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Seasonal changes in quality and trophic state of surface water in a small retention reservoir

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ABSTRACT

The aim of this study was to identify the water quality of a small reservoir, including its trophic state subjected to anthropogenic influences and its impact on river water quality. The study was carried out on reservoir water sampled from five points, in four quarters of the hydrological year. The following determinations were carried out: turbidity, true colour, electrolytic conductivity, pH, concentrations of ammonia nitrogen, nitrate and nitrite, organic nitrogen and phosphate as well as total phosphorus. The nature of the trophic state of the 'Turośń' reservoir was determined in accordance with the table on the trophic state index according to Carlson. Significant seasonal variations were found in the turbidity and true colour of the reservoir water tested, and to a lesser extent – in conductivity and pH values. These parameters were influenced by the location of water sampling. Elevated concentrations of ammonium ions in reservoir water, occurred in autumn and depended on the sampling point and were higher in outflowing water than in inflowing water. Significant seasonal variations occurred in the concentrations of oxidised forms of nitrogen ($N\text{-}NO_3$ and $N\text{-}NO_2$) and organic nitrogen. The highest concentrations of nitrate and organic nitrogen occurred in winter and nitrite in autumn. The reservoir had a positive effect on the concentrations of both forms of nitrogen, which was reflected in their concentrations in the water leaving the reservoir and, in the case of organic nitrogen, an inverse relationship was noted. Phosphate concentrations were highest in the water sampled in summer and total phosphorus in autumn. In the samples from the other quarters of the hydrological year, the concentrations of both forms of phosphorus were lower. Phosphate concentrations varied little between sampling points, and for total phosphorus there was considerable variation across the reservoir water sampling points. Some phosphate and total phosphorus were retained in the reservoir during the study period. Due to the concentration of nitrogen, the water in the Turośń Reservoir can be predominantly classified as eutrophic. Taking into account total phosphorus, on the basis of the obtained test results, waters in winter and summer are defined as oligotrophic, while in spring and autumn they corresponded to the values characterising a mesotrophic state. A number of factors could have contributed to the increasing eutrophication of the water in the studied reservoir. The construction of the reservoir itself undoubtedly affects the value of the indices in question. The shallow depth of the hydro-technical facility results in a more rapid development of eutrophication. Accumulation of various substances is ideal for aquatic organisms, which use them as nutrients, thus increasing the risk of eutrophication. The degradation of the small retention reservoir is also attributed to growing transport, tourism and recreation, continuous climate change, pollution of agricultural origin and disordered sewage management.

Keywords: trophic state index, biogenic compounds, small retention reservoir.

INTRODUCTION

Surface water are the most important source available water found in nature (Łubkowska, 2016). In addition to rivers and lakes, this group also includes water reservoirs known as retention reservoirs or retention ponds, which significantly improve, but still maintain the correct water balance within hydrological catchments (Mioduszewski, 2015, Siemieniuk et al., 2017). A characteristic feature is their shallow depth and relatively small surface area (Ostrowska, Sałdak, 2015). They are built as a result of the damming of river water and are constructed in the areas favourable to the location of the damming structure. River valleys are the optimal location for this type of hydrotechnical facilities (Rzętała, 2008). They are anthropogenic reservoirs characterised by frequent and large water level changes. They are often described as dam lakes. Due to their type and location, dammed reservoirs are divided into mountain and lowland reservoirs. Dam reservoirs are created as a result of human activity. They play an important role in the environment and their great economic importance is known worldwide. The positive aspect of the presence of such reservoirs is the enhancement of the landscape and the ecosystem surrounding them. The concept of dam reservoirs is based on the prevention of water deficits. The water stored by hydrological objects is used for a wide range of industrial, tourism and recreational purposes, as well as supporting agriculture and energy (Jankowski, 2017).

One of the main reason for creating retention reservoirs is flood protection. The water of these reservoirs are largely intended to meet consumer needs. The benefit for agriculture and forestry is the possibility of irrigating fields, meadows or forest areas, especially in the periods of drought with water from dam reservoirs. These reservoirs are largely intended to meet consumption needs. The benefit for agriculture and forestry is the possibility of irrigating fields, meadows or forest areas, especially in periods of drought with water from dam reservoirs (Jaguś, 2018). Reservoir water contains mineral and organic compounds of both natural and anthropogenic origin. These components enter the water, as it circulates and moves through the environment, and their concentration depends on the origin of the water. Thus, they may be present in trace or significant quantities (Adamczyk and Jachimowski, 2013, Aspin et al., 2020).

The natural factors that adversely affect dam reservoirs are long-lasting and often extreme climatic phenomena. These include earthquakes, tornadoes, violent storms and downpours. Strong fluctuations in water levels and the dynamics of oscillations or vibrations of water impacts also determine the proper maintenance of these reservoirs. Another very serious threat is the enrichment of reservoirs with nutrients, flowing in from agricultural areas, wastewater treatment plants or urbanised areas. The phosphorus and nitrogen compounds that are present in predominant concentrations often have a negative impact on the aesthetic qualities of the water in the reservoir and lead to massive phytoplankton blooms, thus reducing the possibility of using the retention water for various purposes (Jaguś, 2011).

The trophic state is based on the analysis of physico-chemical properties and determines the condition of surface water. Indicators, such as electrolytic conductivity, pH, turbidity, nutrient concentration and many others are taken into account in assessing the trophic status of water (Kociołek-Balawejder and Stanisławska, 2012, Siemieniuk and Szatyłowicz, 2014). The Carlson index, also known as the trophic state index, is also used to determine the degree of intensity of eutrophication phenomena in freshwater ecosystems (Jodłowski and Gutowska, 2012).

The aim of this study was to determine the water quality of a small reservoir including its trophic state subjected to anthropogenic influences and impacts on river water quality.

STUDY AREA AND METHODOLOGY

Reservoir characteristics

The study was based on water samples taken from the small reservoir "Turośń" located in north-eastern Poland. The "Turośń" dam reservoir is a fairly modern facility, commissioned in 2014. It is located in the valley of the Turośnianka River. "Turośń" as an artificial water reservoir is an investment created as a part of the development of so-called "small retention". An ecosystem such as a small retention pond initiates the creation of a certain system that triggers numerous reactions leading to a maximally achievable ecological balance.

The reservoir measures 1000 m long and 82 m wide. The area of the reservoir is 11 ha and the catchment area is 94.5 km^2. The reservoir has a depth of 2.5 m and a capacity of 94.5 m^3. In hydrographical terms, the municipality of Turośń Kościelna, where the reservoir is located, forms the buffer zone of the Narew National Park. The area of the commune is located in the catchment area of the Narew River, which is the central point of surface water run-off. The hydrographical network consists of the following rivers: Turośnianka, Narew and Czaplinianka-Niewodnica including their tributaries. The catchment soil typology is quite diverse. Sandy soils, pseudo-loamy soils, brown soils and chernozem prevail here. Pseudo-polylic soils are most characteristic of the municipality southern region, while the northern and central parts are characterised by sandy soils of different genetic types. Arable land, including: cropland, grassland, meadows, pastures, occupies as much as 8928 ha, which indicates 63.6% of the total area (Kasperowicz, 2017). The Turośń hydro-technical facility is designed to perform specific functions, which include: maintaining the best possible surface water quality class by improving its purity, increasing the attractiveness of the municipality area by improving landscape values, improving the microclimate in the vicinity of the reservoir, preventing water erosion, increasing the economic activation of the municipality, ensuring environmental protection and safety, as well as fire protection and supporting the agricultural needs with retention water (irrigation of agricultural land). The creation of an open water surface characterised by a sizable area has resulted in ideal conditions for restoring the ecological balance of the ecosystem. With the adaptation of the reservoir in the landscape, many new plant and animal species have appeared (Marszałek, 2009).

Research methodology

The water from the reservoir was sampled in four quarters of the hydrological year 2022/23 (autumn, winter, spring, summer). Five sampling points were set on the reservoir in order of the direction of water flow through it (Figure 1).

The sampling points were positioned to be characteristic of the development type in the reservoir catchment area. The first point was located at the inflow of water into the reservoir from the river. Points two, three and four were located within residential buildings, farms and fishing sites, and point five was located at the reservoir outflow. The water samples for testing were taken once a month from a depth of up to 25 cm from each point and the average sample consisted of 6 individual samples. The following were determined in the samples: turbidity, true colour, electrolytic conductivity, pH, concentration of ammonia nitrogen, nitrate nitrogen and nitrite nitrogen, organic nitrogen, phosphates, and total phosphorus. The turbidity of the sampled water was measured using the nephelometric technique with a TURB 550 IR turbidimeter. True and apparent colours were determined spectrophotometrically (Dojlido 1995) using a HACH DR/4000 spectrophotometer. The specific electrolytic conductivity and pH value was determined using an InoLab Multi 9430 IDS digital multifunction meter. Ammonium nitrogen was determined by the direct nesslerisation method, nitrate nitrogen and nitrite nitrogen was measured after the addition of appropriate reagents using a HACH DR/4000 V spectrophotometer. Organic nitrogen was determined using the Kjeldahl's method, which involves mineralising nitrogenous organic compounds in concentrated sulphuric acid (VI) and perhydrol at high temperature and measuring the absorbance on the above-mentioned spectrophotometer. Phosphate and total phosphorus concentrations were also determined after prior mineralisation in sulphuric acid. Absorbance was measured on a HACH DR/4000 V. The results of the nitrogen and phosphorus concentrations were used to calculate the Carlson Index, and TSI was used to assess the trophic status of water in detail (Jodłowski, Gutkowska 2012). The value range is from 0 to 100, and results are given as averages for each study point and each year quarter.

Statistical analysis of obtained test results

The obtained tests results were evaluated by applying statistical analysis using the STATISTICA version 12 computer programme. For this purpose, an analysis of variance – two-factor classification

Figure 1. Location of water sampling points

ANOVA (ANalysis Of VAriance) was used to compare several populations. This is a technique for examining outcomes (dependent or explanatory variables) that depend on the factors at work (grouping or classification factor). It was tested whether the factors analysed have an effect on the observed results. The aim was to test the significance of differences in population means. Non-parametric Kruskal-Wallis tests were used to assess the significance of differences between the groups, at a significance level of $p=0.05$. Multiple comparison procedures were then used - post-hoc tests to see which of the means differ and which are equal. These are based on comparing the differences between pairs of sample means with the size of the least significant difference (NIR). Of the many tests, the Tukey HSD test was chosen as the most popular and recommended for comparing pairs of means. The following relationships were considered: (1) analysis of the values of individual water quality parameters of the reservoir depending on the sampling date, (2) demonstration of differences in the values of water quality parameters depending on the sampling point located in the studied reservoir.

RESEARCH RESULTS AND DISCUSSION

Surface water turbidity is a result of the presence of fine clay and sand particles or dispersed organic substances of plant, animal origin, humic substances, and plankton (Gomółka and Szaynok, 1997). This optical property is based on the scattering and absorption of part of the visible radiation spectrum by dispersed particles present in the water. The turbidity value of the water samples taken from the reservoir differed in seasons (Figure 2).

The highest value of turbidity was determined in water sampled in the summer season and was significantly higher compared to the other quarters. Water turbidity was influenced by the point of water abstraction and the highest average turbidity values occurred at point four during winter and summer. At the other points, the value of this parameter was significantly lower, with the exception of the summer period. Changes in the turbidity of the reservoir water result from the type of its sub-catchments, which is indicated by the data from the summer period in the central part of the reservoir. In addition, precipitation and a given season of the year play an important role, because turbidity varies from season to season (Szczykowska and Siemieniuk, 2011).

Seasonal changes in the true colour values of reservoir water are shown in Figure 3. The colour of the water was variable depending on the sampling date and its lowest value was found in winter and significantly higher in spring and summer, which may be due to the increase in intensified use of the reservoir (fishing and recreation) during these quarters.

Some variation in values of these water parameters can be seen at the sampling points. The smallest values were found at the inflow of water into the reservoir, and higher values in the middle part of the reservoir. Colour is caused by the presence of substances that form non-ideal solutions, characterised by a high degree of dispersion (Szczykowska and Siemieniuk, 2011). In the case of surface waters, the content of humic substances, manganese compounds and iron compounds are responsible for the true colour (Dojlido, 1995). The high true colour increase during the summer period is due, to a greater extent, to the presence of a large amount of phytoplankton and more intensive mixing of the

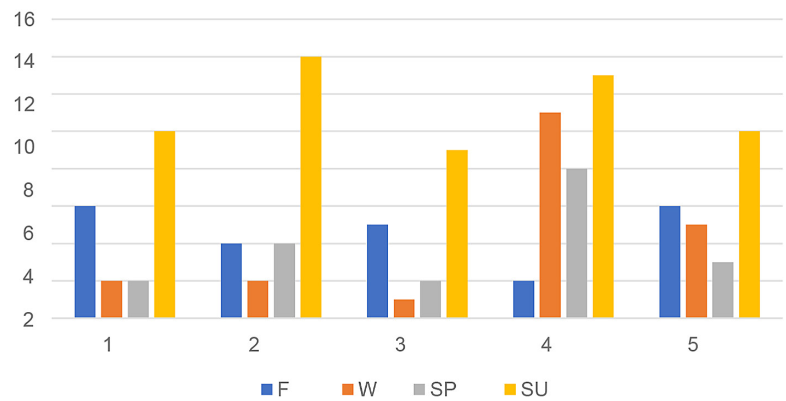

Figure 2. Turbidity of water in 'Turośń' reservoir in NTU (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

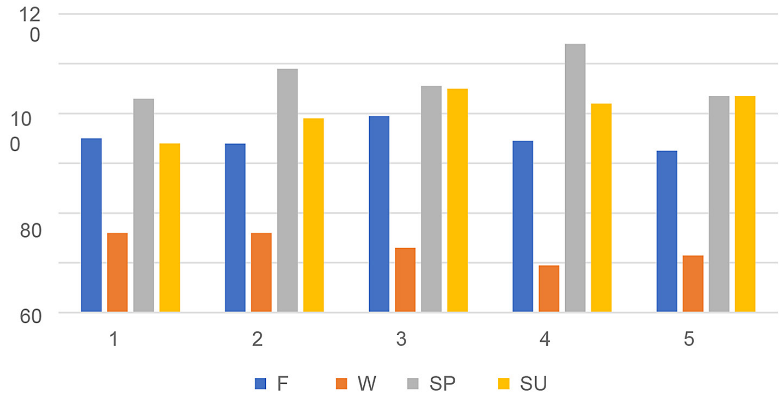

Figure 3. True colour value in mg Pt/dm³ (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

waters of the shallow reservoir than during the other periods, and this may have led to an increase in the value of this parameter. The measurement of electrolytic conductivity allows determining the mineral content of the test water and, in addition to this, it is possible to determine what concentration of dissolved ions is present in the water (Figure 4). This parameter determines the degree of salinity in a given water body (Dojlido 1995). During the other quarters, it was higher by nearly 150 μ S/cm and similar with respect to each other. There were no significant differences for this parameter between the study points. The results obtained are characteristic of Class I surface waters according to the Regulation of the Minister for Maritime Affairs and Inland Navigation (Rozporządzenie Ministra Gospodarki Morskiej i Żeglugi Śródlądowej, 2019) and the determinations of this parameter did not exceed 1000 μS/cm.

Most surface water types have an alkaline reaction, which is due, among other things, to increased photosynthesis (Gomółka and Szaynok, 1997). Assimilative processes, which occur very intensively at this time of year, are responsible for the highest pH values in summer, and then the pH increases markedly, even within the pH=10 range (Szczykowska and Siemieniuk, 2011). In addition to this, it is worth pointing out that the pH value increases with increasing temperature, which is reflected in the test results obtained (Figure 5). In the spring and summer months, the pH value of the tested reservoir water was close to 9, while in the autumn and winter months it was significantly lower, the difference being almost a unit, and the difference was statistically proven. No significant differences of this parameter were noticed in the water from the various points. According to the limit values included in the Regulation of the Minister of Maritime Affairs and Inland Navigation of 11 October 2019, the obtained results of the pH of the water from Turośń reservoir can be classified as second class.

Concentrations of ammonium nitrogen in the studied water were low and did not exceed 0.5 mg $N\text{-}NH_4^+/dm^3$ (Figure 6). It was varied in the sampling points, and the water from the fourth point was distinguished by an increased concentration of this form of nitrogen in comparison with the water

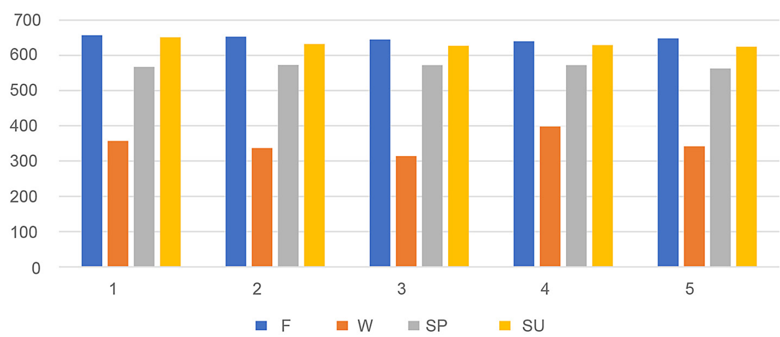

Figure 4. Conductivity value of reservoir water in μS/cm (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

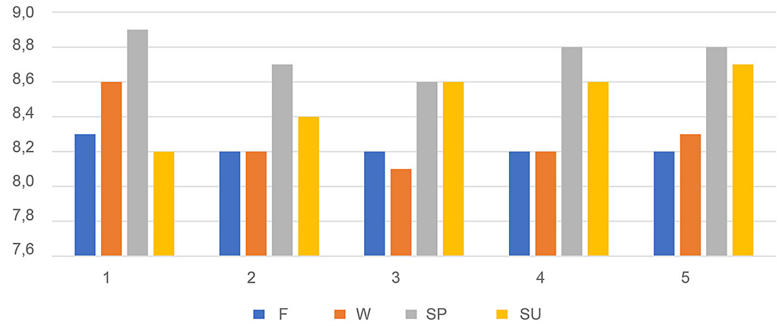

Figure 5. pH value of reservoir water (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

samples from the other points. Ammonium form concentrations were subject to seasonal variations. The highest was recorded in autumn and the lowest in winter and these were statistically proven differences. Ammonium nitrogen in surface water may originate from the biochemical decomposition of organic nitrogenous compounds of plants or animals, and its presence in water may also be caused by discharges of municipal or industrial wastewater, as indicated by the concentration of this form of nitrogen in the autumn period in the water of the studied reservoir. Elevated amounts of ammonium nitrogen are inadvisable in usable waters, as high levels of ammonium nitrogen may pose a risk especially in municipal water use (Dojlido, 1995). This form of nitrogen is very well absorbed by autotrophs and is a potential food source for phytoplankton (Adamczyk and Jachimowski, 2013). Large amounts of ammonium ions, this means a few to several or more mg $N\text{-}NH_4^+/dm^3$, present in surface waters usually indicate pollution by domestic or industrial effluents and may originate from decomposition processes of water-dwelling vegetation. The water from the middle part of the reservoir contained higher amounts of ammonium nitrogen than the water entering the reservoir. The reservoir had a negative effect on the concentration of this form of nitrogen, particularly in autumn, as evidenced by the results of water flowing out of the reservoir. The analysed waters should be classified as out-of-class waters due to this parameter (Rozporządzenie Ministra Gospodarki Morskiej i Żeglugi Śródlądowej 2019).

During the study period, significantly higher nitrate concentrations were found in winter and lower in autumn (Figure 7). This is due to the inflow of nitrates to the surface water during the so-called dead period with reduced temperatures from the areas bordering the surveyed reservoir. In addition, the development of plankton and aquatic vegetation is limited and this results in a lack of nitrate uptake, as pointed out by Czaplicka-Kotas (2012). In higher-temperature quarters of the year, growing plants take up nitrate and its influx into the water is reduced. The influence of the sampling location was also marked, as there was little variation in nitrate nitrogen concentrations except during the winter period. The reservoir had a positive effect on the out flowing water, which mostly discharged less nitrate during the study period compared to the incoming water, indicating uptake of this form of nitrogen by the reservoir plants (Aspin et al.,

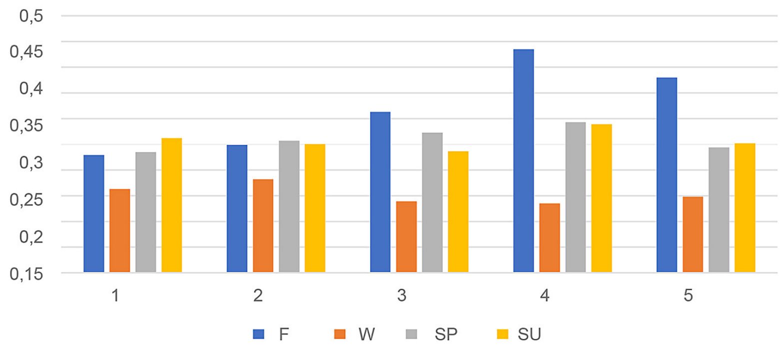

Figure 6. Concentration of ammonium nitrogen in reservoir water in mg $N\text{-}NH_4^+/dm^3$ (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

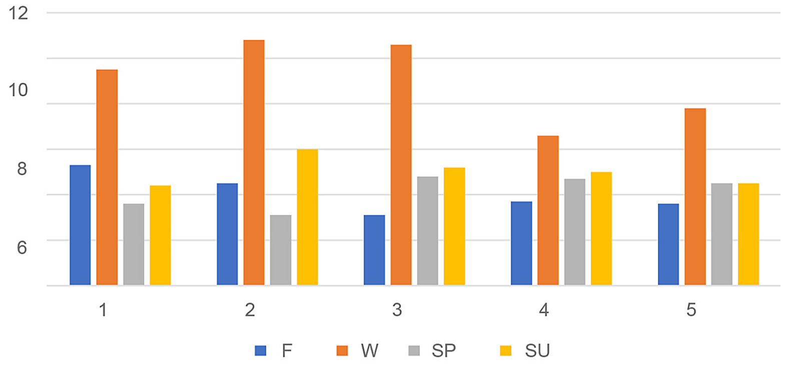

Figure 7. Concentration of nitrate nitrogen in reservoir water in mg$N\text{-}NO_3^-/dm^3$ (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

2020). According to the 2019 Regulation of the Minister of Maritime Affairs and Inland Navigation, it has been established that the studied waters are out-of-class due to the concentration of nitrate nitrogen, as this value exceeded 5 mg $N\text{-}NO_3^-/dm^3$ (Rozporządzenie Ministra Gospodarki Morskiej i Żeglugi Śródlądowej 2019).

The water from the first point of the reservoir, as it flowed into the reservoir, was characterised by the highest concentration of nitrite nitrogen during autumn and winter. This concentration was significantly higher compared to the other dates and points in the middle part of the reservoir and in the outflowing water (Figure 8).

Considering the study periods, it can be seen that their highest concentration was in the water taken in winter, which is due to the reduction of biological life in the reservoir and this form of nitrogen remained in the water. During spring and summer, the lowest concentrations of this form of nitrogen were recorded, which is due to its uptake by the plants and phytoplankton of the reservoir as well as the oxidation process to nitrate. The nitrites in surface water are formed by biochemical processes of transformation of nitrogen-containing compounds. Pure surfaces water usually contain trace amounts of nitrite, namely not exceeding thousandths of a milligram in 1 dm^3. Slightly higher values of this parameter can be observed in the water flowing from swampy areas (Szczykowska and Siemieniuk, 2011). Excessive presence of nitrite ions in the reservoir is toxic to the fish species that live there, as well as to other aquatic organisms, but the determinations obtained for this indicator are low and do not pose a great threat to these organisms. The reservoir had a positive effect on the process of reducing concentrations of this form of nitrogen, as evidenced by the difference in concentration between inflowing and outflowing water during the study period. Organic nitrogen present in all kinds of surface water is usually associated with the presence of pollution from agricultural areas, but also with the decomposition of organic matter in the water. This observation is confirmed by the results obtained for the concentration of this form of nitrogen in the studied water of the Turośń reservoir.

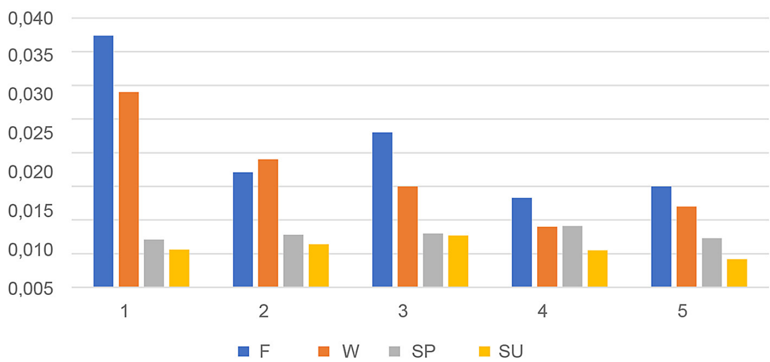

Figure 8. Nitrite nitrogen concentration in reservoir water in mg $N\text{-}NO_2^-/dm^3$ dm^3 (during the seasons: F = fall, W = winter, SP = spring, SU = summer) 1–5 research points

The concentration of organic nitrogen in the reservoir water followed a similar pattern to that of the nitrogen forms discussed above (Figure 9). It varied depending on the date and location of sampling. The water sampled in winter was characterised by the highest concentration of organic nitrogen at four points in the reservoir, which is related to the deposition of organic matter in the reservoir after the growing season, and these differences were significant. Similar observations were made by Wiatkowski et al. (2021), who assessed several small reservoirs in Dolny Śląsk (Poland). At point three, similar concentrations of this form of nitrogen occurred in water sampled in all quarters of the year. Organic nitrogen seasonal changes are due to changes that occur in surface water during the year. Throughout the study period, the lowest concentrations of organic nitrogen were in the water sampled in spring and summer, which may be indicative of the conditions favourable for organic matter biodegradation processes. In this process, plant-available mineral nitrogen compounds are formed (Szczykowska et al., 2017). The stages of transformation are directed towards the use of complex organic nitrogen compounds, in the form of tissue and cell fragments of soil micro-, meso- and macrofauna, plant residues, dead microbial cells, animal excreta, and intentionally added organic fertilisers: manure, composts. These transformations involve enzymatic hydrolysis until simple mineral compounds of biogenic elements are obtained, which are taken up by the producers – green plants (Krasowska, 2017).

The concentrations of phosphate ions in the tested reservoir water samples were significantly higher in the summer period in relation to the concentrations in the water from the other quarters of the year (Figure 10). In the water from the first point, the concentration in this period was at the level of 14 mg/dm^3, while in the remaining points, especially in the central part of the reservoir, the concentration was lower by several mg. In other quarters of the year, the phosphate ions concentration in the water was slightly above 6 mg/dm^3 at all points in the reservoir. The differences between these quarters at individual points can be considered negligible. Higher phosphate concentrations in summer are an effect of resuspension, which is the movement of phosphate ions accumulated in sediments at the bottom of the reservoir by wave action and strong water movements, resulting in the leaching of the ions in question from bottom sediments (Krasowska, 2017, Szczykowska et al., 2017). Benthic organisms or fish also play their part in this process and can induce water movement to some extent. In spring, with increased rainfall, there was mixing of the water in the reservoir, so there was an activation of the bottom sediments and a release of phosphate ions from them (Kajak, 2001). Untreated wastewater, which enters from unsewered areas in close proximity to the reservoir, has also played an important role in the accumulation of phosphorus in the aquatic environment of this reservoir, acting as an external source of phosphorus. Another reason for the high phosphate concentration is surface runoff and the movement of soil particles, which are a source of phosphorus to surface waters (Wiatkowski et al., 2021), as evidenced by the summer phosphate concentration in the water entering the reservoir, which was higher than in the outflow water. The reservoir inflow water runs through agriculturally used areas and carries soil particles, which are a source of phosphates.

Phosphorus, in contrast to nitrogen, is a low-mobile biogenic compound. Hence, sources of phosphorus in surface water include runoff from fields containing phosphorus fertilisers,

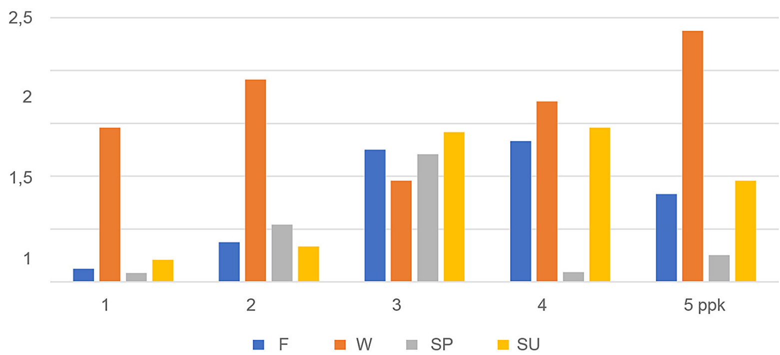

Figure 9. Concentration of organic nitrogen in reservoir water in mg N/ dm^3 (during the seasons: F = fall, W = winter, SP = spring, SU = summer,) 1–5 research points

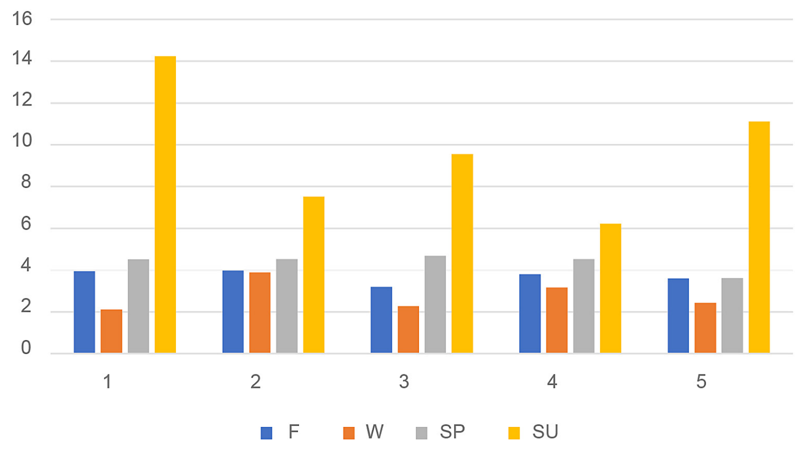

Figure 10. Concentration of phosphate ions in water in mg PO_4^{3-}/dm^3 (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

pollutants from industrial and domestic sewage treatment plants, as well as from decomposition processes of organic substances of animal and plant origin (Adamska et al., 2015). Total phosphorus occurring in the water from the Turośń reservoir varied depending on the sampling point and was largely subject to seasonal variations (Figure 11). On the other hand, the outflow water was characterised by lower phosphorus concentrations than the water in the middle points of the reservoir, which indicates phosphorus being retained in the organic matter of the reservoir and phosphorus being mobilised after the end of the growing season. Phosphorus compounds under aerobic and anaerobic conditions in surface water undergo transformations identical to those of nitrogen compounds. During aerobic processes, phosphorus compounds are converted to phosphate (V), which is considered the last stage of mineralisation. Under anaerobic conditions, these compounds can even be reduced to PH_3.

The performed determinations of the water quality of the small reservoir 'Turośń ' show instability in its quality because most of the parameters were subject to seasonal variability. The water of the reservoir were not self-purifying and negatively affected the water of the Turośnianka River. Similar observations were made by Wiater et al. (2011) while investigating the impact of the reservoir on water quality in the Supraśl River. The trophic status of the Turośń reservoir was determined according to the Carlson trophic state index table (Table 1).

By analysing the table above showing the trophic state on the basis of total nitrogen, it can be seen that the waters of the Turośń reservoir are mostly eutrophic. The lowest TSI(TN) value, indicating the mesotrophic character of the water body, of 42.46 mg/dm^3, was observed in spring. On the basis of the trophic state results including total phosphorus, the character of 'Turośń' reservoir water can be defined as oligotrophic,

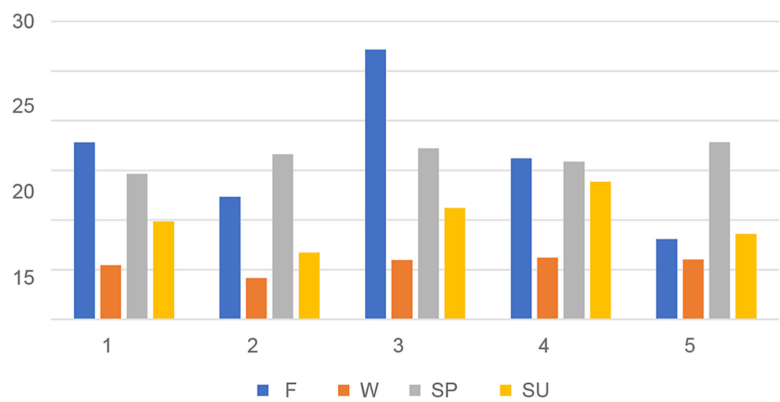

Figure 11. Concentration of total phosphorus in water in mg P/dm^3 (during the seasons: F = fall, W = winter, SP = spring, SU = summer), 1–5 research points

Table 1. Carlson's trophic state index of surface water

Season	TSI (TN)	Trophic state	TSI (TP)	Trophic state
Fall	50.91	eutrophic	44.43	mesotrophic
Winter	61.97	eutrophic	28.91	oligotrophic
Spring	42.46	mesotrophic	44.51	mesotrophic
Summer	52.46	eutrophic	37.43	oligotrophic

falling in the winter and summer seasons, and mesotrophic corresponding to the autumn and spring seasons. TSI(TP) values ranging from 28.91–37.43 mg/dm^3 indicate oligotrophy, while 44.43–44.51 mg/dm^3 indicate mesotrophy. The inflow of nutrients from an agriculturally used catchment and domestic sewage, together with the slowing down of water flow in the reservoir compared to the feeder watercourses, favour eutrophication processes while constituting a barrier to the good ecological status of small retention reservoirs (Wojtkowska and Bojanowski, 2021). In rivers where nutrient inflows have been high for long periods of time, a lot of phosphorus compounds can accumulate in the bottom sediments, which may continue to contribute to high nutrient levels in the water after inflows are reduced (Mainstone and Parr, 2002). Aspin et al. (2020) suggest that nutrient input to surface waters should be considered as an integral component of environmental flows. Water quality indicators should be linked to the effects of flow and migration of constituents from the catchment.

CONCLUSIONS

There were significant seasonal variations in the turbidity and true colour of the tested water of Turośń Reservoir, and to a lesser extent in conductivity and pH values.

Water was significantly differentiated in points of intake due to turbidity and colour, in the case of conductivity and pH values, it was less differentiated.

Particularly during the autumn period, there were increased ammonium ions concentrations in the reservoir water. The concentration of this form of nitrogen was highest at point 4 and 5 of the water sampling, which was caused by their release from decomposing organic matter. There was more of the ammonium form of nitrogen in the outflowing water than in the incoming water during the autumn period. This relationship was not observed in other quarters.

There were significant seasonal changes in the concentration of nitrogen oxidised forms ($N\text{-}NO_3$ and $N\text{-}NO_2$), with the highest concentrations of nitrate occurring in winter and nitrite in autumn. It can be concluded that the reservoir had a positive effect on the concentration of nitrogen both forms, which was reflected in their concentrations in the water leaving the reservoir (sampling point 5).

Organic nitrogen concentrations varied between seasons, with the highest value in water during winter period. The reservoir had a negative effect on the concentration of this form of nitrogen, as evidenced by the increased concentration in the outflow water compared to the inflow water, particularly evident during the winter period.

Phosphates were highest in the water sampled in summer and total phosphorus in autumn. In the samples from other quarters of the year, the concentration of both forms of phosphorus was lower. Phosphate concentrations varied slightly from one sampling point to another, and for total phosphorus there was considerable variation across the reservoir water sampling points. Some phosphate and total phosphorus were retained in the reservoir during the study period.

Considering the content of total nitrogen, eutrophic waters prevailed in the 'Turośń' reservoir. On the basis of the total phosphorus results, the water in winter and summer showed an oligotrophic character, while in spring and autumn, they corresponded to values characterising a mesotrophic state.

The worsening phenomenon of eutrophication in the water of the study reservoir may have been influenced by a number of factors. The construction of the reservoir undoubtedly affects the value of the indicators in discussion. The shallow depth of the studied hydro-technical object causes a faster development of the eutrophication process. The accumulation of various substances is beneficial to aquatic organisms, which use them as nutrients, thereby increasing the risk of eutrophication. Degradation of the small retention reservoir is also attributed to growing transport, tourism and recreation, continuous climate change, pollution from agriculture and disordered sewage management.

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