Rocznik Ochrona Środowiska

Volume 23 Year 2021 ISSN 1506-218X pp. 151-167

https://doi.org/10.54740/ros.2021.010 open access

Received: 12 January 2021 Accepted: 30 April 2021 Published: 06 December 2021

The Influence of the Przebędowo Reservoir on the Water Quality of the Trojanka River in the First Years of its Functioning

*Błażej Waligórski**
State Water Holding Polish Waters
Regional Water Management Board in Poznań, Poland

Ewelina Janicka
Department of Land Reclamation, Environmental Management and Spatial Management, Poznań University of Life Sciences, Poland
https://orcid.org/0000-0001-9616-6184

**corresponding author's e-mail: blazej.waligorski@wody.gov.pl*

Abstract: Agriculture, mainly biogenic compounds (nitrogen and phosphorus) and plant protection products are one of the sources of environmental pollution. The sources of pollution are both farm buildings and intensively used agricultural land. Therefore, a crucial element of the environment contributing to the improvement of surface water quality are the aforementioned shallow reservoirs covered by vegetation that act as biofiltres or reservoirs such as dammed reservoirs. The analysed reservoir is located in the Greater Poland Province, about 25 km to the north from Poznań, in Murowana Goślina commune. The research on the analysed reservoir was conducted during the growing seasons, from 2016 to 2018, at three measurement and control points: at the Przebędowo reservoir inflow, it the Przebędowo reservoir and at the Przebędowo reservoir outflow. They included determining 4 groups of physico-chemical indicators supporting biological elements, including indicators characterising aerobic conditions, salinity, acidification (pH) and indicators characterising biogenic conditions. Based on the conducted research, a great influence of the reservoir was proven, especially in the context of the concentration of dissolved oxygen at the outflow, where, concerning this indicator, the reservoir was classified as water quality class I. The presented research results also confirmed that in the context of the complexity of hydrological and physico-chemical processes taking place in dammed reservoirs, it is necessary to continuously control them both in terms of water quantity and quality.

Keywords: small-scale water retention, dammed reservoirs, water quality

1. Introduction

Changes in the quality of surface water of a catchment are particularly visible in small water reservoirs. The factors that influence the size of the biogenic compounds and their migration in surface water are the development of the catchment, the size and depression of the land, the type and degree of vegetation cover, population density, sanitation infrastructure, level and method of fertilisation, livestock density and others (Giercuszkiewicz-Bajtlik 1990, Ilnicki 2002). Concerning the functions of reservoirs, there are also two vital aspects, from which conflicting purposes of its use emerges. On the one hand, reservoirs are an important element of industrial infrastructure and indispensable source of water for cities and settlements but, on the other hand, because of their impact on the environment, they are also a vital element of the ecosystem (Wicher 2004). However, reservoirs which have a dam (dammed reservoirs), apart from their basic functions, also improve the purity of surface water. After damming, sedimentation and retention of up to 90% of mineral and organic particles that are in the water flowing into a reservoir occurs. Nonetheless, one cannot unequivocally determine whether reservoirs improve or deteriorate the water quality as these issues are very complex (Wiatkowski et al. 2010).

Agriculture, mainly biogenic compounds (nitrogen and phosphorus) and plant protection products are one of the sources of environmental pollution. The sources of pollution are both farm buildings and intensively used agricultural land (Saunders et al. 2001, Elser et al. 2007, Chislock et al. 2013). Chemical compounds from applied mineral fertilisers and plant protection products, leaking septic tanks and sewage systems are washed away by rain and directed to surface waters. Reduction of the amount of these pollutions can be achieved by suitable management of agriculture, building a treatment plant. However, even with such management, some of the compounds that get into the soil during fertilisation will always be washed away by precipitation water and will enter surface waters. Therefore, a crucial element of the environment contributing to the improvement of surface water quality are the aforementioned shallow reservoirs covered by vegetation that act as biofiltres or reservoirs such as dammed reservoirs. According to Galicka et al. (2007) dammed reservoirs can periodically retain up to 90% of the total amount of matter flowing into them. Wiatkowski (2008, 2010) states that after flowing of the water of the Prosna river through the Psurów reservoir, one could spot a significant reduction of phosphates (by 21%), nitrates (V) (by 26%), nitrates (III) (by 9%) and ammonia (by 5%).

The influence of a dammed reservoir on water quality in the rivers located below it depends on the amount of stored water and the flow as well as on the time of water retention and the location of the reservoir (on the water-course or as a side-reservoir). Reservoirs with a long time of retention of water are "trap" for the river nutrient material such as phosphorus and nitrogen and limit the amount of mineral suspensions. Depending on the depth and location of discharge, reservoirs can lower the water temperature in summer (deep reservoirs with a long time of water retention, in which stratification occurs and water discharge is below the thermocline) or raise it (shallow reservoirs with a long time of water retention). Water leaving deep reservoirs with a discharge below the thermocline on a short section below the dam has a low oxygen concentration. Some dammed reservoirs retain the water of poor quality (with a high content of phosphorus and nitrogen compounds) and introduce biological contaminants, namely large amount of phytoplankton into the river below, causing the algal bloom. The phenomenon caused by the algal bloom of water occurs in small and medium rivers with shallow reservoirs with a long time of retention.

Storage reservoirs in Poland are located mainly in catchments that are characterised by agricultural use, mostly in the lower or middle course of the river. Certainly, this is related to the problems with their functioning and exploitation. Such reservoirs are exposed to excessive accumulation of biogenic compounds, mainly organic and inorganic nitrogen and phosphorus compounds (as it was mentioned earlier). The result is the deterioration of the quality of the stored water and eutrophication (Przybyła et al. 2014).

The aim of this study was to assess the impact of Przebędowo reservoir on the water quality of the Trojanka river in the first years of its functioning.

2. Materials and methods

The analysed reservoir is located in the Greater Poland Province, about 25 km to the north from Poznań, in Murowana Goślina commune (Fig. 1). According to natural regions of Poland based on physical geography (Kondracki 2000), the area of research, characterised by the early post-glacial landscape, is located in the Greater Poland Lakeland (Polish: Pojezierze Wielkopolskie) in the area of the Poznań Warta Gorge (Polish: Poznański Przełom Warty) (315.52). The discussed catchment area of about 100^2 is covered mainly by forests, and to a lesser extent, arable lands in the area adjacent to the reservoir. The structure of land use according to Corine Land Cover 2018.

The Przebędowo reservoir was constructed in the valley of the Trojanka river at km 6+915-8+371 of its course, by the Provincial Management of Drainage, Irrigation and Infrastructure in Poznań and commissioned in November 2014. The reservoir is 1450 meters long and 120 meters wide. The front dam is class IV and is 334 meters long. It should be noted that the Trojanka river acts as a local wildlife corridor for a river system. The river is vital for the connection of the area of Puszcza Zielonka Landscape Park (established in 1994) Special Area of Conservation Natura 2000 "Uroczyska Puszczy Zielonki" and the Warta river to which it flows. Due to this fact, the reservoirs maintain connections between area of the Trojanka river above the damming and the Warta river valley. The main task of the reservoir is to store water for agricultural purposes, as well as to improve ambient and water conditions on adjacent agricultural land and to protect the area below the dam and area adjacent to the reservoirs from flooding and fire. 13 meters wide ecological buffer zone (biogeochemical barrier) was established around the reservoir and it serves as a transition zone between the reservoirs and the agricultural land in order to limit the flow of biogenic compounds (nitrogen, phosphorus) and plant protection products from the adjacent areas.

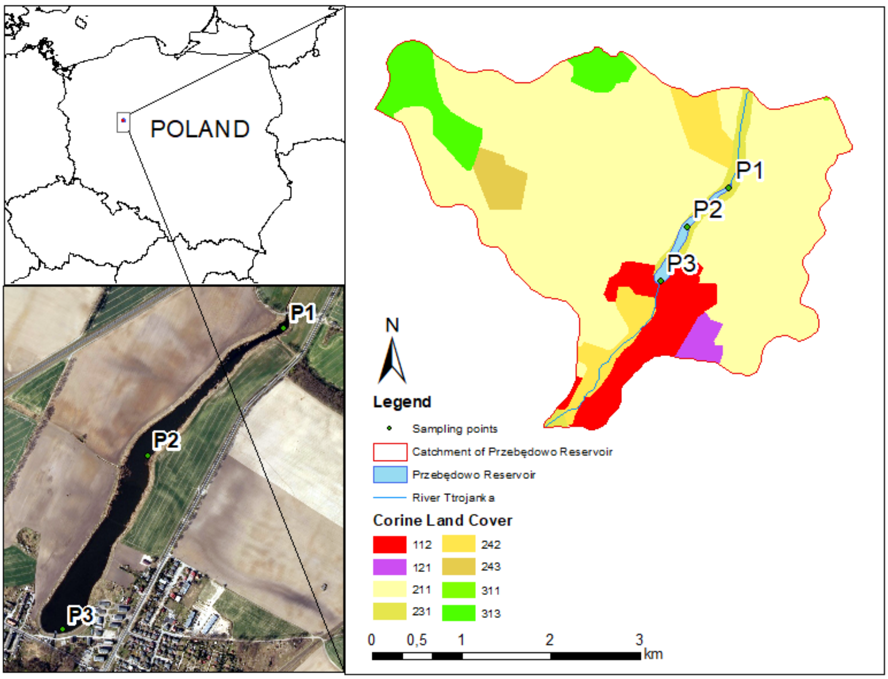

Fig. 1. Location of the Przebędowo Reservoir with water sampling points (P1 – inflow, P2 – reservoir, P3 – outflow) and use of the catchment area

The research on the analysed reservoir was conducted during the growing seasons, from 2016 to 2018, at three measurement and control points: at the Przebędowo reservoir inflow (Trojanka river), it the Przebędowo reservoir and at the Przebędowo reservoir outflow (Trojanka river). The tests of water samples were collected once a month and carried out in the laboratory of the Institute of Land Improvement, Environmental Development and Geodesy of the Poznań University of Life Sciences. They included determining 4 groups of physico-chemical indicators supporting biological elements, including indicators characterising aerobic conditions (dissolved oxygen content and biochemical oxygen demand $_5$), salinity indicators (calcium, magnesium, sulfates and electrolytic conductivity), acidification (pH) and indicators characterising biogenic conditions (ammoniacal nitrogen, nitrate nitrogen (V) nitrate nitrogen (III) and phosphate (V)) in accordance with applicable standards.

Fig. 2. 13 meters wide ecological buffer zone (biogeochemical barrier)

Statistical inference about the significance of the differences in the values of indicators between the measurement and control points was carried out with the non-parametric Mann-Whitney U test at the significance level $\alpha = 0.05$. This test was chosen due to the lack of normal distribution of most of the analyzed indicators.

The analysis of the ecological status of Trojanka river was carried out in accordance with the Regulation of the Ministry of Marine Economy and Inland Navigation of 11 October 2019 (hereinafter referred to as "the Regulation") on the classification of the ecological status, ecological potential and chemical status, method of classifying the status of a body of surface water, as well as environmental quality standards for priority substances. The ecological status was determined by characterising surface water quality for the abiotic 17 type (lowland sandy river) of a body of surface water, which is the Trojanka river, taking into account the physicochemical elements included in the Regulation.

3. Results and discussion

Analysing the indicators characterising the aerobic conditions, namely the concentration of dissolved oxygen, one can conclude that the average values of this indicator in the discussed vegetation periods of the analysed extent of time, at the inflow of the Przebędowo reservoir and in the reservoir itself were 6.37 and 6.64 g·dm^{-3} respectively, and are lower than the requirements of the Regulation for water quality class II, for which the limit value is set at 6.80 mg·dm^{-3}. However, at the outflow of the reservoir, the average content of oxygen dissolved in water was 7.57 mg·dm^{-3} and exceeded the limit for class II. The water flowing out from the reservoirs can be classified as water quality class I regarding dissolved oxygen concentration (Fig. 3). Nonetheless, the extreme values of the discussed indicator were: min. – 4.0 mg·dm^{-3}, and max – 12.8 mg·dm^{-3} respectively. The analysis of the water in the reservoir shows their good oxygenation. Slightly different results were obtained by Bogdał et al. (2015) at the Goczałkowice reservoir, where the average values of dissolved oxygen concentration at the outflow were lower than at the inflow (inflow – 9.51 mg·dm^{-3}; outflow – 8.46 mg·dm^{-3}). According to these authors, such results were due to the blooming of cyanobacteria.

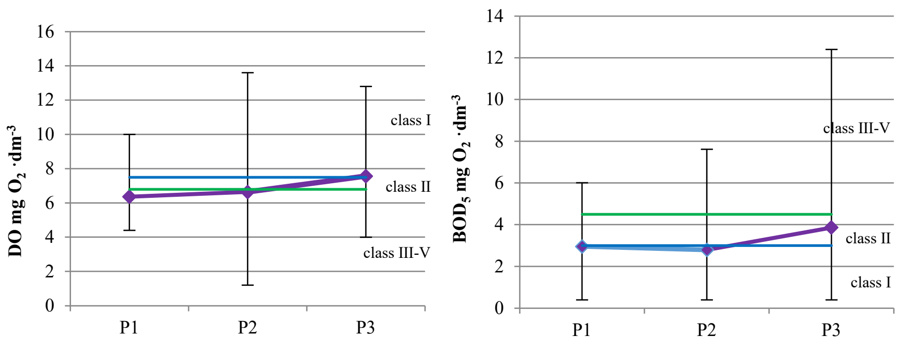

Fig. 3. The content of dissolved oxygen and biochemical oxygen demand $_5$ in the Trojanka river and the Przebędowo reservoir on the three measurement points, during the growing seasons 2016-2018 (average values of indicators)

The analysis of the second indicator characterising aerobic conditions, which is BOD$_5$, allowed to determine that in the discussed period its values at the inflow ranged from 0.4 to 6.01 mg·dm^{-3}, and the average was 2.96 mg·dm^{-3}, which classifies it as the water quality class I. 2). The quality of waters below the reservoir deteriorated, the value of BOD$_5$ ranged from 0.4 to 12.4 mg·dm^{-3}, and the average was 3.86 mg·dm^{-3}, which, concerning the analysed growing seasons, would classify it as the water quality class II. Similar values were obtained by J. Kanclerz et al. (2014) on the Stare Miasto reservoir. There, the waters on the inflow were also classified according to BOD_5, as water quality class I, while after flowing through the reservoir, the water quality deteriorated and was also classified as water quality class II.

In general, one can state that the load of organic matter in the Trojanka river and the analysed reservoir that influence oxygen consumption in the self-purification process was irregular.

The results of research conducted in the laboratory and its analysis proved that waters at all three measure points (P1, P2, P3) had a slightly alkaline pH, with the average of P1 = 8.48; P2 = 8.59; P3 = 8.52 respectively, which classified those as water quality class III-V (Fig. 4). The results obtained were consistent with the results of Kanclerz et al. (2014) on Stare Miasto reservoir, where the authors also found a slightly alkaline pH of the waters of the Powa river (the average pH was 8.3), however, according to then binding Regulation of 2011, the waters of the Powa river were classified as water quality class I – of very good quality. Currently, for water quality class I and II, the pH values should be between 7.0 and 7.9.

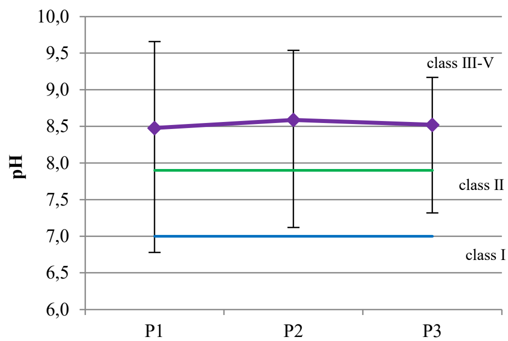

Fig. 4. The pH in the waters of Trojanka river and the Przebędowo reservoir at three measurement points, during the growing seasons 2016-2018 (average values of indicators)

The analysis of indicators characterising salinity of water in the aforementioned measurement points showed that the average values of calcium in the water during the growing seasons in years 2016-2018 were very similar to each other: inflow – 111.33 $mg \cdot dm^{-3}$; reservoir – 108.0 $mg \cdot dm^{-3}$ and outflow – 110.11 $mg \cdot dm^{-3}$ (Fig. 5) and, according to the Regulation, exceeded values necessary for classification as water quality class II.

Also, no major differences were found in the values of chlorides between the measuring points analysed. The average value of these elements in the analysed years was: at the inflow 34.72 mg·dm^{-3}; in the reservoir 35.14 mg·dm^{-3} and at the outflow 39.86 mg·dm^{-3} (Fig. 5) and according to the Regulation, exceeded the value necessary for classification as water quality class II which is 33.7 mg·dm^{-3}. Based on the obtained results, the quality of water was classified as class III-V.

In the research conducted by Przybyła et al. (2014) on the Jutrosin reservoir, the authors obtained slightly better results in relation to the aforementioned indications, as the concentration of chlorides allowed to classify the quality of water as class I and the concentration of calcium allowed to classify the quality of water as class II.

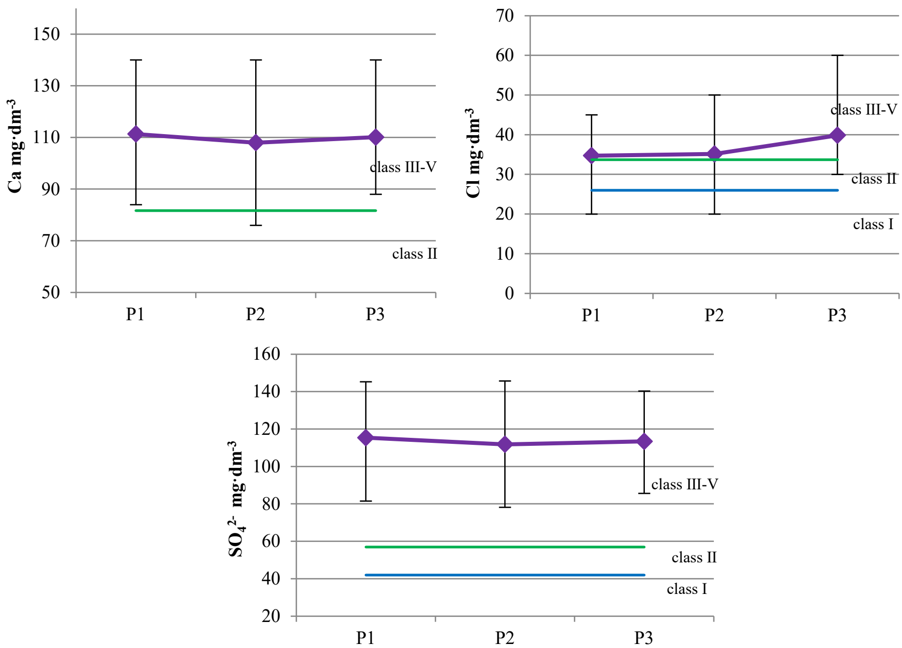

Fig. 5. The content of calcium, chlorides and sulphates (VI) in the waters of Trojanka river and the Przebędowo reservoir at three measurement points, during the growing seasons 2016-2018 (average values of indicators)

The analysis of another indicator characterising salinity of water, i.e. sulphates (VI) proved that, in the discussed period, the lowest values of 78.19 mg·dm^{-3} were recorded in the reservoir, while at the inflow and the outflow from the reservoir values were 81.48 mg·dm^{-3} and 85.59 mg·dm^{-3} respectively (Table 1). The obtained results allowed to classify those waters, in respect of the content of sulphates, as water quality class III-V. The average values of this indicator were: P1 – 115.4 mg·dm^{-3}; P2 – 111.85 mg·dm^{-3}; P3 – 113.39 mg·dm^{-3}. According to the Regulation, the limit value for classification as water quality class III-V is 57 mg·dm^{-3} (Fig. 5).

Table 1. Minimum, maximum, average and median of the physico-chemical indicators in the measurement points in the Trojanka river during the growing seasons 2016-2018

Indicator	Control and measurement points		
	Inflow (P1)	Reservoir (P2)	Outflow (P3)
/1/	/2/	/3/	/4/
Dissolved oxygen DO (mg O_2 · dm^{-3})	4.4-10 6.37 (6.10)	1.2-13.6 6.64 (6.32)	4.0-12.8 7.57 (6.81)
Biochemical oxygen demand, BOD_5 (mg O_2 · dm^{-3})	0.4-6.01 2.96 (2.65)	0.4-7.62 2.79 (2.28)	0.4-12.4 3.86 (3.11)
Acidification (pH)	6.78-9.66 8.48 (8.75)	7.12-9.54 8.59 (8.75)	7.32-9.17 8.52 (8.68)
Calcium Ca (mg · dm^{-3})	84.0-140.0 111.33 (116.0)	76.0-140.0 108.0 (108.0)	88.0-140.0 110.11 (110.0)
Magnesium Mg (mg · dm^{-3})	4.86-21.89 13.78 (14.59)	7.30-19.46 13.24 (12.16)	9.73-24.32 14.59 (13.38)
Chlorides Cl (mg · dm^{-3})	20.0-45.0 34.72 (35.0)	20.0-50.0 35.14 (35.0)	30.0-60.0 39.86 (40.0)
Nitrate nitrogen (V) N-NO_3 (mg · dm^{-3})	0.02-7.6 1.49 (1.05)	0.02-4.1 1.06 (0.9)	0.02-3.4 1.01 (0.85)
Nitrate nitrogen (III) N-NO_2 (mg · dm^{-3})	0.005-0.09 0.05 (0.05)	0.005-0.15 0.03 (0.025)	0.01-0.09 0.04 (0.02)
Ammoniacal nitrogen N-NH_4 (mg · dm^{-3})	0.01-0.15 0.04 (0.04)	0.01-0.12 0.03 (0.01)	0.01-0.14 0.04 (0.01)
Sulphates (VI) SO_4^{2-} (mg · dm^{-3})	81.48-145.26 115.4 (123.45)	78.19-145.67 111.85 (114.5)	85.59-140.32 113.39 (118.51)
Phosphate (V) P-PO_4 (mg · dm^{-3})	0.01-0.25 0.08 (0.05)	0.01-0.34 0.08 (0.02)	0.01-0.38 0.10 (0.07)
Electrolytic conductivity EC (µS · cm^{-1})	402.0-714.0 565.22 (555.0)	426.0-674.0 519.22 (514.0)	447.0-725.0 556.94 (548.5)

In the research of Bogdała et al. (2015) on the Goczałkowice reservoir, the authors obtained results allowing them to classify the water, in respect to the average or even maximum values of content sulphates as water quality class I. It may have resulted from the fact that, unlike Przebędowo reservoir, in the catchment of Goczałkowice reservoir, there are no arable lands as well as the parts of the area surrounding it is the protected area of Natura 2000.

The analyses carried out on another crucial indicator of salinity of water, which is the content of magnesium, showed that at each measurement point both minimum and average values of magnesium were at a low level during the test period which allows to classify the water quality as class I. However, by analysing the results, one might conclude that the values of magnesium increased with the flow of water between the points. The lowest value above the reservoir was 4.86 $mg \cdot dm^{-3}$, and in the reservoir itself 7.30 $mg \cdot dm^{-3}$. At the outflow, the lowest value was 9.73 $mg \cdot dm^{-3}$. The maximum values were as follows: inflow 21.89 $mg \cdot dm^{-3}$, reservoir 19.46 $mg \cdot dm^{-3}$, outflow 24.32 $mg \cdot dm^{-3}$ (Table 1). The average values were: inflow13.78 $mg \cdot dm^{-3}$, reservoir 13.24 $mg \cdot dm^{-3}$, outflow 14.59 $mg \cdot dm^{-3}$ (Fig. 6). It should be noted that, according to the Regulation, the limit value for classifying as water quality class I is 18.4 $mg \cdot dm^{-3}$.

The last analysed indicator that measures salinity was the electrolytic conductivity. During the research, it ranged from 402 to 714 $\mu S \cdot cm^{-1}$ for the waters at the inflow of the Przebędowo reservoir and from 426 to 674 $\mu S \cdot cm^{-1}$ for the waters stored in the reservoir and from 447 to 725 $\mu S \cdot cm^{-1}$ for the waters at the outflow of the reservoir (Table 1). It was found that the average values of electrolytic conductivity at the analysed measurement points allow to classify the waters at the inflow as water quality class II, the waters in the reservoir as class I and the waters at the outflow as class II (Fig. 5).

Such a tendency of fluctuation of average values of electrolytic conductivity, and consequently, convergent results, were also obtained by Kozłowski et al. (2017), at the Cedzyna reservoir on the Lubrzanka river. On the mentioned reservoir, the average values were: inflow – 272 $\mu S \cdot cm^{-1}$; reservoir – 222.9 $\mu S \cdot cm^{-1}$; outflow – 229.4 $\mu S \cdot cm^{-1}$.

The last group of analysed physico-chemical indicators is that characterising biogenic conditions.

The first analysed indicator in this group of compounds were phosphates. According to Pawełek et al. (2005), the presence of these compounds in the surface water is due to the soil erosion, sewage inflow, dissolution of all kinds of minerals as well as precipitation.

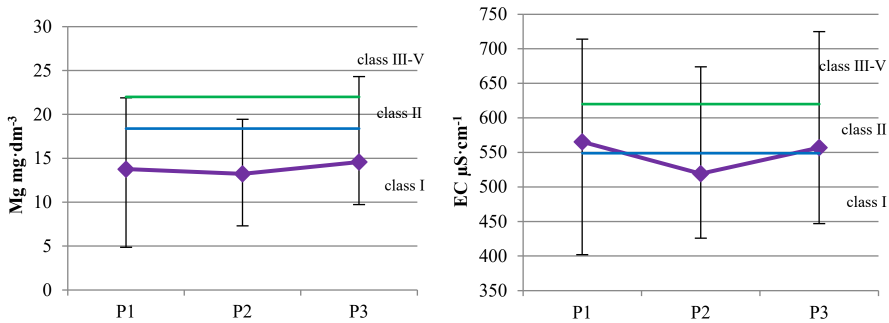

Fig. 6. The content of magnesium and specific electrolytic conductivity in the waters of the Trojanka river and the Przebędowo reservoir at three measurement points, during the growing seasons 2016-2018 (average values of indicators)

Average phosphate values at the inflow of the Przebędowo reservoir and in the reservoir itself were 0.08 mg·dm^{-3}, while at the outflow 0.10 mg·dm^{-3} (Fig. 7). Average phosphate values for the water samples tested during the research period are within the limit value defined by the Regulation for water quality class II, i.e. between 0.065 mg·dm^{-3}, and 0.101 mg·dm^{-3}. The highest (maximum) values for the individual measurement points were: at the inflow 0.25 mg·dm^{-3}, in the reservoir – 0.34 mg·dm^{-3} at the outflow 0.38 mg·dm^{-3} .

Slightly higher values of phosphate were obtained by Pawełek et al. (2008) at the inflow of the Dobczycki reservoir. In their research, the authors analysed the concentration of biogenic compounds in the water of the streams flowing into the reservoir. Average phosphate values for the Dębnik and Wolnica tributaries were 0.136 mg·dm^{-3} and 0.142 mg·dm^{-3}.

Another analysed indicator characterising biogenic conditions was nitrate nitrogen (V). It is a form of nitrogen that is not bound by sorbent soil and therefore is easily washed out. During the research, the average values of the analysed indicator above, below and in the reservoir itself were: P1 – 1.49 mg·dm^{-3}; P2 – 1.06 mg·dm^{-3}; P3 – 1.01 mg·dm^{-3}, which allowed to classify this water, regarding this parameter, as class I (Fig. 7). According to the regulation, the limit value for water quality class I for nitrate nitrogen (V) is 2.2 mg·dm^{-3}.

The results obtained regarding nitrate nitrogen (V) were largely comparable to the results of Kanclerz et al. (2010) obtained from the Stare Miasto reservoir, where the average values of the discussed indicator were also within the limit value of water quality class I.

Indicators characterising ammoniacal nitrogen constitute an important element of assessing the quality of water in reservoirs which catchments are used for agricultural purposes. According to the Regulation, the limit value for the water quality class I for the aforementioned indicator is 0.25 mg·dm^{-3}. In the analysed period, on the reservoir in question, the maximum values did not exceed this limit and were: at the inflow – 0.15 mg·dm^{-3}, in the reservoir – 0.12 mg·dm^{-3}, at the outflow – 0.14 mg·dm^{-3} (Table 1). Average values of ammoniacal nitrogen: P1 – 0.04 mg·dm^{-3}; P2 – 0.03 mg·dm^{-3}; P3 – 0.04 mg·dm^{-3} (Fig. 7).

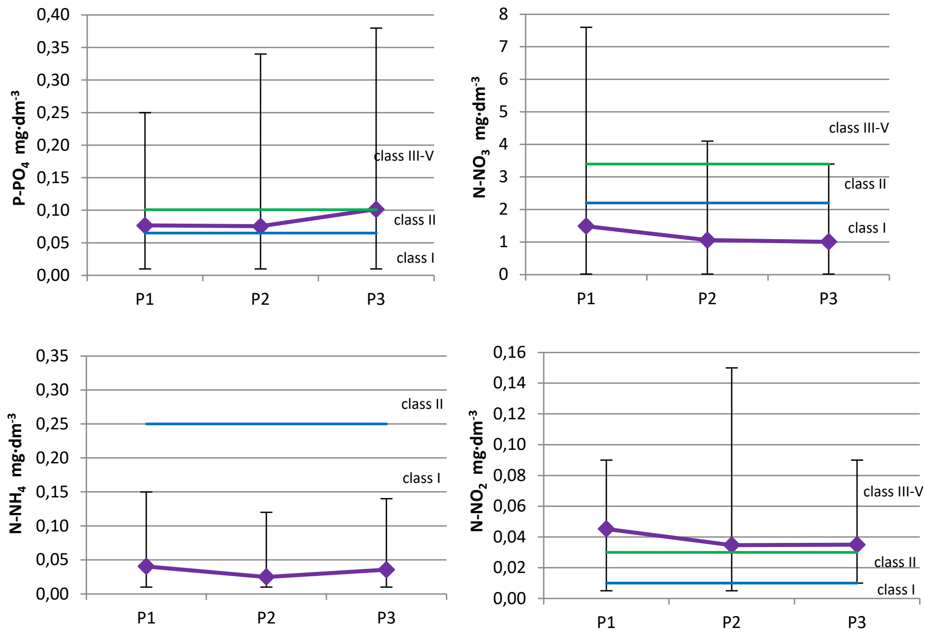

Fig. 7. The content of phosphate (V), nitrate nitrogen (V), ammoniacal nitrogen and nitrate nitrogen (III) in the waters of the Trojanka river and the Przebędowo reservoir at three measurement points, during the growing seasons 2016-2018 (average values of indicators)

Similar results were obtained by Szczykowska (2013), during the analysis of the water quality of the Koryncin reservoir. Ammoniacal nitrogen concentration was relatively low and allowed to classify this as water quality class I. However, the author emphasized that during the winter period, the values of this indicator might be increased, which is largely due to the intake of water from under the ice layer, when processes of ammonification of organic matter of sediments take place. Nonetheless, the observed increase in the value of ammoniacal nitrogen in the spring period might be related to the slopewash in the indirect and direct area of the catchment of the reservoir.

The last analysed indicator was nitrate nitrogen (III). The results obtained in the research period showed that the values of the indicator ranged from 0.005 to 0.9 mg·dm^{-3} concerning the waters at the inflow of the Przebędowo reservoir, from 0.005 to 0.15 mg·dm^{-3} concerning the waters stored in the reservoir and from 0.01 to 0.09 mg·dm^{-3} concerning the waters at the outflow of the reservoir (Table 1). The average values for individual measurement points were: P1 – 0.05 mg·dm^{-3}; P2 – 0.03 mg·dm^{-3}; P3 – 0.04 mg·dm^{-3}. According to the Regulation, the obtained results of the average concentration of the analysed indicator allow to classify these waters as water quality class III-V.

Analysing the average values of nitrate nitrogen (III) it was found that the value of the indicator in the reservoir itself is lower than in the waters at the inflow and the outflow. These results are consistent with the ones of Wiatkowski (2008) obtained on the Młyny reservoir on the Julianpolka river in which the author determined that the average values of this indicator were lower in the reservoir itself than in the waters at the inflow and the outflow.

Statistical analysis performed with the Mann-Whitney U test showed that the values of the two examined indicators differed significantly between the measurement and control points (Table 2). Statistically higher values of dissolved oxygen in water and chlorides were found in point 1 (inflow) compared to point 3 (outflow).

Table 2. Importance of the water indicators' values between the measuring-control points P1 and P3 of the Przebędowo Reservoir – Mann-Whitney's nonparametric test*

Index	Unit	Median of sample points		Test probability, *p*
		Inflow (P1)	Outflow (P3)	
Dissolved oxygen DO	(mg O_2 · dm^{-3})	6.10	6.81	0.037
Biochemical oxygen demand BOD_5	(mg O_2 · dm^{-3})	2.65	3.11	0.734
Acidification	pH	8.75	8.68	0.518
Calcium Ca	(mg · dm^{-3})	116.00	110.00	0.786
Magnesium Mg	(mg · dm^{-3})	14.59	13.38	0.738
Chlorides Cl	(mg · dm^{-3})	35.00	40.00	0.020

Table 2. cont.

Index	Unit	Median of sample points		Test probability, *p*
		Inflow (P1)	Outflow (P3)	
Nitrate nitrogen (V) $N\text{-}NO_3$	$(mg \cdot dm^{-3})$	1.05	0.85	0.459
Nitrate nitrogen (III) $N\text{-}NO_2$	$(mg \cdot dm^{-3})$	0.05	0.02	0.387
Ammoniacal nitrogen $N\text{-}NH_4$	$(mg \cdot dm^{-3})$	0.04	0.01	0.462
Sulphates (VI) SO_4^{2-}	$(mg \cdot dm^{-3})$	123.45	118.51	0.707
Phosphate (V) $P\text{-}PO_4$	$(mg \cdot dm^{-3})$	0.05	0.07	0.653
Electrolytic conductivity EC	$(\mu S \cdot cm^{-1})$	555.00	548.50	0.460

*Statistical values in red mean statistically significant differences at $p < 0.05$

4. Conclusions

1. The research has shown that the parameters characterising aerobic conditions and biogenic conditions with the exception of nitrate nitrogen (III) meet the requirements necessary to classify this reservoir as water quality class II. However, other elements, indicators of salinity and acidification do not meet the requirements necessary to classify this reservoir as water quality class II. Based on the analysis of average values of physico-chemical parameters, the ecological status of the Trojanka river at the inflow and the outflow of the reservoir does not meet the requirements necessary to classify it as water quality class II. Therefore, the ecological status of the waters of the Trojanka river was classified as below good.
2. Out of 12 tested physicochemical indicators of the Trojanka river water, the values of only 2 indices were statistically higher at the outflow from the reservoir.
3. Based on the conducted research, a great influence of the reservoir was proven, especially in the context of the concentration of dissolved oxygen at the outflow, where, concerning this indicator, the reservoir was classified as water quality class I. This situation might be influenced by located on the reservoir discharge and spillway structure with damming height of 3.8 m, which makes the oxygenation process more intensive.

4. The Przebędowo reservoir is a new one as it was commissioned in November 2014. Also, its ecosystem does not yet have its internal mechanisms that transform the excess of the biogenic compounds. This makes the reservoir susceptible to water quality fluctuations. Over the years one can expect the quality parameters to be better.

References

Bogdał, A., Kowalik, T., Witoszek, K. (2015). Wpływ Zbiornika Goczałkowickiego na zmianu jakości wód w rzece Wiśle. *Inżynieria Ekologiczna. 45*, 124-134 (in Polish).

Chislock, M. F., Doster, E., Zitomer, R. A., & Wilson, A. E. (2013). Eutrophication: causes, consequences, and controls in aquatic ecosystems. *Nature Education Knowledge, 4*(4), 10.

Czamara, W., Czamara, A., Wiatkowski, M. (2008). The use pre-dams with plant filtres to improve water quality in storage reservoirs. *Arch. Environ. Prot., 34*, 79-89.

Elser, J. J., Bracken, M. E., Cleland, E. E., Gruner, D. S., Harpole, W. S., Hillebrand, H., ... & Smith, J. E. (2007). Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. *Ecology letters*, *10*(12), 1135-1142.

Galicka, W., Kruk, A., Zięba, G. (2007). Bilans azotu i fosforu w zbiorniku Jeziorsko. *Nauka Przyr. Technol. 1*(2), #17 (in Polish).

Giercuszkiewicz-Bajtlik, M. (1990). *Prognozowanie zmian jakości wód stojących*. Instytut Ochrony Śroodowiska, Warszawa (in Polish).

Górniak, A. (2006). Ekosystem zbiornika Siemianówka w latach 1994-2004 i jego rekultywacja. Publishing House of the University of Bialystok, Poland (in Polish).

Kanclerz, J., Wicher-Dysarz, J., Dysarz, T., Sojka, M., Dwornikowska, Ż. (2014). Wpływ Zbiornika Stare Miasto na jakość wody rzeki Powy. *Nauka Przyr. Technol. 8*(4), #54 (in Polish).

Kanownik, W., Kowalik, T., Bodgał, A., Ostrowski, K., Rajda, Wł. (2011). Jakość i walory użytkowe wód odpływających ze zlewni zbiorników małej retencji planowanych w rejonie Krakowa. Wyniki badań przeprowadzonych w ramach projektu rozwojowego nr R12 001 02 sfinansowanego przez Ministerstwo Nauki i Szkolnictwa Wyższego [Quality and utility value of water flowing from the catchment of planned small retention reservoirs near Kraków. Results of studies conducted within the R&D project no. R12 001 02 financed by the Ministry of Science and higher Education], 36 (in Polish).

Kondracki, J. (2000). *Geografia regionalna Polski*. PWN, Warszawa (in Polish).

Kozłowski, R., Przybylska, J., Kaleta, J. (2014). Wpływ zbiornika zaporowego Cedzyna na wybrane parametry jakości wody rzeki Lubrzanki w okresie letnim. *Monitoring Środowiska Przyrodniczego, 19*(1), 81-89 (in Polish).

Pasternak, K. (1968). Skład chemiczny wody rzek i potoków o zlewniach zbudowanych z różnych skał i gleb. *Acta Hydrobiologica, 10*, 1-25 (in Polish).

Pawełek, J., Spytek, M. (2005). *Substancje biogenne w dopływach zbiornika Dobczyckiego*. Infrastruktura i Ekologia Terenów Wiejskich, PAN, 4/2005 99-113 (in Polish).

Pawełek, J., Spytek, M. (2008). *Stężenie związków biogennych w wodzie potoków dopływających do zbiornika Dobczyńskiego*. Infrastruktura i Ekologia Terenów Wiejskich, PAN, 5/2008 179-190 (in Polish).

Pęczuła, W., Suchora, M. (2011). Analiza przyczyn występowania złej jakości wody w zbiorniku retencyjnym w Kraśniku w pierwszych latach jego funkcjonowania. *Prz. Nauk. Inż. Środ. 54*, 321-332 (in Polish).

PN-91 C-04537-09:1973 Woda i ścieki. Badania zawartości związków fosforu. Oznaczanie fosforanów ogólnych metodą kolorymetryczną lub ekstrakcyjno-kolorymetryczną.

PN-C-04576-08:1982 Woda i ścieki. Badania zawartości związków azotu. Oznaczanie azotu azotanowego metodą kolorymetryczną z salicylanem sodowym.

PN-EN 1899-2:2002 Jakość wody. Oznaczanie biochemicznego zapotrzebowania tlenu po n dniach (BZTn) - Część 2: Metoda do próbek nierozcieńczonych.

PN-EN 26777:1999 Jakość wody. Oznaczanie azotynów. Metoda absorpcyjnej spektrometrii cząsteczkowej.

PN-EN 27888:1999 Jakość wody. Oznaczanie przewodności elektrycznej właściwej.

PN-EN 25813:1997 Jakośc wody. Oznaczanie stężenia tlenu rozpuszczonego.

PN-EN ISO 9963-1:2001 Jakość wody. Oznaczanie zasadowości. Część 1: Oznaczanie zasadowości ogólnej i zasadowości wobec fenoloftaleiny.

PN-ISO 7150-1:2002 Jakość wody. Oznaczanie azotu amonowego. Część 1. Manualna metoda spektrometryczna.

PN-ISO 9280: 2002 Jakość wody. Oznaczanie siarczanów(VI) - Metoda grawimetryczna z chlorkiem baru

PN-ISO 9297:1994 Jakość wody. Oznaczanie chlorków - Metoda miareczkowania azotanem srebra w obecności chromianu jako wskaźnika (Metoda Mohra).

PN-ISO 8288:2002 Woda i ścieki – badania zawartości metali metodą absorpcyjnej spektrometrii atomowej - Oznaczanie cynku, miedzi, ołowiu, kadmu, niklu, kobaltu, żelaza i manganu w wodzie z zastosowaniem wstępnego zagęszczenia metodą chelatowania i ekstrakcji.

Przybyła, Cz., Kozdrój, P., Sojka, M. (2014). Ocena jakości wód w lateralnych zbiornikach Jutrosin i Pakosław w pierwszych latach funkcjonowania [Assessment of water quality in the Jutrosin and Pakosław lateral reservoirs in the first years of their operation]. *Inżynieria Ekologiczna, 39*, 123-135 (in Polish).

Puczyńska, I., Skrzypski, J. (2009). Integracja działań biologicznych i technicznych jako podstawa intensyfikacji procesów samooczyszczania się zbiorników zaporowych (na przykładzie zbiornika Sulejowskiego) [Integration of biological and engineering measures as the basis for intensification of self-purification in dam reservoirs (based on the Sulejowski reservoir)]. *Ecological Chemistry and Engineering S, 16*(S2), 221-23 (in Polish).

The Regulation of the Ministry of Marine Economy and Inland Navigation of 11 October 2019 on the classification of the ecological status, ecological potential and chemical status, method of classifying the status of a body of surface water, as well as environmental quality standards for priority substances.

Saunders, D. L., & Kalff, J. (2001). Nitrogen retention in wetlands, lakes and rivers. *Hydrobiologia, 443*(1), 205-212.

Szczykowska, J., Siemieniuk, A., Wiater, J. (2013). Problemy ekologiczne zbiorników małej retencji na Podlasiu. *Ekonomia i Środowisko, 4*(47) (in Polish).
Wiatkowski, M. (2008). *Wstępne wyniki badań jakości wody dopływającej i odpływającej ze zbiornika Psurów na rzece Prośnie*. W: Meteorologia, hydrologia, ochrona środowiska – kierunki badań i problemy. Red. A. Dubicki. Monogr. IMGW: 407-414.
Wiatkowski, M. (2010). Zmiany wybranych wskaźników jakości wody rzeki Prosny przepływającej przez zbiornik Psurów. *Proc. ECOpole 4*(2), 495-500.
Wiatkowski, M. (2010). Ocena jakości wody zbiornika Komorów na potoku Milikówka. *Infrastruktura i ekologia terenów wiejskich, 8*(2), 51-64 (in Polish).
Wicher, J. (2004). *Akumulacja rumowiska w nizinnych zbiornikach wodnych*. Maszynopis. Katedra Inżynieriii Wodnej i Sanitarnej UP, Poznań (in Polish).
Wicher-Dysarz, J., Kanclerz, J. (2012). Funkcjonowanie małych zbiorników nizinnych z wydzieloną częścią wstępną na przykładzie zbiorników Jezioro Kowalskie i Stare Miasto. *Rocznik Ochrona Srodowiska, 14*(1), 885-897 (in Polish).