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INFLUENCE OF MSCIWOJOW PRE-DAM RESERVOIR ON WATER QUALITY IN THE WATER RESERVOIR DAM AND BELOW THE RESERVOIR

WPŁYW ZBIORNIKA WSTĘPNEGO MŚCIWOJÓW NA JAKOŚĆ WODY W ZBIORNIKU ZAPOROWYM I PONIŻEJ ZBIORNIKA

Abstract: The paper presents results of research carried out in the period of November 2006 – October 2008 and focused on the influence of the Msciwojow pre-dam reservoir on the quality of water in the main reservoir and below. The following water quality indicators were determined: NO_3^-, NO_2^-, NH_4^+, PO_4^3, water temperature, pH, electrolytic conductivity, dissolved oxygen and chlorophyll *a*. The measurements were carried out for the Msciwojow reservoir, located on the Wierzbiak river in Lower Silesia province (south-western part of Poland).

Contribution of the pre-dam reservoir to the reduction of pollutants in water of the Wierzbiak and Zimnik rivers flowing into the main reservoir was analyzed. During the performed analyzes the following reductions of the main physico-chemical indicators in the pre-dam reservoir were observed, ie nitrates(V) by 69.9 %, phosphates by 32.9 %, nitrates(III) by 63.2 % and ammonia by 62.9 %. The increase of water temperature, pH and dissolved oxygen was also recorded. In the study the quality of water flowing into the Msciwojow reservoir, outflowing water and water stored in the pre-dam and in the main reservoir was assessed. The obtained results showed that the pre-dam reservoir contributed to the improvement of the quality of water flowing into the main reservoir. Proposals for defining dimensions of pre-dam reservoirs and designing principles were presented.

Keywords: pre-dam, water reservoir, pre-dam reservoir efficiency, water quality, water protection

Small water reservoirs, due to their location in the lowest part of the catchment, collect pollutants from the entire catchment area, which testifies to their high sensitivity to processes occurring in the catchment. Apart from their main functions (flood control, agricultural irrigation, fish-farming, water power generation and recreation) they also play an important role in the development of water resources and natural amenities, constituting a key element in water quality protection [1–5]. Small water reservoirs are usually located in agricultural catchments and they form ecosystems accumulating biogenic substances, such as nitrogen and phosphorus compounds as well as various

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pollutants. These processes may result in deterioration of water in reservoirs, their eutrophication and alluviation. Phosphorus and nitrogen compounds transported by rivers generally come from point and area sources [6–8]. For many years attempts have been made to stop biogenic substances at the reservoir inlets. The reduction of their inflow, particularly phosphorus and nitrogen, as well as prevention from alluviation can be achieved in many ways and with different effects. One of these methods is construction of a pre-dam reservoir [9].

Examples of using pre-dam reservoirs to reduce the inflow of nutrients to the main reservoir and the effectiveness of such actions can be found in literature [6, 10–14]. The main functions of pre-dam reservoirs are: stopping the bed load, suspended sediments and fertilizing substances; visual improvement of the landscape at the end of backwater; preventing from uncovering in backwater areas at the main reservoir drawdowns; protecting from eutrophication and landscape deformation; providing additional storage of water in the pre-dam reservoir; storing up water for emergency situations; and recreation purposes (water sports) [14].

Pre-dam reservoirs are constructed directly in front of the main reservoir, usually at its backwater part or aside [15–16].

The aim of this study was to assess the influence of the pre-dam reservoir on the reduction of pollutants in water supplying the main reservoir and below it. Based on the Msciwojow pre-dam reservoir some guidelines for setting up dimensions of such reservoirs were presented.

Study area and methodology

The Msciwojow reservoir was constructed by dividing the Wierzbiak river with an earth dam at 35 + 375 km of its course. A watercourse called Zimnik also flows into the river (Fig. 1). Before the construction of the reservoir Wierzbiak and Zimnik valleys converged at the place of the present bowl. The Msciwojow reservoir is situated in the municipality of Msciwojow, county of Jawor, Lower Silesia province. The Wierzbiak catchment at the reservoir dam's profile covers the area of 47.0 km^2, including the partial surface area of Zimnik, ie 14.3 km^2. The main functions of the reservoir are: flood control, providing water for irrigation of agricultural areas, recreation and fishing. The reservoir has been operating since 1999. Its bowl was divided into the main reservoir and a pre-dam with a sedimentation tank and biological barriers (the main reservoir is separated from the pre-dam by a biological barrier III) (Fig. 1). Such a solution resulted from the necessity of partial removal of biogenic substances and suspended solids from the inflowing water in the pre-dam reservoir. Biological barriers are in the form of levees. Their role is to direct the flow to extend the retention time in the pre-dam reservoir. This prolongs the contact of water with water plants and microorganisms, which by absorbing the biogenic substances improve its quality.

The total capacity of the Msciwojow reservoir at a normal operational fill level (NPP) is 735000 m^3 and the filling area – 34.59 ha. The average depth of the reservoir is 2.0 m. As far as the pre-dam reservoir is concerned, its total capacity at the normal operational fill level amounts to 175000 m^3, whereas the filling area is 14 ha. The

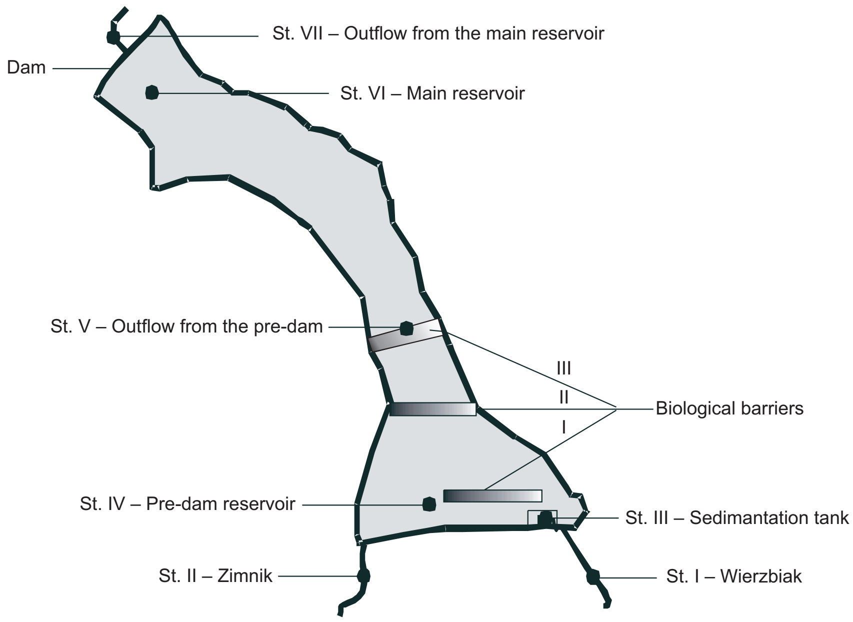

Fig. 1. Location of the Msciwojow reservoir on Wierzbiak and Zimnik rivers. Sampling points: St. I – Wierzbiak (reservoir inlet); St. II – Zimnik (reservoir inlet); St. III – sedimentation tank; St. IV – bowl of the pre-dam reservoir; St. V – outflow from the pre-dam; St. VI – main reservoir; St. VII – outflow from the main reservoir

average depth of the pre-dam reservoir is 1.3 m. The average flow in the reservoir profile amounts to 0.171 $m^3 \cdot s^{-1}$, ie 0.122 $m^3 \cdot s^{-1}$ (the Wierzbiak river) and 0.049 $m^3 \cdot s^{-1}$ (the Zimnik river) [6]. The average retention time in the main reservoir is about 38 days and in the pre-dam – about 12 days.

The reservoir catchment is used for agricultural purposes. There is no sewerage system in the catchment. Wastewater from the Msciwojow reservoir, mainly municipal and domestic effluents, are discharged directly to the Wierzbiak and Zimnik rivers, above the reservoir.

The quality of water in the reservoir area was measured once a month at 7 sampling points: above the Msciwojow reservoir, on the Wierzbiak river, at 37 + 540 km of its course (St. I); on the Zimnik river, at 0 + 800 km (St. II); in the sedimentation tank (St. III); in the pre-dam reservoir (St. IV); at the outflow from the pre-dam reservoir (St. V); in the main reservoir (St. VI) and at the outflow from the main reservoir (St. VII) – Fig. 1.

At the reservoir inlet and outlet water samples were collected from the subsurface layer in the stream. In the reservoir water was sampled at the depth of about 50 cm below the water-table. The following parameters were determined: NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, water temperature, pH, electrolytic conductivity, dissolved oxygen and chlorophyll *a*. The latter one was determined by the Province Inspectorate of Environmental Protection in Opole according to PN-86/C-05560/02 standard. Water pH, electrolytic conductivity and water temperature were measured *in situ*. Determination of water quality chemical indicators was performed in the laboratory of the Department of Land Protection University of Opole. Additional analyses of water quality were carried out in the laboratory of the Department of Construction and Infrastructure at Wroclaw University of Environmental and Life Sciences.

Based on the average values of the selected water quality indicators for the Wierzbiak (St. I) and Zimnik rivers (St. II) flowing into and out of the Msciwojow reservoir, obtained during a 2 years' measurement period and hydrometric measurements – loads [kg] of inflowing and outflowing pollutants were calculated.

In order to assess the impact of the pre-dam reservoir on the quality of water in the main reservoir and below, the average values of particular physico-chemical indicators of the Wierzbiak (St. I) and Zimnik rivers (St. II) were determined according to the following equations:

$$\overline{W}_{iD} = \frac{C_{Xi} W \cdot QW + C_{Xi} Z \cdot QZ}{QW + QZ} \tag{1}$$

where: $\overline{W}_{iD}$ – average concentration of *i* physico-chemical indicator in water flowing into the reservoir bowl [mg/dm^3];

$C_{Xi}W$, $C_{Xi}Z$ – average concentration of *i* physico-chemical indicator in Wierzbiak and Zimnik rivers [mg/dm^3];

QW, QZ – water volume of Wierzbiak and Zimnik in Δt [m^3].

Changes [%] of nitrate(V), nitrate(III) and ammonia loads in the pre-dam and the main reservoir were calculated based on the difference between their average values in the inflowing water (St. I and St. II), water flowing out of the pre-dam reservoir (St. V) and water flowing out of the main reservoir (St. VII).

The quality of the Wierzbiak and Zimnik water flowing into the reservoir, water at the reservoir outlet as well as water stored in the reservoir was assessed according to the Regulation on the ways of classifying the uniform parts of surface water bodies [17]. Assessment of the eutrophication process was presented and the sensitivity of the analyzed water to nitrogen compounds coming from agricultural sources was determined in the context of the above-mentioned Regulation [18].

Results and discussion

Characteristics of water flowing into the Msciwojow reservoir, water stored in the sedimentation tank, pre-dam reservoir and the main reservoir, as well as water flowing out of the pre-dam and the main reservoir in the period of 2006–2008 is presented in Table 1.

It can be noticed that the highest averaged values in water flowing into the reservoir (St. I and St. II) were recorded for nitrates(V), nitrates(III), phosphates and electrolytic conductivity. In the sedimentation tank (St. III) the highest values were found for water temperature and dissolved oxygen, whereas in the pre-dam reservoir (St. IV) – for water pH.

Table 1

Characteristics of water flowing into the Msciwojow reservoir (St. I, St. II), water in the sedimentation tank (St. III) and pre-dam reservoir (St. IV), water flowing out of the pre-dam reservoir (St. IV), water in the main reservoir (St. V) and water flowing out of the main reservoir in November 2006 – October 2008

Water quality indicator	Inflow to the pre-dam reservoir (Wierzbiak) St. I	Inflow to the pre-dam reservoir (Zimnik) St. II	Sedimentation tank St. III	Pre-dam reservoir St. IV	Outflow from the pre-dam reservoir St. V	Main reservoir St. VI	Outflow from the main reservoir St. VII
	minimum – maximum – mean						
Nitrates(V) [mg NO_3^-/dm^3]	10.6–61.0 31.39	12.1–44.0 32.83	2.2–35.00 22.61	0.8–35.0 12.18	0.80–31.0 9.58	0.80–25.0 5.63	0.8–26.0 8.80
Nitrites(III) [mg NO_2^-/dm^3]	0.03–0.66 0.22	0.02–0.5 0.22	0.07–0.59 0.21	0.003–0.3 0.1	0.003–0.23 0.081	0.003–0.15 0.054	0.003–0.20 0.071
Ammonia [mg NH_4^+/dm^3]	0.03–0.82 0.26	0.05–2.60 0.67	0.05–0.50 0.16	0.05–0.26 0.13	0.03–0.33 0.14	0.05–0.64 0.19	0.05–2.56 0.34
Phosphates [mg PO_4^{3-}/dm^3]	0.2–1.6 0.61	0.28–2.00 0.77	0.13–1.34 0.57	0.17–1.46 0.56	0.05–1.26 0.44	0.06–1.2 0.45	0.10–1.97 0.61
Water temperature [^oC]	2.0–23.4 10.41	2.1–23.2 10.25	2.0–25.9 11.86	2.1–27.2 11.34	2.0–27.5 11.60	2.0–27.6 11.13	2.5–26.1 10.51
Reaction (pH) [-]	7.2–8.6 7.83	7.0–8.3 7.64	7.1–9.8 8.41	7.1–9.4 8.46	6.90–9.50 8.42	7.2–9.10 8.36	7.4–9.1 8.1
Electrolytic conductivity [µS/cm]	662–783 715.41	437–901 706.45	578–743 668.82	556–708 641.38	545–676 618.86	532–887 624.30	532–887 617.81
Dissolved Oxygen [mg O_2/dm^3]	8.02–13.86 10.60	7.03–11.73 8.63	8.69–17.5 13.3	8.57–13.87 11.68	8.43–13.66 10.84	8.76–13.48 10.96	4.23–13.0 8.0

The analyzed data also show that at St. V sampling point (outflow from the pre-dam) higher values of water temperature, water pH and dissolved oxygen were observed in comparison with St. I and St. II (inflow to the reservoir). At St. VII (outflow from the main reservoir) the values of ammonia and phosphates were higher than at St. V.

In the summer season water blooms were observed in the Msciwojow reservoir (St. IV and St. VI). In 2008 the content of chlorophyll *a* in the reservoir varied from 56.4 $\mu g/dm^3$ (01.07.2008) to 107.6 $\mu g/dm^3$ (26.08.2008). The values of chlorophyll *a* exceeded the limit values for water quality indicators defined for uniform parts of surface water bodies, such as lakes and other natural water reservoirs from class V [17].

Wierzbiak and Zimnik water (St. I and St. II) flowing to the Msciwojow reservoir as well as water from the sedimentation tank (St. III) and the pre-dam reservoir (St. IV) were classified as euthrophic. At the above-mentioned sampling points the annual average concentration of nitrates exceeded the limit value (10 mg $NO_3 \cdot dm^{-3}$) and the concentration of chlorophyll *a* exceeded the limit value (25 $\mu g/dm^3$) defined in the Regulation of the Minister of the Environment from 2008 [17]. Moreover, it was found out that Wierzbiak water was sensitive to nitrogen compounds coming from agricultural sources as the concentrations of nitrates were higher than the values (50 mg $NO_3 \cdot dm^{-3}$) defined in the Regulation [18].

From nine water quality indicators analyzed in the Msciwojow reservoir seven (except for phosphates and nitrates(III)) are taken into consideration in the water quality classification [17].

The analysis of Wierzbiak and Zimnik water quality (St. I and St. II) showed that the values of $N\text{-}NH_4^+$, water pH, electrolytic conductivity and dissolved oxygen did not exceed the limit values of water quality indicators for uniform parts of surface water bodies in natural watercourses, such as rivers of class I. However, concentrations of $N\text{-}NO_3^-$ and water temperature were higher than the limit values defined for class II [17].

The analysis of Wierzbiak water below the reservoir (St. VII) showed that values of $N\text{-}NO_3^-$, $N\text{-}NH_4^+$, electrolytic conductivity and dissolved oxygen did not exceed the limit values of water quality indicators for uniform parts of surface water bodies in natural watercourses, such as rivers of class I. However, water temperature and pH were higher than the limit values defined for class II [17].

In order to assess the impact of the Msciwojow pre-dam reservoir on the quality of water stored in the main reservoir and below it, downstream the Wierzbiak river, physico-chemical indicators describing the quality of water in front of the reservoir (St. I and St. II), at the outlet from the pre-dam reservoir (St. V) and below the reservoir (St. VII) were analyzed. The following four indicators were selected: nitrates(V), nitrates(III), ammonia and phosphates. Changes in the loads of the above-mentioned chemical compounds are presented in Table 2.

Table 2 shows that in the investigated period the load of nitrates(V) decreased by 69.9 % (St. V) while flowing through the pre-dam reservoir, and after passing through the main reservoir (St. VII) further reduction was observed (by 8.1 % in comparison with sampling point St. V).

Table 2

Changes in loads of nitrates(V), nitrates(III), ammonia, phosphates, and total suspended solids [$kg \cdot d^{-1}$] at sampling points St. I, St. II, St. V and St. VII in the period of November 2006 – October 2008

Water quality indicator	Average value in water [$kg \cdot d^{-1}$]			% Changes in the pre-dam reservoir (among St. I, St. II and St. V)	% Changes in the main reservoir (between St. V and St. VII)
	Inflow to the reservoir (St. I and St. II)	Outflow from the pre-dam reservoir (St. V)	Outflow from the main reservoir (St. VII)		
Nitrates(V) [kg $N\text{-}NO_3^-$]	106.098	31.950	29.358	69.9	8.1
Nitrates(III) [kg $N\text{-}NO_2^-$]	0.989	0.364	0.319	63.2	12.4
Ammonia [kg $N\text{-}NH_4^+$]	4.334	1.609	3.907	62.9	142.8 (increase)
Phosphates [kg $P\text{-}PO_4^{3-}$]	3.092	2.075	2.876	32.9	38.6 (increase)

The load of nitrates(III) in the pre-dam reservoir was reduced by 63.2 % and after passing through the main reservoir it was still reduced by 12.4 % in comparison with St. V sampling point.

As far as ammonia is concerned, the reduction of its load in the pre-dam reservoir (St. V) in comparison with waters flowing into the reservoir (St. I and St. II) was 62.9 %. The same parameter for water flowing through the main reservoir (St. VII) went up by 142.8 % in comparison to St. V (Table 2).

Concentration of phosphates in water flowing to the Msciwojow reservoir decreased after passing through the pre-dam reservoir. The average load of phosphates in water flowing through the pre-dam reservoir went down by 32.9 % in comparison with St. I and St. II sampling points. After further flow of water through the main reservoir the value for phosphates increased by 38.6 % (Table 2).

According to literature pre-dam reservoirs can improve the quality of water in the main reservoirs. The analysis of the Msciwojow pre-dam reservoir, carried out in the period of 2000–2002 [6], shows that its efficiency was: 66.5 % for nitrates(V), 50 % for nitrates(III), 34.3 % for ammonia and 52.8 % for phosphates. According to Benndorf et al [10–11] the phosphate reduction efficiency calculated on the basis of measurements carried out in 13 pre-dam reservoirs in Germany varied from 14 % at an average retention time of 12 hours in Forchheim pre-dam reservoir to 66.5 % at the retention time of 12 days in Hassel pre-dam reservoir. Information on the elimination of phosphates can also be found in [12]. The authors of this study report on high efficiency of pre-dam reservoirs ranging from 52 % to 74 %.

Effectiveness of the pre-dam reservoir Brzozki on the Pratwa river (Opole province) as described by [19] is 36.5 % for nitrates(V), 28.6 % for nitrates(III), 51.6 % for phosphates and 57.1 % for total phosphates.

Research studies carried by Skonieczek and Szymczyk [20], Skonieczek and Koc [21] showed that a small water reservoir (pond) significantly contributed to the reduction of concentrations and loads of phosphorus and nitrogen compounds in the water of Szabruk watercourse (near Olsztyn) flowing through the reservoir. The average annual reduction of the total phosphorus was 58 % and phosphates P-PO_4^{3-} – 60 %.

Proposals for defining dimensions of pre-dam reservoirs and designing principles

In order to investigate to what an extent a water reservoir is liable to eutrophication and whether it is necessary to build a pre-dam reservoir in backwater some calculations must be made. Below calculations made for the Msciwojow reservoir in the period of 2006–2008 are presented. Based on Vollenweider's criterion [22], in Benndorf's modification [23], and at the assumption that the concentration of phosphates in the potential reservoir (St. I and St. II) is 0.66 mg $PO_4^{3-} \cdot dm^{-3}$ (according to equation 1), it was found out that the amount of phosphates per 1 m^2 of the reservoir was 3.28 g P-$PO_4 \cdot m^{-2} \cdot a^{-1}$ at the ratio of the average reservoir depth of 2,0 m to the retention time. The load of inorganic nitrogen flowing into the reservoir was 305.3 Mg N $\cdot$ a^{-1}. According to Kajak [15] the real loads are usually much higher than the dangerous loads. The annual loads vary from a dozen or so to even more grams of phosphorus and almost 200 g of nitrogen per 1 m^2 of the reservoir surface area. Therefore, the Msciwojow reservoir must be classified as a polytrophic lake. It must be noted here, that calculations were made only for phosphorus and nitrogen coming from inflows and a direct catchment or internal load from sediments were not taken into consideration. Therefore, in order to protect the Msciwojow reservoir against pollutants flowing from the catchment the construction of the pre-dam reservoir in backwater was proposed as early as at the designing stage [24].

To achieve proper operation of the pre-dam reservoir its dimensions should be defined in such a way so that they would guarantee proper operation of the reservoir throughout the entire operating period. Pre-dam dimensioning procedure, based on the Msciwojow reservoir and research studies [10, 25, 26], is presented below. Calculations were made for the assumed retention time in the pre-dam reservoir of 5–15 days [6, 10–12, 25]:

a) For Wierzbiak and Zimnik rivers feeding the Msciwojow reservoir the average flow SQ = 0.171 $m^3 \cdot s^{-1}$, and taking into consideration the retention time Δt = 5 days the required capacity of the pre-dam reservoir V_{zb_wst} should be:

$$V_{pre\text{-}dam\_5} = 86400 \cdot \Delta t \cdot SQ = 0.0738\ 10^6\ m^3 \tag{2}$$

b) At the assumed retention time in the pre-dam reservoir Δt = 12 days (according to Benndorf [10] it is the optimum retention time):

$$V_{pre\text{-}dam\_12} = 86400 \cdot \Delta t \cdot SQ = 0.1773\ 10^6\ m^3 \tag{3}$$

c) Assuming the retention time in the pre-dam reservoir Δt = 15 days:

$$V_{pre\text{-}dam\_15} = 86400 \cdot \Delta t \cdot SQ = 0.2216\ 10^6\ m^3 \tag{4}$$

d) The second criterion determining the operational capacity of the pre-dam reservoir refers to rising flows (flood discharge). Two years' high flow $Q_{50\%}$ (without the volume of the assumed bed load) should be retained in the reservoir for 12 hours. Assuming that:

– capacity of the main reservoir $V_{main\_res} = 0.735\ 10^6\ m^3$,
– rising flow (flood discharge) $Q_{50\ \%} = 5.5\ m^3 \cdot s^{-1}$,
– volume of the sediments $V_o = 0.01 \cdot V_{main\_res} = 0.0735\ 10^6\ m^3$

the capacity of the pre-dam reservoir should be:

$$V_{pre\_dam} = Q_{50\ \%} \cdot 0.5 \cdot 86400 + V_o = 0.2376\ 10^6\ m^3 \tag{5}$$

e) The current capacity of the Msciwojow pre-dam reservoir is $V = 0.175\ 10^6\ m^3$. However, according to equations 2–5 the reservoir capacity should be 0.0738–0.2376 $10^6\ m^3$. It must be pointed out here, however, that too high capacity of the pre-dam reservoir is not recommended if wastewater management in the reservoir catchment is changed.

For the assumed parameters of the pre-dam reservoir a potential average annual reduction of phosphorus can be estimated, based on relationships presented in [27]. The average annual water flow Q [m^3/d] in the watercourse feeding the pre-dam reservoir and the average annual retention time at Msciwojow pre-dam t = V/Q [days] should be assumed (where V – capacity of the existing or planned pre-dam reservoir; Q – average annual flow). Then the average annual phosphorus reduction for the previously defined parameters of the pre-dam reservoir should be about 60 %. It should be stressed here, that this is the best method for pre-dam reservoirs provided that the phosphorus load is not too big. Otherwise, it must be assumed that the reduction will be lower [27]. Such a situation was in the case of the Msciwojow reservoir in 2006–2008.

Based on the gained experience as well as literature data some recommendations for the optimum operation of pre-dam reservoirs can be given. Firstly, they should be located at the river inflow to the reservoir bowl. Their average depth should not exceed 3 m, which enables optimum use of light in the process of primary production of phytoplankton. The flow rate should guarantee longer contact of water with vegetation in the pre-dam reservoir and with microorganisms, which absorb biogenic substances contributing to the improvement of water quality. Moreover, the pre-dam reservoir should be equipped with an upper spillway to enable the release of surface water with the lowest phosphorus concentrations. It is also recommended that the pre-dam reservoir should be cleaned on a regular and stage-by-stage basis.

Conclusions

Based on the research carried out in the Msciwojow reservoir in the period of 2006–2008 the following conclusions can be drawn:

1. Wierzbiak and Zimnik water (St. I and St. II) flowing to the Msciwojow reservoir was classified as euthrophic due to the concentration of phosphorus, nitrogen and chlorophyll *a*. It was also found out that the Wierzbiak water was sensitive to nitrogen

pollutants coming from agricultural sources. This justified the construction of the pre-dam reservoir in backwater of the Msciwojow reservoir.

2. The pre-dam reservoir contributes to the changes of water quality in the Wierzbiak and Zimnik rivers. Changes of selected water quality indicators observed at the inflow to the Msciwojow pre-dam reservoir and at its outflow confirm its significant role in the retention of the analyzed indicators. Water retention in the pre-dam reservoir resulted in the reduction of pollutant loads: nitrates(V) by 69.9 %, nitrates(III) by 63.2 %, ammonia by 62.9 % and phosphates by 32.9 % (Table 1 and Table 2)

3. Water flowing out of the main reservoir (St. VII) shows lower values of the analyzed biogenic substances than water flowing into the reservoir (St. I and St. II) – (Table 2).

4. In order to avoid water eutrophication it is necessary to reduce the concentrations of biogens in water flowing to the reservoir. One of the solutions is the construction of the pre-dam reservoir, which will contribute to the improvement of water quality in the main reservoir and extend its operating time. This should be taken into consideration not only in designing new reservoirs but also in the case of the existing ones (provided that location conditions are favorable).

5. The proposed methodology for the preliminary assessment of the pre-dam efficiency in the reduction of phosphorus can be applied to Polish reservoirs and it should be verified on a larger number of facilities. The presented guidelines concerning the designing process should be taken into account at the construction of reservoirs.

6. It is recommended that the research initiated in the Msciwojow reservoir should be continued. This would contribute to the development of more comprehensive methodology for reduction of pollutants in pre-dam reservoirs as well as to a more detailed analysis of the processes taking place in the reservoirs.

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WPŁYW ZBIORNIKA WSTĘPNEGO MŚCIWOJÓW NA JAKOŚĆ WODY W ZBIORNIKU ZAPOROWYM I PONIŻEJ ZBIORNIKA

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Abstrakt: W pracy przedstawiono wyniki badań, przeprowadzonych w okresie od listopada 2006 do października 2008 r., dotyczące wpływu zbiornika wstępnego na jakość wody w zbiorniku głównym Mściwojów i poniżej zbiornika. Pomiarami objęto następujące wskaźniki jakości wody: NO_3^-, NO_2^-, NH_4^+, PO_4^3, temperaturę wody, pH, przewodność elektrolityczną (konduktywność), tlen rozpuszczony i chlorofil *a*. Badania przeprowadzono na zbiorniku Mściwojów zlokalizowanym na rzece Wierzbiak, w woj. dolnośląskim (Polska południowo-zachodnia).

Analizowano wpływ zbiornika wstępnego na zmniejszenie się zanieczyszczeń w wodach rzek zasilających zbiornik główny (Wierzbiak i Zimnik). Badania wykazały, że w zbiorniku wstępnym ma miejsce obniżanie się podstawowych wskaźników fizyczno-chemicznych wody: azotanów(V) o 69,9 %, fosforanów o 32,9 %, azotanów(III) o 63,2 % i amoniaku o 62,9 %. Zanotowano wzrost temperatury wody, odczynu i tlenu rozpuszczonego. W pracy przedstawiono ocenę jakości wód dopływających do zbiornika Mściwojów i z niego odpływających, wód retencjonowanych w zbiorniku wstępnym i głównym. Na podstawie otrzymanych wyników badań stwierdzono, że zbiornik wstępny przyczynia się do poprawy jakości wody dopływającej do zbiornika głównego. Podano propozycje zasad wymiarowania zbiorników wstępnych i zalecenia do ich projektowania.

Słowa kluczowe: zbiornik wstępny, zbiornik wodny, skuteczność zbiornika wstępnego, jakość wody, ochrona wód