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POSSIBLE USE OF A WATER RESERVOIR IN CONDITIONS OF AGRICULTURAL ANTHROPOPRESSURE – LAKA DAM RESERVOIR

MOŻLIWOŚCI UŻYTKOWANIA ZBIORNIKA WODNEGO W WARUNKACH ANTROPOPRESJI ROLNICZEJ – ZBIORNIK ZAPOROWY ŁĄKA

Abstract: The paper presents functioning of Laka dam reservoir. Its catchment, drained by the Pszczynka river, is dominated by agriculture. This kind of anthropopressure results in eutrophication of the water environment. The research showed that the reservoir is fed with eutrophicated water. Water fertility increases while flowing through the reservoir. The research included assessment of possible use of the reservoir in such conditions. The reservoir serves flood-control functions and also retains water for industrial plants. Water retained in it cannot be used for consumption. Also, swimming in the reservoir is restricted. It is used for fishing and is regarded as an attractive fishing ground. Increased interest in rest and recreation at the side of the reservoir can be observed. A few water sports centers are operating there. The fact that the banks of the reservoir are managed fosters physical activities. The research shows that multiple-area use of the eutrophic reservoir is possible, but measures aimed to increase water quality are necessary in order ensure comfort and safety for its users.

Keywords: Laka dam reservoir, agricultural anthropopressure, quality of water, water body use

Introduction

Water reservoirs serve multiple utility functions. Among others, they might be used for flood control or retaining water for consumption, industry or agriculture; they could also be used for water sports or plain recreation [1]. Reservoirs are usually multiple-function bodies, unless they were constructed for one particular purpose, eg as technological water reservoirs or fishing ponds [2]. Such typically industrial reservoirs are usually located within areas of industrial plants and are not available for people. Other reservoirs are frequently widely available and the way they are used depends on

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multiple factors like location, limnological parameters (including water resources), water quality and accessibility of the shore zone. The most important factor that determines the use of reservoirs is water quality [3]. It determines, inter alia, costs of water treatment for consumption or swimming possibilities. Heavily polluted reservoirs, even those with large water volumes, are poorly managed, which could be seen for example in case of Dzierzno Duze reservoir [4].

Qualitative parameters of water in a given reservoir depend on catchment inflow and processes that occur in the reservoir basin. Quality of water feeding a reservoir is of major importance. The most polluted is water flowing from heavily urbanized and industrialized catchments [5–7]. Municipal-industrial anthropopressure, related to discharge of various waste and downfall from polluted areas, causes water to be not only loaded with suspended matter and overfertilized, but also polluted with trace substances. Also, agricultural anthropopressure has a negative impact on water quality [8–11]. Sapek [12] claims that an inherent element of agriculture is pollution of water with nutrients and its eutrophication (shortage of oxygen, organic load, low transparency, unfavorable color and smell etc.). Additionally, water can be polluted with dangerous micropollutants, e.g. pesticides [13]. Thus, use of water reservoirs which are functioning in agricultural catchments may be seriously restricted.

The specific aim of the paper was to recognize the use of Laka dam reservoir, which functions in an agricultural catchment (Fig. 1). The author assessed water quality in the Pszczynka river, which flows into the reservoir, and also identified and analyzed the forms of use of the reservoir. The paper also had a general aim – to verify common assumptions that agricultural anthropopressure results in deterioration of water quality (including its eutrophication) and thus restricts its use.

Fig. 1. The catchment of Laka dam reservoir. Source: Google Earth
Methods

The first stage of research included collection of materials which characterize the catchment of Laka reservoir. Physiographic papers (publications, reports, expertise, environmental programs), as well as topographic maps and satellite imagery were analyzed. Also, field observations and community research were carried out, mainly regarding agricultural activities.

Stage two included analyses of quality of water which fed the reservoir (water of the Pszczynka river in the zone of its inflow to the reservoir). Water was taken for analyses at a monthly rate in 2011 (12 measuring series). Analyses were carried out in the laboratory of Voivodship Inspectorate of Environmental Protection (VIEP) in Bielsko-Biała. The following parameters were measured: 1) reaction, 2) suspension, 3) dissolved oxygen, 4) biochemical oxygen demand (BOD$_5$), 5) total organic carbon (TOC), 6) electrical conductivity (EC), 7) sulphates, 8) chlorides, 9) total hardness (TH), 10) ammonium-nitrogen (N-NH$_4$), 11) total Kjeldahl nitrogen (TKN), 12) nitrate(III)-nitrogen (N-NO$_2$), 13) nitrate(V)-nitrogen (N-NO$_3$), 14) total nitrogen (TN), 15) total phosphorus (TP). Methodology of analyses was in accordance with Polish norms and ISO norms. Assessment of water quality was carried out according to respective Polish legal regulations [14–18].

Stage three consisted in recognition and analysis of forms of use of the reservoir. The shore zone was charted and all objects situated near the reservoir which are related to its use were catalogued. Also, field research was carried out to determine forms of use of the reservoir not related to its infrastructure.

Results and discussion

Laka reservoir is situated in the municipality of Pszczyna. It started its operation in 1986 [19]. It was built by damming the valley of the Pszczynka river. With the dam, the water lever is raised in a section about 4 km long – between the dam and the bridge of the road connecting Wisla Wielka and Brzezce villages. Maximum damming level in the reservoir is 250.70 m a.s.l., which makes it possible to retain 12 million m$^3$ of water (Table 1).

<table>
<thead>
<tr>
<th>Water damming level [m a.s.l.]</th>
<th>maximal</th>
<th>250.70</th>
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<tbody>
<tr>
<td>normal (September–May)</td>
<td>250.35</td>
<td></td>
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<tr>
<td>normal (June–August)</td>
<td>250.15</td>
<td></td>
</tr>
<tr>
<td>minimal</td>
<td>246.50</td>
<td></td>
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<tr>
<td>Capacity [mln m$^3$]</td>
<td>total</td>
<td>12.00</td>
</tr>
<tr>
<td></td>
<td>flood (September–May) – included in total</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>flood (June–August) – included in total</td>
<td>2.30</td>
</tr>
<tr>
<td>Area [km$^2$]</td>
<td>at maximal damming level</td>
<td>4.18</td>
</tr>
<tr>
<td></td>
<td>at minimal damming level</td>
<td>0.89</td>
</tr>
<tr>
<td>Average depth [m]</td>
<td>at maximal damming level</td>
<td>2.87</td>
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</table>
Szuster [20] calculated that the reservoir receives average 1.7 m$^3$/s of water. This is mainly water from the Pszczynka river and its tributaries (major ones including: Debinka, Osiny, Pawłowka, Nieradka, Kanal Branicki, Kanar, Stencłowka). The river flows for about 20 km above the reservoir. Its springs are at about 270 m a.s.l., in the area of the Rybnik Plateau. Several kilometers from the spring, the Pszczynka flows on the area of the Pszczyna Plain [21]. The geological base of both of those regions includes Carboniferous layers, but the surface is dominated by fluvioglacial sands and gravels, loesses, river clays and sands, and silts. Those conditions created brown and podzolic soils, and, in valleys, peat soils.

Physiographic conditions of the catchment of Laka reservoir are favorable for growing agricultural activities. The catchment is an area of 157.92 km$^2$, of which as much as 121.7 km$^2$ (77.1 %) is taken by formerly or currently arable land. Forests take 12.7 % of the catchment and urbanized areas – 7.9 % [22]. Farmland is characteristic of the whole area, including the direct catchment of the reservoir (Fig. 1). In the past, it also covered the area which is occupied by the reservoir now. Before flooding the basin of the reservoir with water, 127 ha of arable land, 187 ha of meadows, 95 ha of forested areas and 95 ha or other farmland were bought from owners [19]. After several years, agriculture was restricted also in the backwater zone of the reservoir (above the bridge), and two flood control polders were created.

Results of field observations and community interviews showed that farming activities are the main anthropogenic factor affecting the quality of the water environment in the catchment of the reservoir. Agriculture is related to functioning of villages (eg Krzyzowice, Warszowice, Pawłowice, Suszec, Kryry, Studzionka, Mizerow), but wastewater which is produced there is in large part subject to the treatment process [20]. Agriculture has changed in this region in the past several years. Most of small farms were transformed into large ones, which became profitable thanks to specialization. These are livestock farms (pig, poultry, cattle or milk farms), crop farms (grains or rapeseed) or specialized farms (eg mushroom growing). What makes a serious threat to water quality is liquid manure from livestock farms, which is poured directly over arable land. On the other hand, specialize crop farms use artificial fertilizers (because of shortage of natural/animal fertilizers), which are washed from soil easily. Periodically, running waters are also contaminated with eutrophic water discharged from fish ponds.

Catchment conditions determine the quality of water entering the reservoir through the the Pszczynka (Table 2). So far, farming anthropopressure has not resulted in contamination with nitrates (which occurs when concentrations of N-NO$_3$ exceed 11.3 mg/dm$^3$), which happens in many agricultural regions of Europe as a result of incorrect fertilizing policies [23]. However, limit values of some eutrophication indicators have been exceeded. The average yearly concentration of N-NO$_3$ in water of the Pszczynka was 3.4 mg/dm$^3$, and the average yearly concentration of TN was 5.3 mg/dm$^3$. Eutrophication may occur when the average yearly concentration of N-NO$_3$ > 2.2 mg/dm$^3$, and TN > 5 mg/dm$^3$ [14]. Water of Pszczynka entering the reservoir should be regarded as eutrophic. It was characterized by low concentrations of oxygen (average 5.9 mgO$_2$/dm$^3$) and, consequently, excessive concentrations of ammonia and nitrites. High concentrations of dissolved matter were reflected in high values of EC (average
853 μS/cm). According to the legal regulations regarding the environment (Table 2), water under research should not be used for fish farming because of too low contents of oxygen and excessive concentrations of ammonia, nitrates and phosphorus compounds. High concentrations of ammonia and nitrates exclude this water from consumption. Its treatment for consumption is also unjustified (too high values of BOD₅, TOC, EC, N-NH₄, TKN), as it would require expensive, advanced technologies. Values of some parameters of researched water (e.g. reaction, suspension) were equivalent of class one (I), the best class of water quality, but according to the thorough assessment, the quality class was lower than II. These facts show that water of the Pszczynka is contaminated. It flows into the reservoir (still water environment), which may increase eutrophication. Evidence of strong eutrophication of the reservoir was observed periodically during the field research, like algal blooms, unfavorable color, transparency and odor of water. Increased fertility of water from the Pszczynka in Laka reservoir was reported by Niesler and Bielanska-Grajner [24], among others. The authors pointed to unfavorable changes in concentrations and distribution of plankton organisms.

Table 2

<table>
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<tbody>
<tr>
<td>Reaction [pH]</td>
<td>7.05–7.50</td>
<td>yes</td>
<td>A1</td>
<td>yes</td>
<td>I</td>
</tr>
<tr>
<td>Suspension [mg/dm³]</td>
<td>up to 14</td>
<td>yes</td>
<td>A1</td>
<td>#</td>
<td>I</td>
</tr>
<tr>
<td>Oxygen [mgO₂/dm³]</td>
<td>3.4–10.3</td>
<td>no</td>
<td>#</td>
<td>#</td>
<td>I, II and lower class</td>
</tr>
<tr>
<td>BOD₅ [mgO₂/dm³]</td>
<td>2.3–5.3</td>
<td>no/yes**</td>
<td>A1, A2 and A3</td>
<td>#</td>
<td>I and II</td>
</tr>
<tr>
<td>TOC [mg/dm³]</td>
<td>5.6–17.6</td>
<td>#</td>
<td>A2, A3 and out of category</td>
<td>#</td>
<td>I, II and lower class</td>
</tr>
<tr>
<td>EC[μS/cm]</td>
<td>656–1095</td>
<td>#</td>
<td>A1, A2, A3 and out of category</td>
<td>yes</td>
<td>I and II</td>
</tr>
<tr>
<td>Sulphates [mg/dm³]</td>
<td>71.8–139.0</td>
<td>#</td>
<td>A1</td>
<td>yes</td>
<td>I</td>
</tr>
<tr>
<td>Chlorides [mg/dm³]</td>
<td>93–219</td>
<td>#</td>
<td>A1</td>
<td>yes</td>
<td>I and II</td>
</tr>
<tr>
<td>TH [mgCaCO₃/dm³]</td>
<td>162–222</td>
<td>#</td>
<td>#</td>
<td>yes</td>
<td>I and II</td>
</tr>
<tr>
<td>N-NH₄ [mg/dm³]</td>
<td>0.16–2.76</td>
<td>no</td>
<td>A1, A2, A3 and out of category</td>
<td>no</td>
<td>I, II and lower class</td>
</tr>
<tr>
<td>TKN [mg/dm³]</td>
<td>0.82–3.70</td>
<td>#</td>
<td>A1, A2, A3 and out of category</td>
<td>#</td>
<td>I, II and lower class</td>
</tr>
<tr>
<td>N-NO₂ [mg/dm³]</td>
<td>0.047–0.227</td>
<td>no</td>
<td>#</td>
<td>no</td>
<td>#</td>
</tr>
<tr>
<td>N-NO₃ [mg/dm³]</td>
<td>1.96–6.00</td>
<td>#</td>
<td>A1</td>
<td>yes</td>
<td>I, II and lower class</td>
</tr>
<tr>
<td>TN [mg/dm³]</td>
<td>3.88–7.40</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>I and II</td>
</tr>
<tr>
<td>TP [mg/dm³]</td>
<td>0.076–0.450</td>
<td>no</td>
<td>#</td>
<td>#</td>
<td>I, II and lower class</td>
</tr>
</tbody>
</table>

Legend: * based on data from VIEP; ** no for salmon family fish, yes for carp family fish; # no restrictions.
Laka reservoir was built for the following purposes [19]:
– to increase low flow on the Pszczynka river (> 1 m³/s);
– to reduce flood flows (by about 45–46 %);
– to provide water to coal mines of the Rybnik Coal Area;
– to provide water to households and companies from the region of Pszczyna;
– to provide water to the Tychy car factory;
– to provide conditions for rest and recreation for residents of the Silesian conurbation.

The reservoir has not been considered as a part of the water supply system and has been excluded from that function until now. However, it is used in many ways in spite of low quality of its water.

The main function of the reservoir is to provide water to the industry (mainly mining and energy plants). Water is taken by Water Management and Reclamation Enterprise in Jastrzebie Zdroj and distributed for own needs as well as to [25]: Jastrzebie Coal Company (7000 m³/day), Rybnik Coal Company (7070 m³/day), Power Engineering Company of Jastrzebie (2900 m³/day), Laziska Power Station (27600 m³/day) and other minor recipients (150 m³/day). For example, the company used 3895478 m³ of water from the reservoir in 2010 [20]. Water management in the reservoir – water intake with guaranteed flow below the dam (0.3 m³/s) and flood control functions – generate high fluctuations of water levels. Błażycza [26] reports that in hydrological years 1988–2010 water levels changed between 248.03 m a.s.l. to 250.94 m a.s.l. The highest level was reported during the flood in July 1997 – it exceeded the maximum damming level by 24 cm.

Locally, the reservoir serves flood control functions. Subsequent flood occurrences throughout the time of its functioning showed the need for improvements of its infrastructure (e.g., construction of embankments). After the flood in 1997, additional flood gate was made and flood polders were created in the backwater zone. Currently, a number of additional investments are considered to ensure safety of the reservoir and the city of Pszczyna, which is located below the reservoir.

Laka reservoir is used for fishing. Activities in that regard are administered by the Pszczyna Office 44 of the Polish Angling Association. It has a waterside fishing hotel on the southern bank near the municipality of Wisła Wielka. The administrator is responsible for fish stocking (generally with carp) and registering fishing. In 2010 the reservoir was used by 1390 fishers who caught a total of 11058 kg of fish. The share of the catch was as follows: bream – 40.5 %, pike perch – 23.8 %, carp – 12.8 %, pike – 6 %, ide – 4.8 %, perch – 2.8 %, roach – 2.2 %, tench – 1.8 %, crucian carp – 1.6 %, other – 3.7 % [27]. This distribution was considered favorable because of large share of break and pike perch, which are favored predatory species (only small share of perch is unsatisfactory). Fishing functions of the reservoir, besides recreational-culinary importance, also has an educational aspect – fishing courses are organized there as well as fishing ground cleaning actions.

Laka reservoir plays an important part for recreation. No investments related to this function were planned at the initial stage of its functioning due to the poor quality of its water, resulting from agricultural anthropopressure, which was very strong in the 1980s,
and inflow of untreated wastewater. At present, however, the water quality of the reservoir is much better, which results in growth of sports-recreation facilities. Thanks to an agreement between the Regional Water Management Board in Gliwice and Pszczyna Town Hall, 5 campsites were built around the reservoir (camping outside authorized areas is forbidden). Bathing in the reservoir is periodically not recommended – it should be completely avoided in case of algal blooms. On the other hand, activities in water sports, i.e. those using all kinds of sailing equipment, are growing. Within the region of Poreba village, there is a windsurfing center and a branch of Pszczyna Sports Association. They offer rental of sailing equipment and organize sports events. At the bank of the reservoir, near Wisla Wielka, there is a scout hostel, which serves training purposes (swimming, rowing, sailing instructions etc.) for scouts from the Silesian Province and popularizes water sports in many ways. Town’s Water Sports Center (a body of the Pszczyna Town Hall) was built on the south-eastern bank of the reservoir, and a beach was created next to it. It enjoys much popularity and contributes to activation of local people. Next to it, there is a private venue “Decha u Lecha”, which is the only one at the banks of the reservoir with its own catering facilities. Besides the mentioned venues, walking paths and cycling routes have been arranged near the reservoir (European cycling route EuroVelo 4 runs there).

The range and comfort of use of the reservoir is limited by the quality of its water, and interest in recreation at its banks is growing. Hence, in order to improve water quality, the following measures should be taken: agricultural impact should be reduced by introducing pro-environmental agrotechnology, protecting green zone (free from use of fertilizers) should be established around the reservoir, villages which do not have water treatment plants should be sewered, bottom deposits should be removed from the zone of the Pszczynka inflow to the reservoir, and the bank zone should be cleaned regularly (including removal of excessive vegetation).

**Conclusions**

1. Agricultural anthropopressure in the catchment of the reservoir has negative impact on the quality of the water environment. Both running and retained water is subject to eutrophication.

2. Contamination of water in the reservoir has no impact on retaining management in case of flood emergency (flood control function of the reservoir is maintained).

3. The eutrophic water body may be a reservoir of water for industry, while its use for consumption is not reasonable, as it would require a costly treatment process.

4. Eutrophication does not exclude fishing functions of the reservoir or using it for practicing water sports. Both of these forms of use may be connected with educational functions.

5. Multiple ways of use of reservoirs which are subject to agricultural anthropopressure are possible; however, steps should be taken in order to improve water quality and, consequently, safety and comfort of users.
References


Słowa kluczowe: zbiornik zaporowy Łąka, antropopresja rolnicza, jakość wód, użytkowanie zbiornika wodnego