Journal of Ecological Engineering
Volume 15, No. 2, April 2014, pp. 7–16
DOI: 10.12911/22998993.1094973

Research Article

MŚCIWOJÓW RESERVOIR – STUDY OF A SMALL RETENTION RESERVOIR WITH AN INNOVATIVE WATER SELF-PURIFICATION SYSTEM

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Received: 2014.02.07
Accepted: 2014.03.17
Published: 2014.04.04

ABSTRACT
The study presents the characteristics of the Mściwojów Reservoir equipped with a unique pre-reservoir structure that supports the process of self-purification of waters. The authors present more than ten years of studies, focusing mainly on the issues of water quality and the concentration of phosphorus, which is considered as the main factor influencing water eutrophication process. Quite a high concentration of phosphates was noted in the outflow from the main reservoir, in spite of a lower concentration of these compounds in the water leaving the pre-reservoir. Basing on the conducted analyses, the catchment of the reservoir was qualified as group 4, being very prone to the movement and supply of material to the reservoir. The negative value of the retention coefficient of phosphorus obtained for the main part of the reservoir points to the existence of an internal source of phosphorus supply to the reservoir. During over 10 years of studies, new directions of the development of the rural areas were determined. Future works should be extended so as to cover all elements of the ecosystem of the reservoir. In a longer term it seems natural to extend the research works to cover the whole catchment of Wierzbiak River.

Keywords: surface water quality, eutrophication, dam reservoir, phosphorus retention.

INTRODUCTION

The retention reservoir Mściwojów was constructed in the end of the 1990's, in Przedgórze Sudeckie (Sudetian Foothills), as a result of the involvement of local community. The design of the object was a result of joint works of the employees of the Institute of Environmental Engineering of the former Agricultural University of Wrocław (now the Wrocław University of Environmental and Life Sciences) and of the design studio Water Service in Wrocław. The investor and administrator is the Lower Silesian Board for Amelioration and Water Management (DZMiUW). The Mściwojów Reservoir was designed mainly for the purposes of water supply for agriculture and flood protection. Presently, the reservoir is also used for fishing and recreational purposes.

CHARACTERISTICS OF THE MŚCIWOJÓW RESERVOIR

Mściwojów is a dam reservoir located on the Wierzbiak River (Figure 1), which is also supplied by the Zimnik watercourse. The shares of Wierzbiak and Zimnik in the total river supply is, respectively: 71% and 29% [Wiatkowski et al. 2006]. Wierzbiak is a right-side tributary of Kaczawa. The catchment area to the cross-section of the reservoir A = 47 km^2. This is a submontane area of an average inclination of 2.26% and forest coverage below 10%. It is a typical agricultural region, which is confirmed by the land usage structure. Agricultural lands account for over 80% of its area, of which more than 60% are arable lands. Due to quite good quality of soils (soils of the 1st, 2nd and 3rd class), the sowing structure is dominated by cereals followed by root plants.

The proper operation of this multi-purpose reservoir in a typically agricultural catchment was to be ensured by the innovative concept of usage, consisting in the separation of a pre-reservoir with a sedimentation tank (Figure 1).

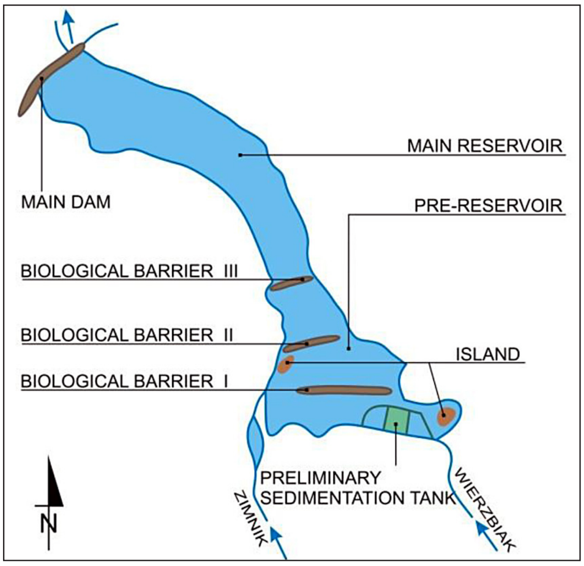

Figure 1. Mściwojów Reservoir

The main function of the reservoir is the storage of water for agricultural purposes, which means that the water should be retained during the season preceding plant vegetation. The operational capacity designated for securing water for agriculture is 700 000 m^3.

The design of the reservoir also foresees the possibility to use the object for the production of electric energy. Due to a small volume of flow and low hydraulic head (approx. 3.5 m), the design of discharge facilities took into account the installation of the smallest turbo generators available at that time. The power generating function mentioned above has not been realised so far.

For the local community it is important to increase the attractiveness of the region, because, in the opinion of local inhabitants, this object should have a positive influence on economic growth through the development of its tourist and recreational functions as an additional, non-agricultural activity in the region. This task of the reservoir requires proper water management in the object and ensuring a constant level of elevation along with good water quality.

A detailed specification of the parameters of the reservoir and technical data is presented in Table 1 [Zbiornik… 1995].

Individual designed elements of the reservoir, such as the dam (Figure 2), the bowl and the sediment tank create a functional structure, integrated with the landscape of the Sudetian Foothills.

The bowl of the reservoir is the valley of Wierzbiak and Zimnik (Rakowiec). The average length of the reservoir along the axis is approx. 1600 (depending on the elevation), and the maximum approx. 2250 m. The area of normal elevation is limited by the isohypse 193.35 m above sea level and the maximum elevation by the isohypse 194.50 m above sea level. The length of the shoreline at normal elevation level is approx. 5.3 km, total length, including islands – 5.6 km.

The innovative structure, mutually exclusive functions and the resulting implications make this reservoir an object of interest in the field of scientific research.

In the years 2000–2007, Wiatkowski and Kasperek conducted studies on the quantity and quality of sediments. The results allow us to determine that the content of phosphorus in the res-

Table 1. Basic parameters of the Mściwojów Reservoir

Item	Parameter	Symbol	Unit	Amount
1	Mean annual flow (inflow to the reservoir)	SQ	m^3/s	0.20
2	Mean annual outflow	ΣQ	mln m^3	6.30
3	Surface of reservoir at normal storage level (193.35 m.a.s.l.)	F_z	ha	34.59
4	Maximum flood surface	$F_{z\,max}$	ha	57.07
5	Water surface elevation	H	m	7.50
6	Total capacity	V_c	mln m^3	1.35
7	Useful capacity	V_u	mln m^3	0.713
8	Dead storage	V_m	mln m^3	0.024
9	Reserve storage obtained as a result of acceptable elevation	R_f	mln m^3	0.61

Figure 2. Part of the earth dam and spillway of the Mściwojów Reservoir (photo: J. Dąbrowska)

ervoir sediments was not high, and the content of heavy metals remained in the range of the 1st and 2nd class of water purity. Moreover, the study confirmed that the sediment tank and pre-reservoir were effective in retaining the fine fraction of sediments [Wiatkowski 2006, Wiatkowski and Kasperek 2008]. Mokwa and Pikul [2006] analysed the influence of immersed plants on the concentration of the suspended sediments, confirming their beneficial influence on the deposition of sediments in the tank.

The reservoir has a positive influence on water management in the upper part of the Wierzbiak catchment, as it influences the equalisation of flow and the stabilisation of ground water level [Szafrański and Stefanek 2008].

MATERIAL AND METHODOLOGY

The source data for analysis were the results of research that has been conducted in the analysed area since 1999 by scientists from the Wrocław University of Environmental and Life Sciences, the University of Agriculture in Krakow, the Opole University, the University of Environmental and Life Sciences in Poznań. The design documentation of the reservoir has also been used, along with the results of field studies and analyses from the years 1999–2013, conducted by the authors of this article.

The evaluation of the catchment as a supplier of biogenic compounds was conducted with use of the method developed by Bajkiewicz-Grabowska [2002]. This method is a part of the comprehensive evaluation system of the catchment as a supplier of matter and the lake as the receiver. The evaluation system is based on the assumption that the pace of natural eutrophication of a lake (water reservoir) depends on the physical and geographical structure of the catchment and on the morphometric parameters of the reservoir. The influence of the catchment on the reservoir is evaluated basing on the characteristics of the catchment.

The method takes into account the following parameters: the Ohle coefficient (total catchment of the reservoir divided by reservoir area), balance type of the lake – indicator of point sources of matter supply, morphometrics of the catchment in a form of: river network density, average inclination of the catchment and the percentage share of areas without drainage as well as the geological structure and land usage.

The phosphorus retention coefficient in the reservoir was also calculated [Bajkiewicz-Grabowska 2002] in order to diagnose the processes of deposition and release of phosphorus occurring in individual parts of the reservoir.

The presented research issues were divided as follows: design objectives of the innovative structure of the reservoir, the problem of water protection as the verification of design objectives and the correctness of operation, integration of the reservoir with the agricultural landscape and the resulting new development directions for the studied area, further research perspectives.

RESEARCH PROBLEMS

Innovative structure

The first analysed problem was the designing of a reservoir with an innovative structure. The structure of the bowl in the Mściwojów Reservoir is unusual for dam reservoirs, as it is divided into two operational parts. The first is the basic reservoir, being generally a reservoir of pure water, and the second part is the pre-reservoir – where sediments are deposited and biogenic substances are biologically removed. The division is realised by means of earth biological barrier III. The flow of water from the pre-reservoir and its even distribution in the main reservoir occurs through 5 spillways of the ordinate 192.50 m above sea level, situated in the barrier. The width of each spillway in the bottom is 3.0 m. The reservoir is equipped with two additional earth barriers. Biological barrier II is located at approx. 150 m distance from the dam, it has 2 spillways and it divides the pre-reservoir into two parts: sedimentation part and biological part. Barrier I is located near the sedimentation tank (Figure 1).

In front of the pre-reservoir, inside the bowl, a three-chamber earth tank is located. It performs an important role in the first stage of purification of water from Wierzbiak supplying the reservoir. In the first chamber, of an area of 6136 m^2 and bottom ordinate 192.85 m above sea level(depth – 1.1 m) sedimentation of coarser particles occurs. In the second, shallowest chamber, of an area of 4884 m^2 and bottom ordinate 193.10 m above sea level (depth – 0.4 m), which is overgrown by common reed (*Phragmites australis*) is the place where intense processes of biological removal of nitrogen and phosphorus occur. The third, deepest and last chamber, of an area of 4424 m^2 and bottom ordinate 192.10 (depth – 1.4 m) is the receiver of water that flowed through the two preceding chambers. This is where additional purification processes take place with the participation of living organisms [Dąbrowska 2010].

Quality of surface waters

The research on the influence of the sedimentation tank and the pre-reservoir on water quality tested first of all the degree of reduction of such biogenic compounds as nitrate nitrogen, nitrite nitrogen, ammonium nitrogen, total phosphorus and phosphates in specific parts of the reservoir. During the initial period of operation of the object – in the years 2000–2002 – the mean reduction in the concentration of nitrates in the pre-reservoir amounted to 66.5% and further reduction in the content was observed after the water flowed through the main reservoir [Wiatkowski et al. 2006, Czamara and Grześków 2008]. According to Wiatkowski [2006], the nitrites were reduced by 50% and their amount also decreased after leaving the main reservoir. The mean reduction in the content of phosphates flowing through the pre-reservoir and main reservoir was 52.8% in comparison to the total concentration of phosphates flowing into the reservoir [Wiatkowski et al. 2006]. The obtained reduction values are generally similar to data presented in literature by other authors describing the operation of water reservoirs [Lothar 2003, Kasza 2009, Bendorf and Putz 1987a, Bendorf and Putz 1987b, Putz and Bendorf 1988, Mazur 2010]. It is worth mentioning here that the values presented by individual authors referred to reservoirs of various area and depth. These objects also differed by the retention time and flow volume. For example, Mazur [2010] presents the values for a pre-reservoir of an average depth of 0.70 m and an area of 178 ha, and Lothar [2003] for reservoirs from 0.4 to 12 ha, whereas the area of the pre-reservoir in Mściwojów is 14 ha, and the average depth 1.5 m (max. 2.5 m). Basing on research conducted and published so far, the authors of the present study would like to emphasise the issue of changes in the concentration of phosphates in the pre-reservoir and main reservoir.

Table 2 presents the results of measurements of the concentration of phosphates in three observation periods. These are averaged values obtained by different authors. In the years 2006–2008 a quite high concentration of phosphates was noted on the outflow from the main reservoir, in spite of a lower concentration of these compounds in the water leaving the pre-reservoir. The

Table 2. Mean concentration of phosphates (mg $PO_4^{3-}\cdot dm^{-3}$) in the surface waters in the analysed area in the years 2000–2009

Test period	Wierzbiak	Zimnik	Pre-reservoir	Main reservoir	Main reservoir (outflow)	Publication
XI 2000 – X 2002	0.54	0.51	0.25	–	0.25	Wiatkowski et al. [2006]
XI 2006 – X 2008	0.61	0.77	0.44	0.45	0.61	Wiatkowski [2011]
V 2008 – V 2009	0.73	0.78	0.68	–	–	Dąbrowska, Markowska [2012]

problem of the increasing concentration of phosphates in the main part of the reservoir was also addressed in the study by Dąbrowska and Markowska [2012].

The study by Policht-Latawiec [2013], conducted from IV to IX 2012 showed an unusually low concentration of phosphates both in the inflows and in the reservoir. The mean values amounted, respectively, to 0.21 mg $PO_4^3 \cdot dm^{-3}$ for the waters of Wierzbiak, 0.19 mg $PO_4^3 \cdot dm^{-3}$ for the waters of Zimnik and 0.16 mg $PO_4^3 \cdot dm^{-3}$ in the main reservoir. Further research on water quality in the upcoming years may explain whether there is a constant decreasing trend in the concentration of phosphates and whether this results from the completion of the construction of the sewage network in the catchment.

The main objective of the Water Framework Directive is to achieve good water quality. The problem of contamination of water with phosphorus compounds has been widely discussed in literature and phosphorus compounds are considered a factor limiting the processes connected with eutrophication and algal bloom [van Puijenbroek et al. 2014, Bechmann et al. 2005, Larsson and Granstedt 2010]. Phosphorus is introduced into the water reservoir with inflowing waters, from atmospheric deposition, from inflows from the direct catchment, however, in certain conditions, it may be re-activated from bottom sediments. Literature emphasises mainly the fact that external sources, in particular the load carried by supplying water courses, has the strongest influence on the contamination of dam reservoirs, and that inflows from direct catchment of the reservoir account for a smaller share [Dojlido 1995, Dojlido and Woyciechowska 1996, Kasza 2009]. The method protecting the reservoir waters from phosphorus introduced from inflows are pre-reservoirs [Bendorf and Putz 1987a, Bendorf and Putz 1987b, Putz and Bendorf 1988, Lothar 2003]. Kajak [1995], referring only to pre-reservoirs, claimed that too long retention time leads to the development of zooplankton and the re-introduction of biogenic substances into the circulation. However, the same author points out that the internal load of phosphorus has a small significance in comparison to the external load. Kasza [2009] states that the inflow of phosphorus from bottom sediments is relatively low and accounts for 0.2 to 5.3% of the total external supply. He determined this fact basing on data from six analysed reservoirs. It is generally believed that the problem of re-activation of phosphorus from bottom sediments occurs mainly in the case of natural lakes. Its importance in river and lake ecosystems was widely documented by Bajkiewicz-Grabowska [2002]. Bartoszek [2007] presents a broad survey of the issues related to the release of phosphorus from bottom sediments, listing the factors influencing the course of this phenomenon, including: lowered oxygen content above the sediment layer, the existence of ions of iron and calcium, changes in pH, the participation of bacteria in the mineralisation of organic sediments, undulation etc. The author also points out that various mechanisms can contribute to the release of phosphorus, but in the case of water reservoirs in Poland this process has not been well recognised.

The question arises: what may be the reason of the high concentration of phosphates on the outflow from the main reservoir in Mściwojów, in spite of a lower concentration of these compounds in the water leaving the pre-reservoir.

In order to explain this phenomenon, the authors decided to evaluate the catchment as a supplier of biogenic matter and estimate the possibility of contamination of the reservoir with phosphorus from the sediments.

Evaluation of the catchment as a supplier of biogenic compounds

Bajkiewicz-Grabowska [2002] proposed a method of evaluating the catchment on a scale from 0 to 3 points. The final result is the qualification of the catchment to one of 4 groups of exposure to supply of matter to the reservoir. The group is determined basing on the calculation of the average value of the total points awarded.

The author of the method proposes 4 groups of exposure: group 1 – for the average value lower or equal to one, which is proof of a practical lack of possibility of matter supply to the reservoir; group 2 – for average values within the range (1.1–1.4), which suggests low exposure to the activation of the load deposited in the area and only a slight possibility of it being supplied to the reservoir; group 3 for average values within the range (1.5–1.9), which means average exposure to matter supply to the reservoir and group 4 for average values 2 and higher, where the catchment is characterised by high exposure to the activation of the load and its transportation to the reservoir.

Basing on available materials in form of maps (physical map in the scale of 1:25 000, geological map in the scale 1:50 000) and field studies conducted in the years 2000–2013 (geotechnical profiles, verification of land usage) the catchment of the Mściwojów Reservoir was evaluated in the aspect of matter supply.

Table 3 contains a list of the characteristics of the catchment that influence the eutrophication of the reservoir. Table cells containing numerical values of specific parameters or the results of descriptive evaluation for the catchment of the Mściwojów Reservoir are marked grey.

Basing on the conducted analyses and the obtained average value – 2.00 points, the catchment of the reservoir was qualified as group 4, being very prone to the movement and supply of the matter to the reservoir.

The Mściwojów Reservoir belongs to the group of medium-sized reservoirs [Radczuk and Olearczyk 2002] and, due to its size and location, it is particularly prone to matter supply from the area of its catchment, which is confirmed by the analysis conducted pursuant to the method proposed by Bajkiewicz–Grabowska [2002] for the evaluation of the catchment as matter supplier.

Calculation of the phosphorus retention coefficient in the reservoir

The next step in the course of explaining the increased concentration of phosphorus on the outflow from the reservoir was the determination of the possibility of contamination of the water in the main reservoir with phosphorus released from bottom sediments. In order to do so, the following formula [Bajkiewicz-Grabowska 2002] was used:

$$R = 1 - \frac{V_{odp} \cdot TP}{Ł_c}$$

where: R – phosphorus retention coefficient in the reservoir,
V_{odp} – annual outflow from the reservoir [m^3],
TP – total phosphorus concentration in the reservoir [mgP·m^3],
$Ł_c$ – total annual load introduced into the reservoir [mg].

Retention of phosphorus is usually determined with the use of the retention coefficient developed in 1974 by Dillon and Rigler and it is the key element of models used for predicting its concentration and the trophic status of the waters [Hejzlar et al. 2006].

Calculations were conducted for four variants: In variant I the phosphorus retention coefficient "R" was calculated for the whole reservoir. Basing on the field survey and analysis of the physical map 1:25 000, as well as the analysis of available literature [Behrendt and Dannowski 2005], it was assumed that the reservoir is prone to the influence of the area contamination from the direct catchment and to the deposition of phosphorus from atmosphere. Variant II encompassed the calculation of the "R" coefficient for the pre-reservoir supplied by a load of phosphorus introduced by Wierzbiak and Zimnik and,

Table 3. Catchment as the supplier of matter – evaluation of individual parameters

Characteristics	Number of points			
	0	1	2	3
Lake coefficient	<10	10 – 40	40 – 150 Mściwojów: 135.8	>150
Lake balance type	–	outflow	without outflow	flow–through
Density of river network	<5	0.5 – 1.0 Mściwojów: 0.83	1.0 – 1.5	>1.5
Mean slope of the catchment (%)	<5 Mściwojów: I=2.26%	5 – 10	10 – 20	>20
Drainless areas (%)	>60	45 – 60	20 – 45	<20 Mściwojów: ≅ 1%
Geological structure of the catchment	clayey, peaty	sandy, clayey	clayey, sandy	sandy
Land usage	forestry, agriculture and forestry, pasture, agriculture and forestry, pasture and forestry	forestry and agriculture, pasture and agriculture	agriculture, pasture, forestry and agriculture – developed land	forestry and agriculture – developed land, pasture and agriculture – developed land, agriculture – developed land

additionally, phosphorus originating from area sources in the direct catchment and atmospheric deposition onto the surface of the pre-reservoir. In the third variant, the main reservoir was separated, which was supplied with phosphorus by water from the pre-reservoir and the inflow from direct catchment along with atmospheric deposition of phosphorus. Variant IV was based on the assumption that the reservoir is only supplied by river load and atmospheric deposition.

The input data consist of the following:

- mean annual flow for Wierzbiak and Zimnik SQ = 0.171 m^3/s [Wiatkowski 2011],
- annual emission of phosphorus from area sources for the catchment of Kaczawa – 112.6 t P/year [Behrendt and Dannowski 2005],
- annual deposition of phosphorus from atmosphere in the catchment of Kaczawa – 1.2 t/year [Behrendt and Dannowski 2005],
- area of the catchment of Kaczawa – 2261 km^2,
- area of the direct catchment of the main reservoir – 3.5 km^2 (calculated),
- area of the direct catchment of the main reservoir – 2.0 km^2, (calculated),
- area of the pre-reservoir – 14.00 ha,
- area of the main reservoir – 20.59 ha,
- concentration of phosphates on the inflow from Wierzbiak 0.61 mg $PO_4 \cdot dm^{-3}$ [Wiatkowski 2011], share in river supply 71%,
- concentration of phosphates on the inflow from Zimnik 0.77 mg $PO_4 \cdot dm^{-3}$ [Wiatkowski 2011], share in river supply 29%,
- concentration of phosphates on the outflow from the pre-reservoir – 0.44 mg $PO_4 \cdot dm^{-3}$, [Wiatkowski 2011],
- concentration of phosphates on the outflow from the main reservoir – 0.61 mg $PO_4 \cdot dm^{-3}$, [Wiatkowski 2011],

The calculations take into account the conversion of phosphate phosphorus to total phosphorus.The following results were obtained:

- Variant I – R = 0.25,
- Variant II – R = 0.39,
- Variant III – R = -0.13,
- Variant IV – R = 0.08.

The calculated values of coefficients suggest that the quality of waters flowing out of the Mściwojów Reservoir is influenced both by internal and external phosphorus supply. The negative value of the coefficient R = -0.13, considering the area contamination and atmospheric deposition shows the significant influence of the release of phosphorus from bottom sediments on the circulation and transformations of this element in the reservoir. This process has not been analysed in this reservoir so far.

The difference resulting from the comparison of results obtained for variant I (R = 0.25) and IV (R = 0.08) proves that area contamination from direct catchment influences the water quality in the reservoir.

Long-term observations conducted by the authors on the discussed object prove that appropriate maintenance works are not performed here, neither in the sediment tank nor in the pre-reservoir, and that there is no properly managed environmental zone around the object, although it was foreseen in the design as a correctly planted and managed buffer zone capturing the contaminants from the direct catchment. The fact that the reservoir is being intensely exploited for fishing purposes – the supply of biogenic substances with bait and disadvantageous structure of fish species contribute to the deterioration of water quality. Recreational activities on the reservoir are conducted in a disorderly manner, without a sanitary base and waste management. However, cultivation of soil is maintained in the direct proximity of the water, so, in spite of the reduction of biogenic compounds in the pre-reservoir, the water is polluted by the discharge of surface waters from the arable land to the reservoir, even in average humidity conditions as occurred in the years 2006–2008. Only in the year 2008 precipitation was below the normal value and the noted deficit amounted to 5% for the south-western part of the Lower Silesian Voivodeship [Raport… 2009].

The analysis of land formation, soil conditions and field tests and observations shows that the analysed area is exposed to intense phenomena of water and wind erosion. In particular the transportation of wind erosion products from the fields directly to the waters of the reservoir on the western side (land inclination up to 2%) is noticeable, as there are no barriers for the wind in form of hills, buildings or trees. Water erosion is dominant on the eastern coast, with much higher inclinations (>8%).

All the listed factors influence the quality of water leaving the reservoir, which doubtlessly proves that not only technological solutions, such as pre-reservoirs and orderly water and wastewater management in the whole catchment area are important, but also rational management of the areas directly adjacent to the reservoir and located in its direct catchment. Works connected with the transformation of rural areas, promoting such arrangement of area structures that would perform various assigned economic functions, including the protection of water resources, should perform an important role in this aspect.

Works connected with the transformation of rural areas

New development directions for the analysed area were set by Wrocław University of Environmental and Life Sciences, emphasising the need to split monocultures and introduce tree planting in the fields [Kempa 2005], the necessity to balance the needs of agricultural production with the use of resources and assets of the natural environment. A concept of reorganisation of the agricultural production area and the introduction of new functions into the area was developed – the PROJECT "Blue Triangle" (Figure 4). It encompasses the area adjacent to the reservoir.

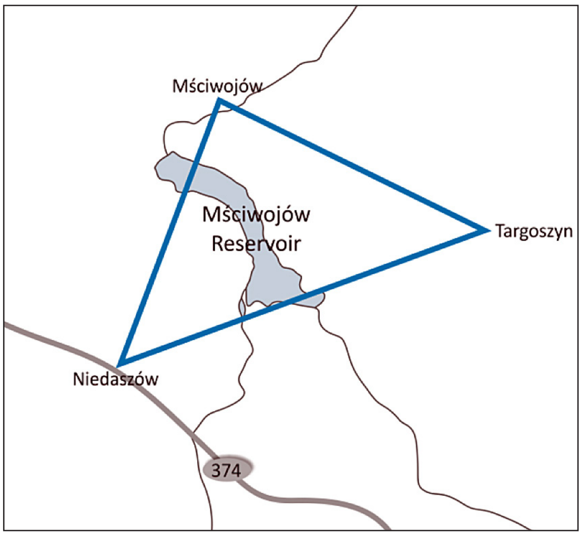

Figure 3. „Blue Triangle" - location

This concept is based on the principle that changes in the agricultural area should be introduced in a planned way and preceded by thorough studies.

A vital element of the concept is the proposal to use the palace and park complex in Targoszyn as a hotel base and to locate the Garden of the Nations here (this is an international project of the Wrocław University of Environmental and Life Sciences, which foresees the creation of a botanical garden on a plot of an area of over 18 ha), as a tourist attraction. Due to the proximity of Rogoźnica and the Museum of Gross-Rosen located there, this village can also provide a source of hotel and service facilities for potential organised trips.

Prospects of further research

The studies conducted for more than ten years were mainly aimed at the verification of the applied design solution and the correctness of the operation. The scope of future studies should encompass broader research on sediments, taking into account also interstitial water, a detailed analysis of taller plants overgrowing the area adjacent to the water course and the reservoir with reference to specific environmental zones, as well as communities of blue algae and algae, including phytoplanctone, periphyton and epiphyton as well as benthos organisms. The quantitative and qualitative aspects of ichtyofauna are also worth noting. Such research works should be aimed at the determination of the role of living organisms in the phosphorus circulation process. This will provide an opportunity to solve the problem of internal supply of phosphorus to the main reservoir.

Studies on the catchment of the reservoir should focus on model and simulation works, based on documented results of field studies. Such activities would result in some proposals, suggesting the optimal management of the catchment of the reservoir in the environmental and economic aspects.

In further perspective, it only seems natural to broaden the scope of research to encompass the whole catchment of Wierzbiak of an area of 273.4 km^2 according to the Hydrographical Map of Poland (MPHP) and to conduct such studies that would lead to the determination of principles of effective water management, taking into consideration flood protection and the threat of failure of hydrotechnical constructions [Sobota et al. 2009], and to the development of a dynamical water economic balance of the catchment that would encompass the hierarchy of needs of various users. This would lead to the creation of water management and environmental framework for spatial development, which would be able to rationally manage the environmental resources for the purposes of the development of economic activity, settlement, infrastructure, as well as the needs of the nature itself.

CONCLUDING REMARKS

The design of the reservoir is a result of several years of researchers' work. The over ten-year operation period of the reservoir presented in this article along with research carried out simultaneously constitutes a certain stage, whose end is the completion of the construction of sewage networks for settlements located in the upper part of the reservoir catchment. Wastewater from Goczałkowo, Kostrza, Rogoźnica, Żółkiewka and Wieśnica will be transported to the developed wastewater treatment plant in Strzegom, and then to the Strzegomka River (left-side tributary of Bystrzyca). This solution will certainly contribute to lowering negative influence of point contamination on the water quality in Wierzbiak, and thus in the Mściwojów Reservoir.

However, the reservoir will still be exposed to area contamination resulting from the nature of the catchment (class 4 of exposure). As shown by the conducted estimate calculations, in certain circumstances the contamination from direct catchment may eliminate the beneficial influence of the sediment tank and the pre-reservoir. This proves doubtlessly that any solutions aimed at the improvement of water quality directly connected with the water reservoir as an object of main focus, are, in a sense, of an ad-hoc nature, as the key to the solution is broader perspective of the problem.

The introduction of the reservoir into an agricultural area and the creation of a research base in its catchment had a positive influence on the local community. It led to the development of tourism and agro tourism, along with recreational opportunities at the reservoir. Projects conducted by academic entities create an opportunity for development for towns and villages located in the proximity of the reservoir. However, recreational activities at the reservoir have to be more orderly: a sanitary base and waste bins are needed in order to avoid potential threats to water quality.

Future works should be extended so as to cover all elements of the ecosystem of the reservoir. In a longer term it seems natural to extend the research works to cover the whole catchment of Wierzbiak River.

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