ARCHIVES OF ENVIRONMENTAL PROTECTION
vol. 36 no. 3 pp. 83 - 96 2010
PL ISSN 0324-8461

IMPACT OF THE SMALL WATER RESERVOIR PSURÓW ON THE QUALITY AND FLOWS OF THE PROSNA RIVER

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Keywords: Small water reservoir, river, water quality, eutrophication, water flows.

Abstract: The paper presents a small water reservoir Psurów located on the Prosna River (right tributary of the Warta River) in the Opolskie Voivodeship (southern Poland). Results of water quality analyses of the Prosna River flowing into the reservoir and the outflowing water, as well as water stored in the reservoir have been discussed. Water flows of the Prosna River above and below the Psurów reservoir were analyzed. The analyses were carried out from November 2006 to October 2008. The following water quality indicators were measured: PO_4^{3-}, NO_3^-, NO_2^-, NH_4^+, BOD_5, DO, water temperature, pH, electrolytic conductivity, TSS and chlorophyll a, for which basic descriptive statistics was calculated. The research showed that the small water reservoir Psurów contributed to the reduction of the following loads: phosphates (by about 21%), nitrates (by 26%), nitrites (by 9%), ammonia (by 5%) and total suspended solids (by 17%). It was found out that there was a statistically significant relationship ($p < 0.05$) between the volume of water flowing out of the reservoir and the inflowing water (Pearson's correlation coefficient: $r = 0.93$). Based on the Vollenweider's criterion the Psurów reservoir was classified to polytrophic reservoirs.

INTRODUCTION

Small water reservoirs are the main elements of the so called "small retention". They fulfill many economic functions, protect against flood and contribute to the increase of water resources [4, 20, 21, 31]. Separating the river valley with a dam and building a water reservoir may have various impacts on the reservoir surroundings, its bed and the river valley below. Quite important is also the knowledge of the reservoir's impact on flows and quality of water in the reservoir and below the structure [14, 19, 33]. Small water reservoirs are usually located in agricultural catchments. Since the reservoirs are built in the lowest part of the catchment they become the place where all pollutants from the catchment accumulate.

According to many authors [9, 15, 16, 31] the catchment is an element of the reservoir's hydrological regime, which determines the quality of water and its trophy. According to Galicka *et al.* [8] breaking the river continuity with a stage of fall contributes to the reduction of water lift force, intensifying sedimentation processes and retention even up to 90% of the load. A considerable amount of biogenic substances is also accumulated, particularly organic and inorganic compounds of nitrogen and phosphorus, as well as many other pollutants. This may deteriorate the quality of water stored in the reservoirs, cause their eutrophication or silting [23–25, 29, 31, 34].

Such phenomena may disturb proper operation of the reservoirs and enable fulfilling the assumed functions. According to the Water Framework Directive (2000) [7] the following actions are required in the field of surface water protection: prevention from deterioration of all water bodies, protection and enhancement of all artificial and heavily modified bodies of water in order to achieve good ecological potential and good surface water chemical status, protection and remediation of water bodies, etc. [3, 7]. Depending on the pollutant load flowing into the reservoir and its morphometry the dam reservoirs can capture up to several dozen per cent of the total amount of inflowing matter [17, 31, 32]. Small water reservoirs may also have a positive impact on intensification of self-purification of the flowing waters [5, 13, 28, 31, 32].

Only heavily polluted waters flowing into the small water reservoir can deteriorate the quality of the stored water [6, 31, 36, 37].

The aim of this paper is to analyze the impact of the small water reservoir Psurów on the quality and flows of the Prosna River flowing through the reservoir. The quality of water flowing into the reservoir, the outflowing water and water stored in the reservoir as well as flows of the Prosna River above and below the Psurów reservoir were analyzed.

METHODS

Psurów reservoir is located at 212.095 km of the Prosna River course in Olesno district, municipality of Radłów. It is one of nine small dam reservoirs in the Opolskie Voivodeship. The catchment in the dam section is 10.6 km^2. The reservoir was put into operation in 1996. The total capacity of the reservoir at the normal operational fill level is 63 000 m^3 and the fill area – 4.58 ha. The average depth of the reservoir is 1.38 m. Characteristic flows of the Prosna River in the reservoir section are the following: average annual flow – 0.042 m^3·s^{-1}, the lowest flow – 0.006 m^3·s^{-1}, average low flow – 0.013 m^3·s^{-1}. The main functions of the reservoir are: providing water for irrigation of arable land in the Prosna River valley, recreation and fishing [22, 32]. The reservoir catchment is used for agricultural purposes, including stock-farming.

The analyses of water flowing into the reservoir, water stored in the reservoir and the outflowing water were carried out from November 2006 to October 2008. Samples were collected in 3 sampling points once a month (except for January 2007 when the analyses were not made at all). The sampling point no 1 (P1) was located in the Prosna River about 300 m above its inlet to the reservoir. Sampling point no 2 (P2) was situated in the reservoir, at the dam, whereas point no 3 (P3) was at the outlet from the Psurów reservoir, 15 m below the dam (Fig. 1).

At the inlet and outlet of the reservoir water was collected from the mainstream at the subsurface layer of water. In the reservoir water was collected at the depth of 0.3 m under the water table. At all sampling points the following water parameters were determined: phosphates, nitrates, nitrites, ammonia, BOD_5, dissolved oxygen (DO), temperature, pH, electrolytic conductivity and total suspended solids (TSS). Additionally in the summer season 2007 and 2008 chlorophyll a was determined. Chlorophyll assay was made by the Voivodeship Inspectorate of Environmental Protection in Opole, according to PN-86/C-05560/02 standard. Water pH, electrolytic conductivity and temperature were measured *in situ*, whereas other water quality analyses were made in a laboratory according to Polish standards [10]. At the sampling points P1 and P3 water flow rate was measured.

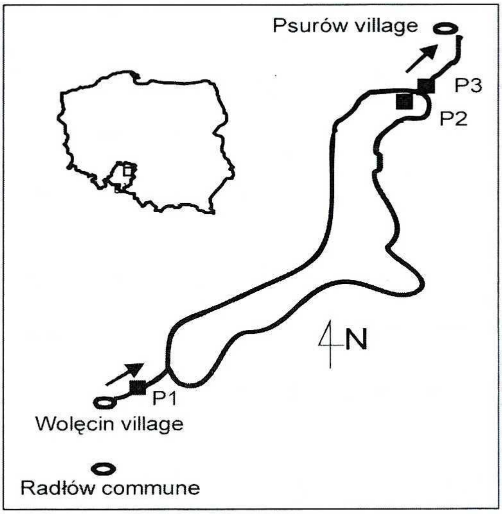


Fig. 1. Location of sampling points and the Psurów reservoir on the Prosna River:
P1 – the Prosna River – reservoir inflow, P2 – reservoir bowl, P3 – reservoir outflow

To assess differences among water quality indicators for water flowing into the reservoir, stored water and the outflowing water the STATISTICA software was used. All statistical analyses were preceded by the Shapiro and Wilk's W test for normality to check whether the analyzed variables were normally distributed [12].

The characteristics of physicochemical indicators and the impact of the reservoir on the quality of water flowing through the Psurów reservoir were determined for 2 hydrological years (1 November 2006 – 31 October 2008), for winter season (1 November – 30 April) and for summer season (1 May – 31 October).

A graphical comparison of the average values and deviations of phosphate, nitrate, ammonia, nitrite and TSS concentrations in water flowing into the reservoir (P1) and the outflowing water (P3) was presented.

To check the significance of differences between the average values of water quality indicators for water flowing into the reservoir and the stored water, as well as between the inflowing and outflowing water, a t-Student test was used for independent samples, at the significance level of $p < 0.05$. Hypotheses on the lack of statistically significant differences between the average values of the analyzed water quality indicators at particular sampling points were rejected.

Based on the average values of water quality indicators for the Prosna River flowing into and out of the Psurów reservoir, obtained in two research years and during hydrometric measurements made within two hydrological years, loads of pollutants [kg] flowing into and out of the reservoir were determined.

The potential risk of eutrophication of the Psurów reservoir was investigated. Therefore, calculations were made for the period of 2006–2008, based on the Vollenweider's criterion [30], in Benndorf's modification [2], taking into consideration the concentration of phosphates and inorganic nitrogen in the water flowing into the reservoir (P1).

The quality of the Prosna River at the reservoir inlet and outlet, as well as for the water stored in the reservoir was assessed according to the Ordinance establishing the way of classifying the state of uniform parts of surface waters [27]. The assessment of eutrophication of the analyzed water was presented and its sensitivity to such pollutants as nitrogen compounds from agricultural sources was assessed according to the Ordinance [26].

RESULTS AND DISCUSSION

Statistical characteristics of physicochemical parameters of water flowing into the Psurów reservoir, water stored in the reservoir and the outflowing water is presented in Table 1.

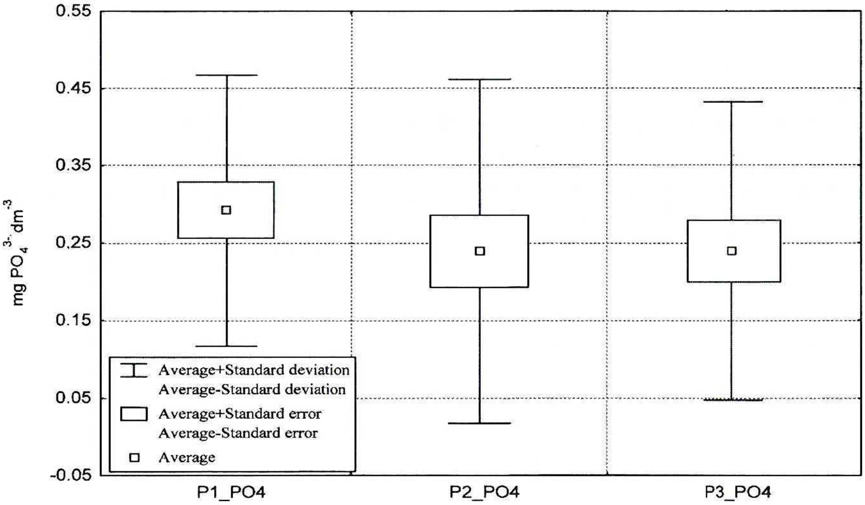
Table 1. Quality of water flowing into the Psurów reservoir (P1), water stored in the reservoir (P2) and the outflowing water (P3) in the period of November 2006 – October 2008

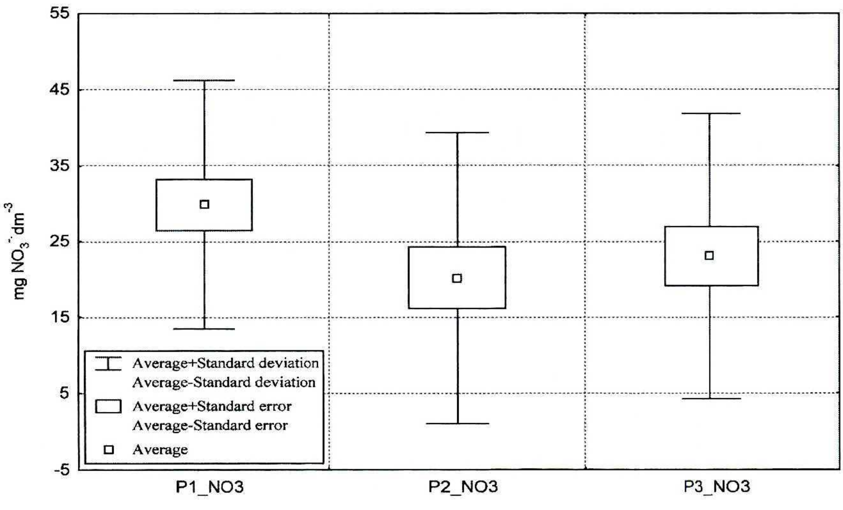
Index	Inflow to reservoir (P1)	Psurów reservoir (P2)	Outflow from reservoir (P3)
	minimum – maximum annual mean – winter mean – summer mean		
Phosphates [mg $PO_4^{3-}\cdot dm^{-3}$]	0.038–0.59 0.292–0.232–0.348	0.014–0.97 0.240–0.144–0.328	0.015–0.57 0.240–0.157–0.316
Nitrates mg $NO_3^{-}\cdot dm^{-3}$]	5.50–79.00 29.859–38.342–22.083	0.18–62.00 20.176–32.871–8.538	2.30–62.00 23.042–32.646–14.238
Nitrites [mg $NO_2^{-}\cdot dm^{-3}$]	0.01–0.43 0.165–0.177–0.154	0.003–0.36 0.145–0.184–0.111	0.029–0.30 0.154–0.181–0.129
Ammonia [mg $NH_4^{+}\cdot dm^{-3}$]	0.011–0.578 0.158–0.247–0.077	0.026–0.656 0.155–0.195–0.119	0.038–0.75 0.157–0.188–0.128
BOD_5 [mg $O_2\cdot dm^{-3}$]	1.00–4.00 1.267–1.126–1.429	1.00–10.00 3.486–1.966–4.571	1.00–7.00 2.732–1.887–4.00
DO [mg $O_2\cdot dm^{-3}$]	7.07–9.82 8.752–8.740–8.754	6.09–17.11 10.278–10.570–10.22	6.85–11.39 9.095–11.390–8.636
Temperature [°C]	2.00–16.50 9.695–6.17–12.633	1.30–24.30 12.223–5.550–17.783	1.30–23.80 11.750–5.540–16.925
Reaction – pH	6.90–8.60 7.572–7.542–7.600	6.90–9.80 8.131–7.798–8.408	6.90–9.30 7.990–7.880–8.091
Electrolytic conductivity [$\mu S\cdot cm^{-1}$]	298.00–393.00 359–365–353	269.00–375.00 342–348–337	270.00–388.00 342–343–341
TSS [$mg\cdot dm^{-3}$]	0.00–340.00 70.74–108.8–35.8	0.00–280.00 50.17–60.36–40.83	2.00–200.00 62.14–65.7–59.17

Table 1 shows that in the water flowing into the reservoir (P1) the highest annual average concentrations of the analyzed indicators were observed for: phosphates, nitrates, nitrites, ammonia, electrolytic conductivity and total suspended solids. For other water quality indicators such as BOD_5, dissolved oxygen, temperature, and pH the highest average annual concentrations were recorded for water stored in the reservoir (P2). In the outflowing water (P3) their concentrations were also higher than in the inflowing water.

From the analyses of the Prosna River flowing into the Psurów reservoir (P1) presented by Wiatkowski [32] it can be concluded that the highest average values of physicochemical parameters were recorded in the case of nitrates, phosphates, electrolytic conductivity and total suspended solids. Moreover, it can be noticed that at the sampling point located at the reservoir outlet (P3) the average concentrations of nitrates, ammonia, BOD_5 and water temperature were higher than at the sampling point P1 (reservoir inlet) [32].

Graphical comparison of average values and concentration ranges of phosphates, nitrates, ammonia, nitrites and TSS in the investigated waters from the Psurów reservoir area is presented in Figure 2.





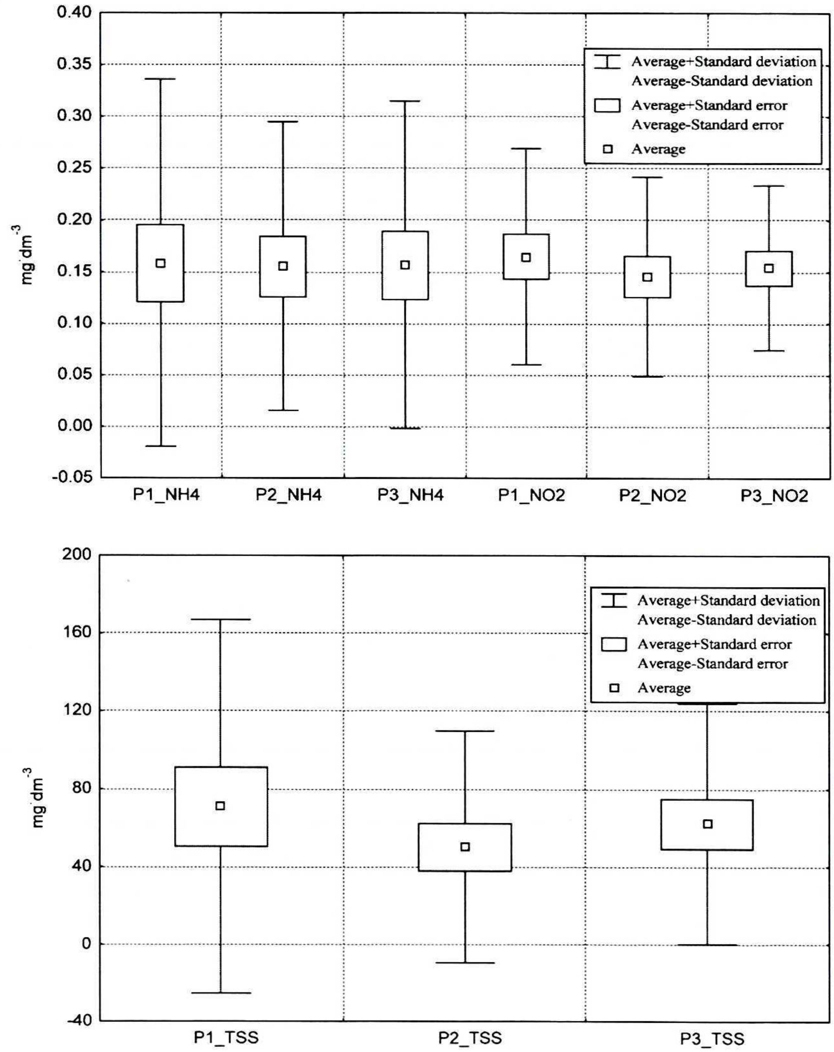


Fig. 2. Graphical comparison of average values and concentration of phosphates, nitrates, ammonia, nitrites and total suspended solids in water inflowing (P1) and outflowing (P3) from Psurów reservoir, and in storied water (P2)

Based on the above-mentioned graphical comparison it can be observed that the highest average concentrations were recorded at P1 for all water quality indicators, i.e. for nitrates, phosphates, ammonia, nitrites and total suspended solids. The higher average of nitrates, phosphates and nitrites corresponded with the lower variability of results, i.e. lower values of standard deviation. In the case of ammonia and total suspended solids the higher average corresponded with the higher value of the standard deviation, which indicates higher variability of results.

Concentrations of phosphates in the water flowing into the Psurów reservoir varied from 0.038 to 0.59 mg PO_4^{3-}·dm^{-3}, whereas in the outflowing water – from 0.015 to 0.57

mg $PO_4^{3-} \cdot dm^{-3}$ (Fig. 3). The highest concentrations of this substance in water at P1 sampling point were observed in June 2007 and at P2 – in June 2008. This might be associated with the removal of this element from arable lands during rainfall or with pouring manure onto the fields.

In the analyzed period the concentrations of nitrates in the inflowing water ranged from 5.50 to 79.0 mg $NO_3^- \cdot dm^{-3}$ and in the outflowing water – from 2.30 to 62.0 mg $NO_3^- \cdot dm^{-3}$. The highest values for nitrates at all sampling points (P1, P2 and P3) were recorded in winter months (March 2007 and 2008), whereas the lowest ones were observed in summer, during the vegetation period (July, August 2007, August 2008) [35] – Figure 4.

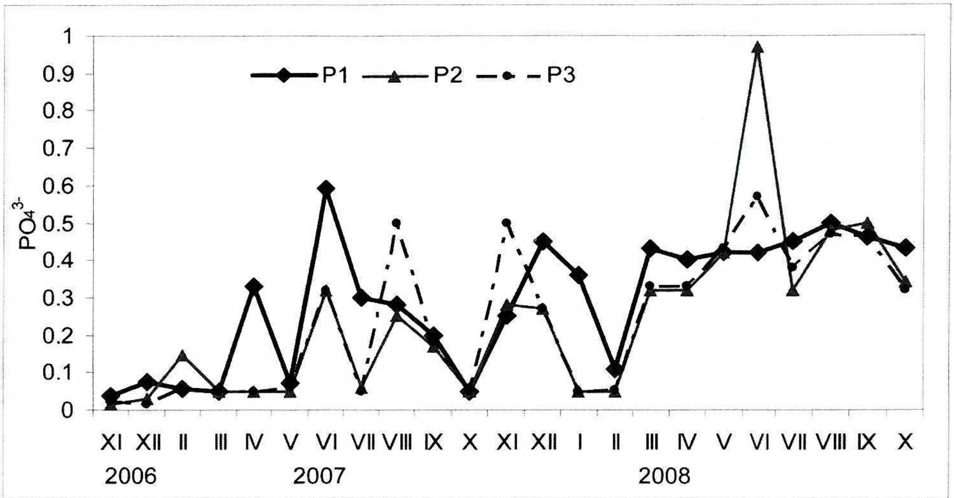


Fig. 3. Changes in concentrations of phosphates in the water flowing into the Psurów reservoir (P1), water stored in the reservoir (P2) and in the outflowing water (P3) in the period of November 2006 – October 2008

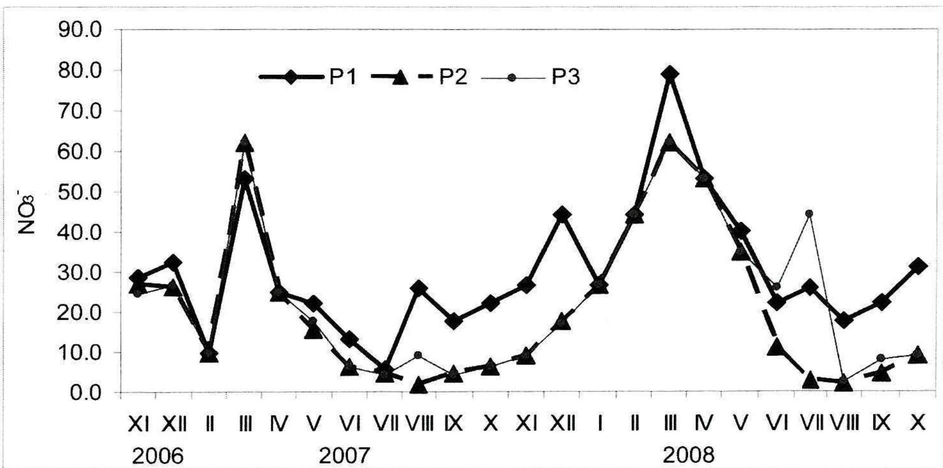


Fig. 4. Changes in concentrations of nitrates in the water flowing into the Psurów reservoir (P1), water stored in the reservoir (P2) and in the outflowing water (P3) in the period of November 2006 – October 2008

As far as other water quality indicators are concerned, i.e. nitrites, ammonia, electrolytic conductivity and the total suspended solids, it was observed that the highest concentrations at all sampling points were recorded in winter months (Tab. 1). The highest concentrations of BOD_5, water temperature and pH in the Prosna River flowing into the reservoir, water stored in the reservoir and the outflowing water were observed in summer months. In the case of dissolved oxygen the highest values in the inflowing water were recorded in summer, whereas at other sampling points – in winter.

The concentration of chlorophyll a in the water of the Psurów reservoir in 2007 varied from 15.8 $\mu g \cdot dm^{-3}$ (18.07.2007) to 279.7 $\mu g \cdot dm^{-3}$ (29.08.2007), whereas in 2008 it ranged from 39.0 $\mu g \cdot dm^{-3}$ (06.07.2008) to 66.0 $\mu g \cdot dm^{-3}$ (27.08.2007).

Out of 10 water quality indicators analyzed in the Psurów reservoir 8 (except for phosphates and nitrites) are taken into consideration in the water quality classification [27].

The analysis of the water quality of the Prosna River flowing into the reservoir (P1) and the water flowing out of the Psurów reservoir (P3) showed that the values of $N\text{-}NH_4^+$, BOD_5, water temperature, DO, electrolytic conductivity and water pH did not exceed the limit values of water quality indicators for uniform parts of surface waters in natural watercourses, such as rivers defined for class I. However, concentrations of $N\text{-}NO_3^-$ and the TSS exceeded the limit values of water quality indicators for uniform parts of surface waters in natural watercourses, such as rivers defined for class II [27]. The analysis of water stored in the Psurów reservoir (P2) showed that the values of chlorophyll a did not exceed the limit values of water quality indicators for uniform parts of surface waters in natural watercourses, such as lakes and other natural water reservoirs defined for class I [27].

The waters of the Prosna River flowing into and out of the Psurów reservoir were considered as euthrophic. At these sampling points the average annual concentration of nitrates exceeded the limit value (10 mg $NO_3 \cdot dm^{-3}$) of this indicator defined in the Ordinance [26]. A similar situation was in the case of chlorophyll a, the limit value of which – defined in the same Ordinance – was 25 $\mu g \cdot dm^{-3}$. Moreover, the water quality analysis of the Psurów reservoir carried out in 2007 showed that the limit values of chlorophyll a were exceeded more than tenfold.

It was found out that the investigated waters were vulnerable to pollution by nitrogen compounds coming from agricultural sources because the average annual concentrations of nitrates were higher than the one recommended in the Ordinance (50 mg $NO_3^- \cdot dm^{-3}$) [26].

The analysis of hydrometric parameters showed that in the period of 2006–2008 water flow rate at P1 sampling point ranged from 0.003–0.096 $m^3 \cdot s^{-1}$. The lowest water inflow was recorded in May 2007 and the highest in March 2007. At the sampling point P3 the water flow rate varied from 0.001–0.110 $m^3 \cdot s^{-1}$. The lowest outflow was observed in June 2007 and the highest one in March 2007. The average values of the water flow rate in the investigated period were: 0.029 $m^3 \cdot s^{-1}$ (P1) and 0.028 $m^3 \cdot s^{-1}$ (P3), respectively. This may be associated with the decrease of water resources in the reservoir catchment in comparison with the multi-year values determined empirically in the study [22]. The average annual discharge (SSQ) for the Psurów reservoir cited in the study was 0.042 $m^3 \cdot s^{-1}$.

The analysis of the relationship between the volume of water flowing into the reservoir (P1) and the water flowing out of the Psurów reservoir (P3), Pearson's correlation coefficient ($r = 0.93$) and a linear regression equation were calculated: P3 = -0.0043 +

1.1072·P1, the parameters of which were determined in such a way as to minimize the sum of deviation squares. Between P3 and P1 a very high correlation was observed ($0.7 < r < 1.0$). This correlation is statistically significant at the significance level $p < 0.05$.

Among many factors having an impact on the reservoir environment the time required for a total exchange of water (i.e. water retention time) seems to be of great importance. It not only determines the hydrological state of the reservoir but also – together with the water mixing intensity – has an impact on the matter cycle in the reservoir, its trophy and the quality of the reservoir water [1].

The average retention time in the Psurów reservoir was assessed using the ratio of the reservoir capacity and the volume of water flowing into the reservoir (determined in the investigated period) [33]. The average water retention time in the Psurów reservoir in the analyzed period was 25 days. According to Wiatkowski *et al.* [31] the retention time in small dam reservoirs varies from more than one to several dozen days.

Based on the two-years' research period the average loads of selected water quality indicators for the Prosna River water flowing into the Psurów reservoir and the outflowing water were calculated (Tab. 2).

Table 2. Changes in loads of phosphates, nitrates, nitrites, ammonia and total suspended solids [$kg·d^{-1}$] at sampling points P1 and P3 in the period of November 2006 – October 2008

Index	Inflow to reservoir (P1)	Outflow from reservoir (P3)
	mean – winter – summer	
Phosphates [kg $P\text{-}PO_4^{3-}$]	0.236–0.282–0.149	0.186–0.196–0.107
Nitrates [kg $N\text{-}NO_3^-$]	17.036–33.038–6.706	12.610–28.80–3.421
Nitrites [kg $N\text{-}NO_2^-$]	0.126–0.205–0.062	0.114–0.215–0.042
Ammonia [kg $N\text{-}NH_4^+$]	0.311–0.733–0.080	0.295–0.570–0.106
TSS [kg]	178.74–415.26–48.19	148.27–247.56–62.96

Table 2 shows that after the flow of the Prosna River through the Psurów reservoir loads of pollutants decreased (phosphates by about 21%, nitrates by 26%, nitrites by 9%, ammonia by 5% and the total suspended solids by 17%). Such a significant decrease can be contributed to the absorption by primary producers (phytoplankton, macrophytes) and deposition in bottom sediments. The greatest decrease of nitrates and nitrites was observed in summer months (by about 50% and 32%, respectively), in the middle of water plant vegetation period. In the summer period (July and August) water blooms appeared in the Psurów reservoir, which rapidly and intensively decreased the concentrations of various forms of nitrogen. A similar situation was in the case of phosphate load reduction in the summer period (about 28%).

As far as the ammonia is concerned, its load in the water flowing out of the reservoir in comparison with the inflowing water increased in the summer season by 32% (from 0.080 $kg·d^{-1}$ to 0.106 $kg·d^{-1}$). In the outflowing water, if compared with the inflowing water a slight increase of nitrites was observed in the winter season (by about 5%) (Tab. 2).

In the case of total suspended solids a significant reduction (40%) was recorded in winter, whereas in summer it increased by about 30%.

Research carried out by Miernik described in [18] and carried out on a small reservoir Górny Młyn, near Końskie, in the Czysta River showed that in the water flowing out of this reservoir – in comparison to the inflowing water – the average loads of BZT_5, phosphates, ammonium nitrogen, nitrite nitrogen and nitrate nitrogen were lower by 9%, 51%, 99%, 68% and 81%, respectively. Similarly, the research carried out by Skonieczek and Koc [28] indicated that the small water reservoir (pond) effectively lowered phosphorus concentrations and phosphorus loads in the water of the Sząbruk watercourse flowing through this pond. Generally, within the year loads of total phosphorus were reduced by 58% and phosphates $P\text{-}PO_4^{3-}$ by 60%.

In order to investigate the risk of eutrophication of the Psurów reservoir calculations were made for the period of 2006–2008. In Benndorf's modification [2], following the Vollenweider's criterion [30] and taking into consideration the fact that the phosphate concentration in the reservoir cross-section is 0.292 mg $PO_4^{3-} \cdot dm^{-3}$ (Tab. 1), it was found out that the amount of phosphorus per 1 m^2 of the reservoir is 1.86 g $P\text{-}PO_4 \cdot m^{-2} \cdot a^{-1}$ at the ratio of average reservoir's depth – 1.3 m to the retention time – 0.069 a. The load of inorganic nitrogen per 1 m^2 of the reservoir is 138 g $N \cdot m^{2} \cdot a^{-1}$ According to Kajak [11] the real loads are usually much higher than the dangerous ones. They may reach up to more than ten grams of phosphorus and almost 200 g of nitrogen annually per 1 m^2 of the reservoir's surface. This exceeds hundred times the dangerous loads level for reservoirs of the depth up to 5 m (2.0 g $N \cdot m^{-2} \cdot a^{-1}$ and 0.13 g $P \cdot m^{-2} \cdot a^{-1}$). Therefore, the Psurów reservoir was classified for polytrophic reservoirs. The calculations, however, referred only to phosphorus and nitrogen supplied by inflows, the direct catchment or internal load from sediments were not taken into consideration.

In order to determine differences between average values of water quality indicators for the inflowing water (P1) and water stored in the Psurów reservoir (P2), and between inflowing (P1) and outflowing water (P3), a t-Student test for independent samples was used, at the significance level $p < 0.05$. In Table 3 statistical significance of the differences in the analyzed physicochemical indicators for the inflowing water, water stored in the Psurów reservoir and the outflowing water was presented.

Table 3. Statistical significance of the analyzed water quality indicators for the inflowing (P1) and stored water (P2), and for the inflowing (P1) and outflowing water (P3) in the period of November 2006 – October 2008; significance level marked with bold; NS – statistically insignificant difference, tn – t-Student test for independent samples

Indicator		Statistical significance of the difference ($p < 0.05$)	
		Inflow to reservoir (P1)	Inflow to reservoir (P1)
		Reservoir (P2)	Outflow from reservoir (P3)
Phosphates [mg $PO_4^{3-} \cdot dm^{-3}$]	Year	NS (tn)	NS (tn)
	Winter	$p < 0.05$ (tn)	NS (tn)
	Summer	NS (tn)	NS (tn)
Nitrates [mg $NO_3^{-} \cdot dm^{-3}$]	Year	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Winter	NS (tn)	NS (tn)
	Summer	$p < 0.05$ (tn)	$p < 0.05$ (tn)

Nitrites [mg $NO_2^{-}\cdot dm^{-3}$]	Year	NS (tn)	NS (tn)
	Winter	NS (tn)	NS (tn)
	Summer	NS (tn)	NS (tn)
Ammonia [mg $NH_4^{+}\cdot dm^{-3}$]	Year	NS (tn)	NS (tn)
	Winter	NS (tn)	NS (tn)
	Summer	NS (tn)	NS (tn)
BOD_5 [mg $O_2\cdot dm^{-3}$]	Year	$p < 0.05$ (tn)	NS (tn)
	Winter	NS (tn)	NS (tn)
	Summer	$p < 0.05$ (tn)	$p < 0.05$ (tn)
DO [mg $O_2\cdot dm^{-3}$]	Year	NS (tn)	NS (tn)
	Winter	NS (tn)	NS (tn)
	Summer	NS (tn)	NS (tn)
Temperature [°C]	Year	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Winter	NS (tn)	NS (tn)
	Summer	$p < 0.05$ (tn)	$p < 0.05$ (tn)
Reaction – pH	Year	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Winter	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Summer	$p < 0.05$ (tn)	$p < 0.05$ (tn)
Electrolytic conductivity [$\mu S\cdot cm^{-1}$]	Year	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Winter	$p < 0.05$ (tn)	$p < 0.05$ (tn)
	Summer	$p < 0.05$ (tn)	NS (tn)
TSS [$mg\cdot dm^{-3}$]	Year	NS (tn)	NS (tn)
	Winter	NS (tn)	NS (tn)
	Summer	NS (tn)	NS (tn)

Between the reservoir inlet (P1) and the reservoir bowl (P2) statistically significant differences were observed ($p < 0.05$) in a one year research period for five water quality indicators: nitrates, $BOD_{5,}$ water temperature, pH and electrolytic conductivity. For phosphates statistically significant differences were recorded in winter between the inflowing water and the water stored in the reservoir. Statistically insignificant differences were observed for nitrites, ammonia, dissolved oxygen and the total suspended solids ($p > 0.05$).

As far as the inlet (P1) and outlet of the reservoir (P3) are concerned statistically significant differences ($p < 0.05$) in a one year research period were observed for the following water quality indicators: nitrates, temperature, pH and electrolytic conductivity.

For BOD_5 statistically significant differences between the water flowing into the reservoir and the outflowing water were observed in summer months. Statistically insignificant differences were recorded for phosphates, nitrites, ammonia, dissolve oxygen and total suspended solids ($p > 0.05$).

CONCLUSIONS

The results obtained during the two years' research on the impact of the small water reservoir Psurów on the quality and flows of the Prosna River allow to draw the following conclusions:

– the reservoir contributed to the reduction concentrations of phosphates, nitrates, nitrites, ammonia as well as electrolytic conductivity and total suspended solids in the water flowing out of the Psurów reservoir (P3), if compared with the inflowing water (P1). In the case of other water quality indicators their increased values were recorded at the reservoir outlet;

- loads of phosphates, nitrates, nitrites, ammonia and total suspended solids discharged from the reservoir were lower than the inflowing ones;
- both in the water flowing into the Psurów reservoir and the outflowing water higher concentrations of mineral nitrogen, electrolytic conductivity and total suspended solids were recorded in winter. In the summer season higher concentrations of phosphates, BOD_5 and higher values of temperature and water pH were observed;
- the investigated waters belong to the II class of water purity due to the content of $N\text{-}NO_3^-$, total suspended solids and chlorophyll a, and they are vulnerable to pollution by nitrogen compounds coming from agricultural sources;
- taking into consideration the Vollenweider's criterion the Psurów reservoir was classified to polytrophic reservoirs;
- between P1 and P3 sampling points significant differences were observed for nitrates, water temperature, pH and electrolytic conductivity. No significant differences were recorded in the case of other water quality indicators;
- the Psurów reservoir compensated flows of the Prosna River. A high correlation was observed between the volume of water flowing out of the Psurów reservoir (P3) and the volume of the inflowing water (P1).

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Received: February 16, 2010; accepted: May 7, 2010

WPŁYW MAŁEGO ZBIORNIKA WODNEGO PSURÓW NA JAKOŚĆ WODY I PRZEPŁYWY W RZECE PROŚNIE

Praca dotyczy małego zbiornika wodnego Psurów zlokalizowanego na rzece Prośnie (prawostronny dopływ rzeki Warty) w województwie opolskim (południowa Polska). W pracy przedstawiono wyniki badań jakości wody rzeki Prosny dopływającej i odpływającej ze zbiornika oraz wody retencjonowanej w zbiorniku. Wykonano także analizę przepływów rzeki Prosny powyżej i poniżej zbiornika Psurów. Badania wykonano w okresie od listopada 2006 do października 2008 r. Pomiarami objęto następujące wskaźniki jakości wody: PO_4^{3-}, NO_3^-, NO_2^-, NH_4^+, BZT_5, tlen rozpuszczony, temperaturę wody, odczyn wody, przewodność elektrolityczną, zawiesinę ogólną i chlorofil a, dla których obliczono podstawowe statystyki opisowe. Wyniki badań wykazały, że mały zbiornik wodny Psurów redukował ładunki fosforanów (średnio o 21%), azotanów (o 26%), azotynów (o 9%), amoniaku (o 5%) i zawiesiny ogólnej (o 17%). Stwierdzono, że między objętością wody odpływającej ze zbiornika Psurów a objętością wody dopływającej do zbiornika istnieje wysoka zależność ($r = 0,93$), istotna statystycznie na poziomie $p < 0,05$. Na podstawie kryterium Vollenweidera zbiornik Psurów zakwalifikowano do zbiorników politroficznych.