.22	1.260	0.045	0.168	1.92	3.39
Maximum	0.12	0.31	2	0.16	0.31	2.63	4.375
Minimum	0.03	0.15	0.852	0.008	0.09	1.09	2.376
SD	0.025	0.043	0.335	0.043	0.063	0.48	0.664
The Strug River – statistics on the basis of 27 measurements							
Average	0.15	0.40	1.28	0.037	0.28	1.93	3.52
Maximum	0.34	1.05	1.7	0.076	0.54	2.78	4.56
Minimum	0.02	0.1	0.82	0.02	0.11	0.90	2.07
SD	0.11	0.28	0.29	0.02	0.12	0.57	0.78
The Wisłok River (outflow) – statistics on the basis of 27 measurements							
Average	0.100	0.310	1.407	0.020	0.22	1.04	2.66
Maximum	0.37	0.95	1.910	0.047	0.39	1.36	3.31
Minimum	0.05	0.15	0.985	0.006	0.10	0.72	1.83
SD	0.066	0.063	0.238	0.009	0.07	0.20	0.36

The analysis of concentrations shows that of two tribuaries the Strug River is slightly more contaminated; however, the Wisłok River as a bigger one supplies the reservoir with 90% of nitrogen and 80% of phosphorus. Table 2 presents average, maximal and minimal concentrations of the loads of biogenic elements in the reservoir inflows and outflow together with the retention values calculated. According to Vollenweider (KAJAK [3]) eutrophication processes are accelerated by twenty-four hour loadings of the order of 0.4 mg of phosphorus per 1 m^2 and 5.5 mg of nitrogen per 1 m^2 of the reservoir surface. In practice, the values of the order of ten and even of hundred higher would not influence the loaded object behaviour (KAJAK [3], PLUŻAŃSKI et al. [5], KOSZELNIK and TOMASZEK [4]). Nevertheless, the loadings calculated are considerably higher than the standard ones (table 2). During the research period 3500 mg of nitrogen $\cdot$ m^{-2} $\cdot$ day^{-1} and 285 mg of phosphorus $\cdot$ m^{-2} $\cdot$ day^{-1} were on average flowing into the reservoir. Such huge nutrient loads affect the reservoir water quality.

Table 2

Nitrogen and phosphorus loadings supplied to the Rzeszów reservoir, retention of the elements being analysed and the N:P ratio in the reservoir superficial waters

Loadings and retentions [mg/d/m^2]	N:P ratio of the superficial water	Inflow	Outflow	Retention	Inflow	Outflow	Retention
		Nitrogen			Phosphorus		
Average	13:1	3500	2712	788	285	305	30
Maximum	44:1	4884	3684	1921	643	918	124
Minimum	7:1	2611	1687	179	127	136	–76
SD	16,6	664	455	528	114	167	60

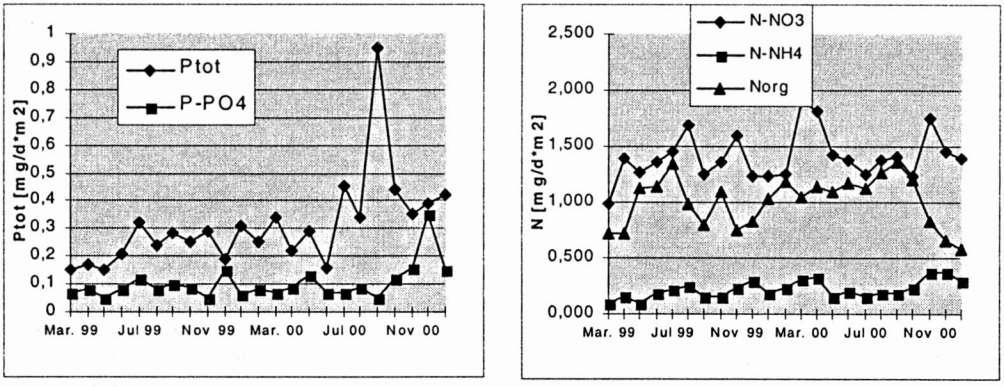

Fig. 4. Seasonal variations of the biogenic compound concentrations in the outlfow

The maximum of nitrogen retention (N_{ret}) was being observed in summer 1999, uncommonly warm spring and summer 2000 (figure 5B). It seems that biochemical factors affect strongly retention. High losses of nitrogen during these periods are not surprising, because the phytoplankton vegetates vigorously and uptakes nutrients. It should be stressed that denitrification process also influences the nitrogen retention in the season of high temperature of water and air (TOMASZEK, CZERWIENIEC [7]). The maximal values of phosphorus retention (P_{ret}) are characteristic of summer months (figure 5A). During that season 30–40% of phosphorus were being stored and processed in the reservoir. Really summer-like weather conditions were kept in early autumn 1999 and in spring 2000 when relatively high level of P_{ret} was also measured. In other seasons, low, often negative, values of phosphorus retention resulted from the inner sources of this element. In general, the warmer the season of a year, the higher the value of the indicator being analysed. As can be seen from table 2, an average amount of phosphorus being retained was only slightly higher than 10% of the phosphorus load supplied to reservoir during the period analysed. In the case of nitrogen, this figure approached 20%. These are significant values for such a small basin of short retention time of water (2 days according to design, now considerably shorter) and heavy nutrient loading. Taking into account the above-mentioned time of appearing the maxima and the minima of the retention of both elements, the conclusion that retention of nitrogen and phosphorus depends heavily on the intensity of biochemical processes in the Rzeszów reservoir seems to be justifiable.

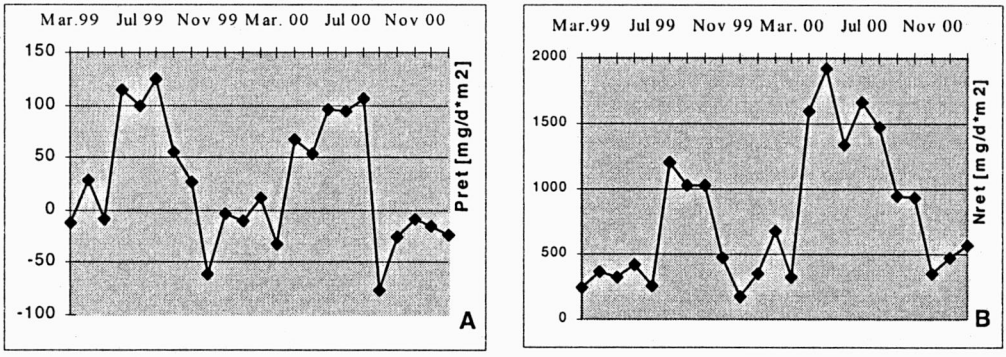

Fig. 5. Dynamics of phosphorus (A) and nitrogen (B) retention in the Rzeszów reservoir

Table 2 also shows the N:P ratio in reservoir's superficial water. An average value of 13:1 suggests that nitrogen is possibly a factor limiting the eutrophication process. The comparison of our results with similar ones obtained earlier can prove that the ratio decreases distinctly with the reservoir age. In 1997, it was 15:1, while in the early eighties an uniform exhausting of both elements according to the stoichiometric N:P ratio of 20:1 was observed, and at the beginning of the reservoir

operation (1973–1975) the phytoplankton growth was limited by phosphorus content (the N:P ratio reached the value of 70–50:1) (TOMASZEK and CZERWIENIEC [8]). The N:P ratio calculated for more easily available (mineral) nitrogen and phosphorus compounds reached an average value of 16:1 when taking into account the whole sampling period and it was also lower than the similar ratio in former years (20–17:1 in 1995–1997).

The variations observed in the content of elements limiting eutrophication processes should be treated as theoretical only, since the abundance of both nutrients ensures appropriate conditions for a rapid growth of phytoplankton.

5. CONCLUSIONS

1. The reservoir tributaries have an adverse effect on the purity of its water. Because of high concentrations of nutrients the water in the reservoir and its tributaries rarely fells into the second class of purity. Most often it was out of classification or fell into the third class of purity.

2. Both nitrogen and phosphorus loadings exceed considerably the permissible limits and are responsible for the reservoir degradation by stimulating the growth of undesirable plants.

3. In the reservoir, considerable amounts of nutrients are accumulated. The highest retentions caused by extensive biochemical processes were observed during high-temperature seasons.

4. The decrease in the N:P ratio from 70:1 in the seventies to 13:1 at present was possibly due to:

– almost complete shallowing and silting up of the reservoir,

– the shortening of the retention time,

– the increase in the concentrations of both nutrients, particularly in the case of phosphorus, caused by high loadings of these elements in the drainage basin and tens of thousands of households lacking a sewage system.

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OBCIĄŻENIE RZESZOWSKIEGO ZBIORNIKA ZAPOROWEGO BIOGENAMI – BILANS MASOWY

Przedstawiono wyniki badań prowadzonych w latach 1999–2000 w ekosystemie zbiornika zaporowego w Rzeszowie. Celem pracy było oszacowanie ładunków azotu i fosforu doprowadzanych do zbiornika oraz określenie ich wpływu na postęp eutrofizacji wód obiektu. Wody zbiornika i dopływów przez większą część okresu badań miały charakter pozaklasowy. Ładunki obu pierwiastków biogennych znacznie przekraczają wartości dopuszczalne i wynoszą średnio: 3500 mg azotu/m^2/dobę i 285 mg fosforu/m^2/dobę. Akumulacji i przemianom biochemicznym w zbiorniku ulegało średnio 788 mg związków azotowych/m^2/dobę i 30 mg związków fosforu/m^2/dobę. Retencja obydwu pierwiastków najwyższe wartości osiągała w miesiącach letnich. Średnia wartość stosunku N:P w zbiorniku wynosząca obecnie 13:1 świadczy o większej dostępności fosforu, który wcześniej był pierwiastkiem ograniczającym eutrofizację.

Reviewed by Lesław Badura