

## AGRICULTURAL POLLUTION AND WATER QUALITY IN SMALL RETENTION RESERVOIR IN KORYCIN

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### ABSTRACT

The study aimed at determining the changes in the trophic status of the processes associated with the risk of eutrophication in small retention reservoir in Korycin, characterized by agricultural performance of direct and indirect catchment. The study was conducted using the surface water samples that were collected systematically every month over four hydrological years (2008 to 2014) from three research points. Mean annual concentration of total phosphorus varied from 0.641 mg P/dm<sup>3</sup> during research conducted in 2007/2008 to 0.874 mg P/dm<sup>3</sup> in 2013/2014 showing an increasing trend from year to year. Taking into account the calculated average values, an upward trend can be seen along with particular years of the study from the annual average value of 1.44 mg N/dm<sup>3</sup> determined in the first year to the value of 2.66 mg N/dm<sup>3</sup> recorded in the last year of the study. It was observed during the study that in non-flowing parts of Korycin reservoir, plankton developed more abundantly than in the central fragments, where the flow of water is more intensive. A mild growth of phytoplankton in the waters of Korycin reservoir is provided by relatively low concentrations of chlorophyll "a" found during all research periods. Concentrations of chlorophyll "a" in waters of the reservoir were within the range of 4.08 to 5.21 g/dm<sup>3</sup>. At a Schindler coefficient > 2, this value, based on the Decree of the Minister of the Environment of 2011, should not exceed 7 and therefore waters of the Korycin reservoir during the research can be classified as the first class. Values of the general trophic level (Trophic State Index) during the first three years of the study ranged from 67.15 to 68.65, which enabled to count waters of the reservoir in Korycin to eutrophic ones. In the last year of the analyzes, this coefficient increased to a value of 72.43, classifying its waters as hypertrophic. The largest share in such a situation was expressed by TSI (TP), which ranged from 97.34 to 101.82, always classifying the waters to hypertrophic ones. In contrast, the indicator TSI (TN) ranged from 59.71 to 68.57 and it classified the reservoir waters to eutrophic, while TSI (Chl) to mesotrophic.

**Keywords:** small water retention reservoir, pollutions, biogenic compounds, trophic status.

### INTRODUCTION

Water deficit in rural areas is a major problem in Polish agriculture. Agrotechnical procedures significantly alter the ability of soil to retain water and additionally as a result of hasty melioration works, it may lead to lowering the groundwater level. Beneficial impact on water resources by controlling the water outflow in the main stream

or controlling using hydro-devices was confirmed by many scientists [1, 2]. Implementing the program of small water retention development in Podlasie region since 1995 leads to a gradual increase in available water resources, particularly for agriculturally used soils. The activities undertaken in this area are one of the elements that meet the demands of the Water Framework Directive, with the very important issue of main-

taining a “good ecological status of waters” [3]. Although significant quantities of nutrients are naturally present in the soil, they are too few to achieve high yields of crops. This creates a need for the supply nutrients in the form of various fertilizers to plants cultivated on agricultural lands. Many-year use of organic fertilizers on the same surface causes an increase in the nitrogen content in soil and should be included in the development plans of fertilization. The proper calculation of the components balance in the soil is particularly important, because it aims at evaluating the risk of nutrients loss. A positive balance of nutrients means that their smaller amount was absorbed by plants and taken along with crops than was introduced in a form of fertilizers. The components that remained in the soil after harvest can be washed out by rainfall and infiltration to groundwater and surface waters. On agricultural areas, both surface and subsurface runoff of biogenic substances from agricultural fields is considered the greatest threat to water quality [4, 5]. The amounts of nitrogen and phosphorus compounds removed from a catchment undoubtedly depends on its performance manners, share of cultivated fields, especially arable lands, total area of the catchment, and intensity of agriculture, taking into account the size of fertilization [6].

The study aimed at determining the changes in the trophic status of the processes associated with the risk of eutrophication in small retention reservoir in Korycin, characterized by agricultural performance of direct and indirect catchment.

## AREA AND METHODS OF STUDY

The small retention reservoir with capacity of 481 thousand m<sup>3</sup>, surface area of 6.8 hectares, and shoreline length of 1000 meters, was put for using in September 2002 in Korycin. The indirect catchment of the reservoir that was located on the river Kumiałka, is dominated by agricultural lands covering 84.9% of the municipality Korycin. Accumulation of water in the reservoir is 195 cm, its average depth 165 cm, width of the reservoir 145 m, and the length 440 m. Referring to soil typology, the largest area of the direct catchment is occupied by brown soils, pseudo-podsolic soils, as well as chernozems and alluvial soils in river valleys. Twenty hectares of adjacent areas were put into use for recreation and sports facilities, tourism, and hospitality. The main purpose

of hydraulic engineering structures in Korycin is regulation of water balance and it also plays the role of the storage and flood reservoir, while in summertime it serves for recreation and sports.

The study was conducted using the surface water samples that were collected systematically every month over four hydrological years (2008 to 2014) from three research points. The selection and placement of measurement and control points in a longitudinal section of the reservoir was a result of the need to capture the changes in selected physicochemical indicators of water samples. The first point was located within the inlet, the second in the middle, and the third at the mouth of water outlet from the reservoir. The water samples were subject to following determinations: total nitrogen, total phosphorus, and chlorophyll “a”, according to obligatory methodology [7, 8].

At the same time, the trophic state of analyzed reservoir was evaluated according to the concentration criteria and based on the calculated trophy indices TSI (Trophic State Index) by Carlson and Kratzer and Brezonik [9]. Trophy indices were calculated after Carlson trophic TSI (Chl) in mg/dm<sup>3</sup>, TSI (TP) in µg/dm<sup>3</sup>, according to Kratzer and Brezonika TSI (TN) in mg/dm<sup>3</sup> as well as the overall trophy of the reservoir TSI was determined using the mean value obtained from the three calculated indicators: TSI (Chl), TSI (TP), TSI (TN). Water transparency measured by Secchi disk was skipped, because it is of little importance in dam reservoirs, when assessing the trophic status. Water inflow during heavy rainfall brings a large amount of suspensions, which cause turbidity of retained water. The reduction in transparency due to this fact is not related to the development of phytoplankton [10, 11]. The values of trophic status indicators to assess due to Carlson are as follows: TSI < 40 – oligotrophy, 40–50 mesotrophy, 50–70 eutrophy, > 70 hypertrophy [8]. The assessment of the eutrophication degree is made on the basis of average annual values of biogenic indicators for flowing waters [9].

## RESULTS AND DISCUSSION

The presence of nitrogen in surface waters is influenced by pollution inflowing from the point and area sources, development of aquatic vegetation, oxygen and temperature conditions. Nitrogen is a key element in monitoring the functioning of aquatic ecosystems and its contents in

surface waters shows fluctuations during the year [12]. During the research, it was observed that the concentrations of total nitrogen were low in summer, during periods of increased vegetation, and under conditions of favorable to biochemical changes. During the growing season, lowering nitrogen concentration was observed, which was affected by developing autotrophic aquatic organisms that are likely to absorb nitrogen compounds and built them into their cells. In winter, when biochemical processes involving microorganisms are inhibited, the concentration of total nitrogen reached higher values. Taking into account the calculated average values, an upward trend can be seen along with particular years of the study from the annual average value of 1.44 mg N/dm<sup>3</sup> determined in the first year to the value of 2.66 mg N/dm<sup>3</sup> recorded in the last year of the study (Tables 1-4). Based on the analysis of total nitrogen concentrations, it can be concluded that during all test series they satisfied the requirements of the quality of the first class water [13], wherein the maximum values were obtained in samples collected in the third measurement point located near the water outflow from the reservoir.

Eutrophication is the most important anthropogenic factor affecting the proper functioning of aquatic ecosystems. The smaller the reservoir, the greater the impact of substances originating from the catchment on water quality in the reservoir. During the studies, a clear seasonal increase in the incidence of total phosphorus in autumn, winter, and spring was recorded, while a significant

reduction in the concentration during summer was observed. The achieved results are confirmed by literature data [4, 5, 10, 14].

Both phosphates and polyphosphates are sorbed on the particles of clay minerals and may form complex compounds with metal ions present in water, especially iron, calcium, magnesium, and aluminum with different pH-dependent coefficients of water solubility [12]. The chemical transformations of phosphorus compounds in water often lead to their precipitation and accumulation in bottom sediments, in which mineral forms are predominant. Phosphorus exchange processes between water and sediments depend on the oxygen conditions, temperature, pH, redox potential, and the surface of bottom sediments to a large extent. In the period of elevated temperatures and under anaerobic conditions, much faster return of phosphates to the water column occurs [15]. During the autumn and spring periods of circulation, vertical distribution of phosphorus is not uniform due to the re-suspending the bottom sediments [12]. Mean annual concentration of total phosphorus varied from 0.641 mg P/dm<sup>3</sup> during the research conducted in 2007/2008 to 0.874 mg P/dm<sup>3</sup> in 2013/2014 showing an increasing trend from year to year. Water in the dammed reservoirs does not flow uniformly with the entire surface, the stream can occupy only a small percentage of the reservoir surface. It was observed during the study that in non-flowing parts of Korycin reservoir, plankton developed more abundantly than in the central fragments, where the flow of water is

**Table 1.** Water testing results for reservoir Korycin in 2007/2008

Korycin 2007/2008		First point	Second point	Third point	Mean value
Tested parameter	Unit	<u>min-max</u> mean	<u>min-max</u> mean	<u>min-max</u> mean	<u>min-max</u> mean
Total nitrogen	mg·N/dm <sup>3</sup>	<u>0.11 – 2.22</u> 1.17	<u>0.32 – 2.65</u> 1.49	<u>0.40 – 2.90</u> 1.60	<u>0.28 – 2.59</u> 1.44
Total phosphorus	mg·P/dm <sup>3</sup>	<u>0.009 – 0.971</u> 0.486	<u>0.046 – 1.122</u> 0.584	<u>0.109 – 1.588</u> 0.849	<u>0.055 – 1.227</u> 0.641
Chlorophyll „a”	µg/dm <sup>3</sup>	<u>2.52 – 5.40</u> 3.96	<u>2.98 – 5.68</u> 4.33	<u>3.23 – 4.67</u> 3.95	<u>2.91 – 5.25</u> 4.08

**Table 2.** Water testing results for reservoir Korycin in 2009/2010

Korycin 2009/2010		First point	Second point	Third point	Mean value
Tested parameter	Unit	<u>min – max</u> mean	<u>min – max</u> mean	<u>min – max</u> mean	<u>min – max</u> mean
Total nitrogen	mg·N/dm <sup>3</sup>	<u>0.15 – 2.59</u> 1.37	<u>0.38 – 2.83</u> 1.61	<u>0.49 – 3.24</u> 1.87	<u>0.34 – 2.89</u> 1.62
Total phosphorus	mg·P/dm <sup>3</sup>	<u>0.011 – 0.984</u> 0.498	<u>0.053 – 1.242</u> 0.648	<u>0.124 – 1.618</u> 0.871	<u>0.063 – 1.281</u> 0.672
Chlorophyll „a”	µg/dm <sup>3</sup>	<u>2.58 – 5.94</u> 4.26	<u>3.02 – 6.07</u> 4.55	<u>3.34 – 6.37</u> 4.86	<u>2.98 – 6.13</u> 4.56

**Table 3.** Water testing results for reservoir Korycin in 20011/2012

Korycin 2011/2012		First point	Second point	Third point	Mean value
Tested parameter	Unit	<u>min. – max</u> mean	<u>min. – max</u> mean	<u>min. – max</u> mean	<u>min. – max</u> mean
Total nitrogen	mg·N/dm <sup>3</sup>	<u>0.17 – 2.62</u> 1.40	<u>0.39 – 2.91</u> 1.65	<u>0.51 – 3.43</u> 1.97	<u>0.36 – 2.99</u> 1.68
Total phosphorus	mg·P/dm <sup>3</sup>	<u>0.016 – 0.989</u> 0.503	<u>0.057 – 1.278</u> 0.668	<u>0.138 – 1.623</u> 0.881	<u>0.070 – 1.297</u> 0.684
Chlorophyll „a”	µg/dm <sup>3</sup>	<u>2.63 – 6.14</u> 3.96	<u>3.03 – 6.15</u> 4.33	<u>3.42 – 6.69</u> 3.95	<u>3.03 – 6.33</u> 4.68

**Table 4.** Water testing results for reservoir Korycin in 20013/2014

Korycin 2013/2014		First point	Second point	Third point	Mean value
Tested parameter	Unit	<u>min – max</u> mean	<u>min – max</u> mean	<u>min – max</u> mean	<u>min – max</u> mean
Total nitrogen	mg·N/dm <sup>3</sup>	<u>0.21 – 3.12</u> 1.67	<u>0.46 – 4.68</u> 2.57	<u>0.78 – 6.69</u> 3.74	<u>0.48 – 4.83</u> 2.66
Total phosphorus	mg·P/dm <sup>3</sup>	<u>0.023 – 1.454</u> 0.739	<u>0.099 – 1.522</u> 0.811	<u>0.156 – 1.988</u> 1.072	<u>0.093 – 1.655</u> 0.874
Chlorophyll „a”	µg/dm <sup>3</sup>	<u>3.16 – 6.73</u> 4.95	<u>3.58 – 6.98</u> 5.25	<u>3.96 – 7.22</u> 5.59	<u>3.57 – 6.98</u> 5.26

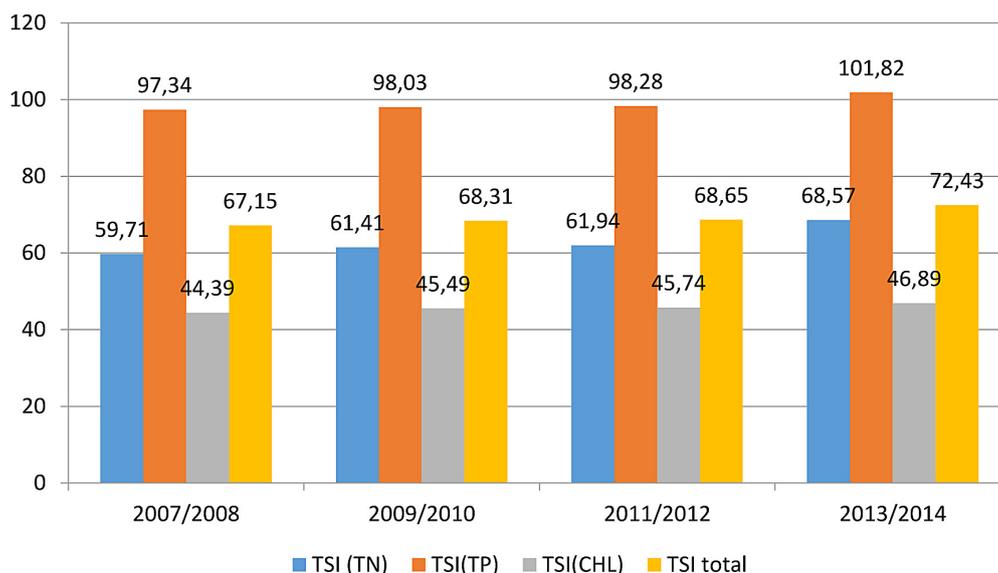
more intensive. Every small retention reservoir shows different susceptibility to degradation. The larger the share of arable lands in the catchment area with small amounts of forest areas, the greater the supply of nutrients, and thus the higher concentrations determined in water [16, 17].

Accumulation of material brought by the river occurs as a result of slow water flow through the reservoir. Precipitating sediments are a mixture of organic and mineral compounds aggregating in front of a dam. If a flow brings waters rich in nitrogen and phosphorus, a deficit of oxygen conditioning the anaerobic metabolism, can quickly appear in benthic zone. Initially, there are no visible changes in the surface layer of the reservoir until the content of biogenic substances in the dammed water does not rise so that algae and phytoplankton would massively grow, i.e. a “water bloom” will occur. Determination of the chlorophyll “a” concentration is a direct indicator of the trophic status of waters, thus it is widely used [8]. Chlorophylls have the ability to absorb the visible light in the range of blue and red color as well as they reflect green light, which gives the plants a green color. The chlorophyll content is an indicative, that is relatively simple to evaluate, but burdened with some disadvantages. The errors may arise from the fact that the concentration of the pigment may vary, depending on physiological properties of algal cells or their species affiliation. The algae cells under poorer light conditions contain more chlorophyll than those exposed to more intense radiation [19]. These results can

hardly coincide with reality also due to disregarding the biomass of macrophytes, although they do not significantly affect the obtained results [19]. A mild growth of phytoplankton in the waters of Korycin reservoir is provided by relatively low concentrations of chlorophyll “a” found during all research periods. Concentrations of chlorophyll “a” in waters of the reservoir were within the range of 4.08 to 5.21 g/dm<sup>3</sup>. At a Schindler coefficient > 2, this value, based on the Regulation of the Minister of the Environment of 2011, should not exceed 7, and therefore, waters of the Korycin reservoir during the research can be classified as the first class [20].

Values of the general trophic level (Trophic State Index) during the first three years of the study ranged from 67.15 to 68.65, which enabled to count waters of the reservoir in Korycin to eutrophic ones. In the last year of the analyzes, this coefficient increased to a value of 72.43, classifying its waters as hypertrophic. The largest share in such a situation was expressed by TSI (TP), which ranged from 97.34 to 101.82, always classifying the waters to hypertrophic ones. In contrast, the indicator TSI (TN) ranged from 59.71 to 68.57 and it classified the reservoir waters to eutrophic, while TSI (Chl) to mesotrophic.

Contamination of water reservoirs with phosphorus compounds is a frequently occurring problem and quite difficult to remove, since in general it results from the distributed nature of its external sources, especially for agricultural catchments. These seasonal changes indicate the release of



**Figure 1.** Annual average trophic level of the Korycin reservoir in particular years of research

phosphates from bottom sediments of previously accumulated organic matter. The secondary pollution of the reservoir is also evidenced by the concentration of total phosphorus in the individual sampling points. During the research, the lowest concentration of total phosphorus was present in the waters flowing into the reservoir, while the highest one was found in the samples collected around the outflow. The values of TSI (TN), TSI (TP), TSI (Chl), and total TSI increasing from year to year, clearly indicate a gradual, slow degradation of water quality in the analyzed reservoir.

## CONCLUSIONS

1. Considering the calculated mean values of total nitrogen, it can be observed an increasing trend along with subsequent years of the research, from the average annual value of 1.44 mg N/dm<sup>3</sup> determined in 2007/2008 to 2.66 mg N/dm<sup>3</sup> in 2013/2014 season.
2. The mean annual concentration of total phosphorus varied from 0.641 mg P/dm<sup>3</sup> in the initial period of the study to 0.874 mg P/dm<sup>3</sup> in the last year, showing a continuous upward trend.
3. The values of the overall trophy during the first three years of the research ranged from 67.15 to 68.65, which enabled to count waters of the Korycin reservoir to eutrophic, whereas in the last year, this coefficient increased to a value of 72.43, classifying the water to hypertrophic ones.

4. During the research, the lowest concentration of total phosphorus was present in the waters flowing into the reservoir, while the highest one was found in samples collected around the outflow and values of TSI (TN), TSI (TP), TSI (Chl), and total TSI increasing from year to year, clearly indicate a gradual and slow degradation of water quality in the analyzed reservoir.

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