Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2013.768043

51 (2013) 4194–4206
May

Taylor & Francis
Taylor & Francis Group

Waterpraxis as a tool supporting protection of water in the Sulejow Reservoir

Aleksandra Zieminska-Stolarska*, Ireneusz Zbicinski, Miroslaw Imbierowicz, Jerzy Skrzypski

Faculty of Process and Environmental Engineering, Lodz University of Technology, Wolczanska 213 Street, 90-924 Lodz, Poland
Tel. +48426313709; email: zaleksandra@tlen.pl

Received 1 February 2012; Accepted 18 September 2012

ABSTRACT

The main aim of this article is to present results of the Waterpraxis project and to share the project experience. The Waterpraxis project entitled "From theory and plans to eco-efficient and sustainable practices to improve the status of the Baltic Sea," partly funded by the EU Baltic Sea Region Program 2007–2013, focuses on developing water management practices, as well as on preparing water protection action plans and measures for selected pilot sites around the Baltic Sea to meet environmental objectives of the Water Framework Directive (2000/60/EC). Waterpraxis identifies needs for improvement of current water management practices and, on the basis of experience gathered during the project, proposes also some changes to current practices. In addition, it provides improved water management action plans and makes it possible to prepare a set of investment plans for selected measures in the project's pilot areas in Poland, Lithuania, Denmark, and Finland. The study area in Poland is the Sulejow Reservoir (Lodz Region, Central Poland). The artificial reservoir is a typical shallow lowland water body covering a large area and is particularly prone to eutrophication, which is determined by a relatively long retention period, shallow depth, and the impact of the inflow of rivers and the direct basin. As a result, the project provides a significant improvement in the level of protection of the local environment. Implementation of the project will also have a positive impact on the standards of living and business environment in the area of the Sulejow Reservoir. It will also contribute significantly to improving quality of life in the area and raise environmental awareness among both local authorities and inhabitants.

Keywords: Sulejow Reservoir; Waterpraxis project; Eutrophication; Action plans

1. Introduction

Water (in particular fresh water) resources, characterized by high quality, are a necessary element for the development of ecosystems. Low water quality limits the possibility of its application for particular purposes, including the needs of industry, tourism, and supplying the population with water for consumption. Poland is classified as a country with poor water resources, which is lagging far behind other

*Corresponding author.

The Sixth Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2011), 25–29 September 2011, Dubrovnik, Croatia

1944-3994/1944-3986 © 2013 Balaban Desalination Publications. All rights reserved.

European countries. The average annual runoff of surface waters from the Polish territory (including the inflow from abroad 7 km^2) in 2000–2008 amounted to 58.9 km^2. Surface water resources, the quantity of which is defined as the mean long-term runoff, are about 1,600 m^3/year per capita on the average, whereas in European countries, the average surface water resources are estimated to be 4,560 m^3/year per capita. The basic problem in the area of supplying population with water is the small availability of water of high quality, whereas due to the clear decrease of consumption in industry and households, the problems with quantity have become much less important. The quantity of surface water resources varies in time, both over a long-term period and within a given year. In dry years, the index of the resources falls to 1,100 m^3/year/capita, whereas in wet years, maximum levels of 2,600 m^3/year/capita were observed. Thus, the large variability makes it difficult to manage surface waters in a rational way and the relatively low retention capacity of artificial reservoirs (about 6% of the mean annual runoff—compared with 12–15% in the neighboring countries) does not allow for elimination of the problems arising from periodical surpluses and deficits of surface waters.

A dammed reservoir represents the unique ecosystem that was created by the imposition of the natural characteristics of the aquatic ecosystem of the river feeding the reservoir and the modification of the natural condition caused by human interference. It is a sedimentary area of mineral matter, organic matter and pollutants carried by the inflow of rivers, which increases its rate of degradation. The character and magnitude of these changes depend on the features of the reservoir: surface, shape, depth, expansion of the littoral zone, water-level fluctuations as well as size and quality of the river on which it was created [1].

In Poland, there are more than 100 reservoirs, with a total surface area of about 350 km^2, representing approximately 0.11% of the Polish territory. By regulating the flow, most reservoirs serve the purposes of flood control and make it possible to raise the minimum water level in the river in the course of drought. Some dammed lakes also play important economic functions—supplying drinking water to large urban agglomerations. They enable the production of low-cost and environmentally friendly electricity, fish farming, as well as create new landscape features and enhance the attractiveness of the areas adjacent to the reservoir. Water quality in lakes and reservoirs undergoes continuous degradation caused by natural processes resulting from eutrophication and due to anthropogenic reasons. On the other hand, the diversity of needs and priorities by which surface waters are assessed is remarkable. The scale of the problem is reflected by, for example cyanosis water blooming. This problem affects primarily eutrophicated (rich in nutrients) lakes and reservoirs [2].

Eutrophication caused by nutrient loads is one of the most serious problems observed in the European freshwaters. Although there are practical measures to restrict them, the implementation of river basin management measures as envisaged in the EU Water Framework Directive is still deficient. Waterpraxis focused on developing water management practices, as well as on preparing water protection action plans and measures for selected pilot sites around the Baltic Sea Region (BSR). The project was carried out with transnational cooperation among authorities and scientific partners and led to concrete improvements in sustainable river basin management in the region. The main idea of Waterpraxis was that by better understanding the problems and constraints, long-term solutions and concrete pilot investments could be identified. The project partnership consists of research organizations, universities, local authorities and NGO's from Denmark, Finland, Poland, Germany, Latvia, Lithuania and Sweden. By putting River Basin Management Plans (RBMP) into practice, the goal of good ecological status should be achieved in all European waterbodies by 2015. However, remarkable gaps and barriers have been identified which stand in the way of general-level RBMPs, action plans at local scale and real investments. Thus, when aiming at the rehabilitation of the whole Baltic Sea, there are many harmonization needs in water management practices in the transnational cooperation between different BSR countries. First, there might be a lack of understanding of the importance of water resources protection and the practical measures available. Furthermore, the measures proposed in several cases are neither cost- nor eco-effective, and the measures proposed on a general level may not gain common acceptance on a local level. Also, it is difficult to get financing for investments. There are also many new challenges arising. New EU directives related to water management will come into force, a fact which suggests that prompt action should be taken so as to ensure the long-term quality and sustainability of water resources.

2. Study area—Sulejow Reservoir

The Sulejow Reservoir (Fig. 1) is situated in central Poland in the middle reach of the Pilica River. The reservoir is located on the territories of four communities: Wolborz, Sulejow, Tomaszow Mazowiecki, and Mniszkow. The drainage basin of the reservoir

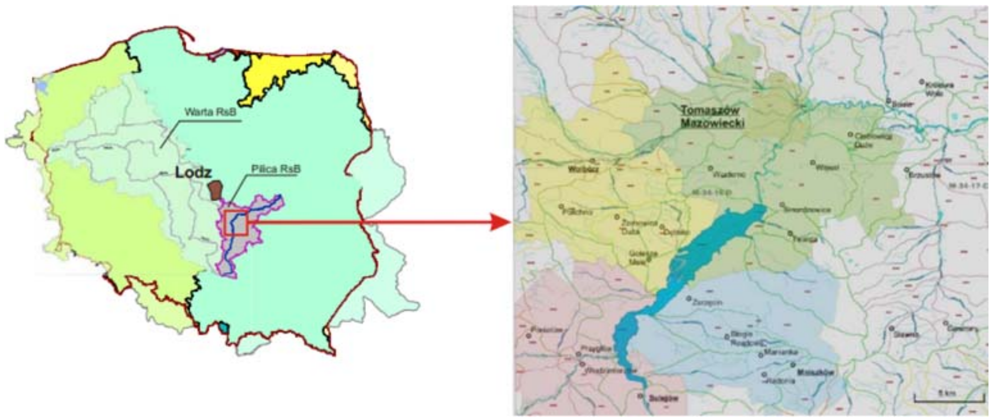


Fig. 1. Sulejow Reservoir and the four communities (Wolborz, Tomaszow Mazowiecki, Mniszkow and Sulejow) responsible for preparing the environmental protection plans (action plans) in the target area.

comprises a farm (64%) and forest (30%) area. Sulejow Reservoir was created by impounding the Pilica River in 1973. It is a typical lowland, low volume reservoir with major fluctuations of water level [3].

The Sulejow Reservoir is a shallow water body with large areas emerging when water levels are low. The retention time ranges from a dozen to four dozen days and its main axis runs from south-west to north-east. This is close to the direction of winds that ripple and mix the water. As a result, the continuous restructuring of the littoral zone and the basin shoreline takes place. For nearly 30 years, the main function of the Sulejow Reservoir was supplying the city of Lodz and Tomaszow Mazowiecki with drinking water, however, problems with water quality restrict this function nowadays. The reservoir still serves as a recreational area but the occurrence of toxic algal blooms may further restrict its use. In 2004, the water company operating the drinking water facility stopped water abstraction from the reservoir intake and switched to wells. But the reservoir is still the main drinking water intake for the city of Tomaszow Mazowiecki. The water body is currently utilized for flood-control purposes. It enables sailing, canoeing and windsurfing as well as fish farming and power generation. The dam in Smardzewice village has three weirs and a hydroelectric power station built inside it with the power output of 3.6 MW. The reservoir is defined by the following parameters:

- length—17.1 km,
- maximum width—2.1 km,
- average width—1.5 km,
- average depth—3.3 m,
- maximum depth—15 m,
- shoreline length—58 km,
- surface area—22 km^2,
- usable capacity—61×10^6 m^3,
- maximum capacity—75×10^6 m^3,
- drainage basin area—4 900 km^2.

The major source of the actual state of the Sulejow Reservoir eutrophication is the excessive quantity of nutrients, particularly phosphorus compounds flowing both from single-point and diffuse sources. It is determined by relatively long retention period, shallowness, permeable basin substrates of the Pilica and Luciaza rivers and the district basin of the reservoir. The concentrations of nutrient indicators are within the norms for Class II in the Pilica and class III in the Luciaza River (Table 1). The Pilica River is the longest left-tributary of the Vistula River (the major river of

Table 1
Concentrations of selected water quality parameters for the two main tributaries of the Sulejow Reservoir

River	Total phosphorus ($mg\,P/dm^3$)	Total nitrogen ($mg\,N/dm^3$)	BOD ($mg\,O_2/dm^3$)	Nitrate ($mg\,NO_3/dm^3$)
Pilica–Sulejow	0.14	2.8	3.4	8.58
Luciaza–Przygłow	0.133	3.4	2.4	11.83

Source: Voivodeship Inspectorate for Environmental Protection in Lodz (2007).

Poland). It has the length of 342 km and catchment area of 9,258 km^2. It has mostly natural character; however, the quality of water is impacted by both point sources of pollution (mostly from the towns of Koniecpol and Przedborz) as well as non-point sources of pollution resulting from agricultural use of over 60% of the catchment area. The concentration of total phosphorus in the river usually ranges from 100 to 300 μg/l; however, in certain hydrological situations, it may amount to as much as 700 μg/l. The quantity of phosphorus absorbed from rivers is one of the major causes of the eutrophication; however, recreational areas and flows of rain water can accelerate the processes of eutrophication as well. Water quality in the Pilica River is mostly determined by its inflows. One of these is the Luciaza River which poses a great threat to the Pilica water quality. The Luciaza river is mostly affected by point sources of pollution due to the higher urbanization and collection of storm water of a town of approximately 77,000 inhabitants (Piotrkow Trybunalski). In addition to the pollutants that enter with these river waters, the reservoir is heavily polluted by point sources in its catchment area: the intermediate pumping station at the village of Podklasztorze, the water treatment facility in the town of Sulejow, and also by three bathing spots located in Zarzecin, Bronislawow, and Borki (Fig. 2). The physicochemical analyses of the water indicated that diverse pollutant concentrations occur in the reservoir. The basic indicators that determine water quality belonged to purity class I, although several of them, such as BOD_5, COD_{MN}, COD_{Cr}, suspended matter, nitrates, phosphates, total phosphorus and manganese, are at values that correspond to classes II and III [1]. Thus, the overall water quality in the reservoir does not conform to the specifications of purity class I [2].

Eutrophication, a biological response to the excess input of nutrients into a waterbody, can arise rarely under natural conditions, but it is more commonly recognized as a consequence of human activities [5]. Resulting increases in cyanobacterial, algal, and plant biomass in waterbodies may reduce water quality in terms of human water-uses, such as increased turbidity and particulate matter resulting in the blockage of water-filters and the production of taste and odor compounds in drinking water [6]. Moreover, mass appearance of blue-green algae disqualifies the reservoir as a recreational area. Eutrophication also results in a reduction of species diversity in waterbodies at all trophic levels. The eutrophication of the Sulejow Reservoir is connected with the problem of toxicity of cyanobacterial blue-green algal blooming. The main species responsible for the algal bloom formation in the Sulejow Reservoir is *Microcystis aeruginosa* [7]. Toxins (cyanotoxins) which are produced by freshwater cyanobacteria can be classified as four main groups: hepatotoxins, neurotoxins, cytotoxins, and dermatotoxins. *Microcystin-LR*—the best known toxin produced by cyanobacteria—is classified as hepatotoxin [8,9]. It may have cancerous and toxic effect on humans, by degrading liver cells, damaging the nervous system or irritating respiratory muscles. Toxins of blue-green algae are very stable substances. This makes them impossible to decompose by the effects of bile acids, digestive enzymes, and boiling water. Long-lasting consumption of even little doses of algae toxins contained in drinking water can lead to increased incidence of liver cancer and susceptibility

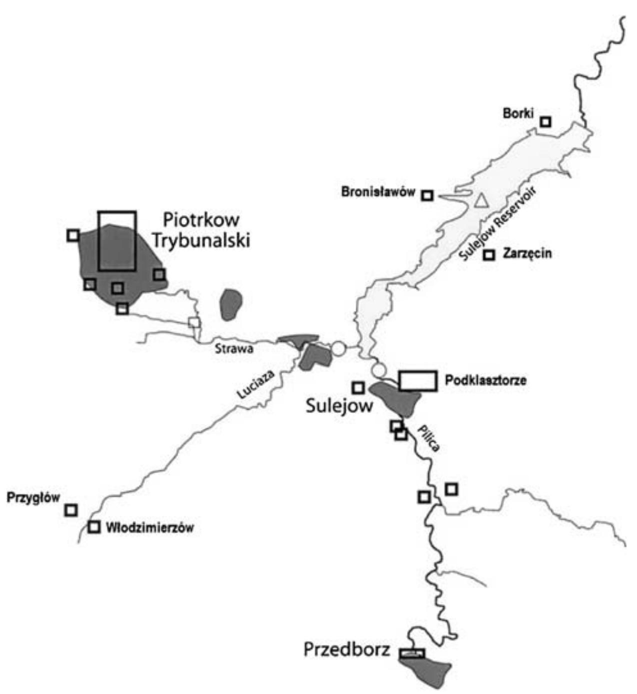


Fig. 2. Location of the main point sources of pollution in the Sulejow Reservoir. Source: [4].

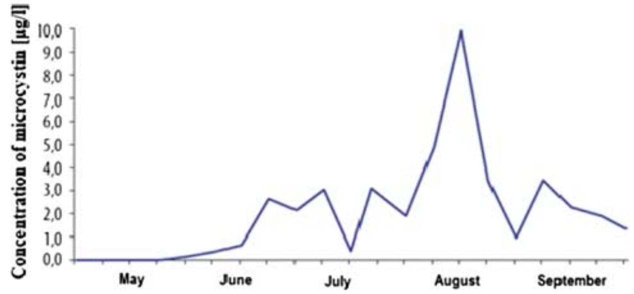


Fig. 3. Seasonal transience of microcystin from May to September 2008. Source: [1].

to other tumors. Chronic exposure to low concentrations of microcystins in drinking water can lead to cancer promotion. Moreover, the diversity of produced toxins complicates monitoring of freshwaters. In the Sulejow Reservoir, physicochemical conditions such as water temperature above 18˚C, pH between 6 and 8, and low N/P ratio support cyanobacterial bloom occurrences especially during the summer (Fig. 3). A strong correlation between the biomass and concentration of microcystins indicates that the increase in phosphorus concentration stimulating cell growth of cyanobacteria also indirectly affects the increased concentration of microcystins. In light of the analyses over many years, particularly worrying is the increasing load of phosphorus in the recent years and especially the persistence of high concentrations of overall phosphorus during the summer (Fig. 4) [1].

In 2008, the Sulejow Reservoir was inspected by the Provincial Inspectorate of Environmental Protection in Lodz with the branch office in Piotrkow Trybunalski as part of the diagnostic monitoring. Furthermore, water analysis was performed paying special attention to fish habitat and to special exploitation of water in order to provide drinking water supplies. The measurements were taken three times in June, August, and September at four measuring and monitoring stations:

- Barkowice Mokre (No. 1)—150.0 km (upper part of the reservoir),
- Zarzecin (No. 2)—145.0 km,
- Bronislawow (No. 3)—142.9 km,
- Tresta (No. 4)—137.0 km (at the outlet of the reservoir).

Location of the measuring stations in the monitoring network is shown in Fig. 5.

The analysis of water in the Sulejow Reservoir was carried out according to the directive of the Ministry of Environment of 27 November 2002 on requirements

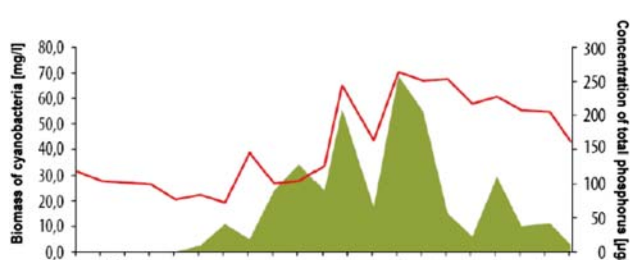


Fig. 4. Seasonal variability of the biomass of cyanobacteria [mg/l] on the variability background of total phosphorus concentrations [μg/l] in 2008. Source: [1].

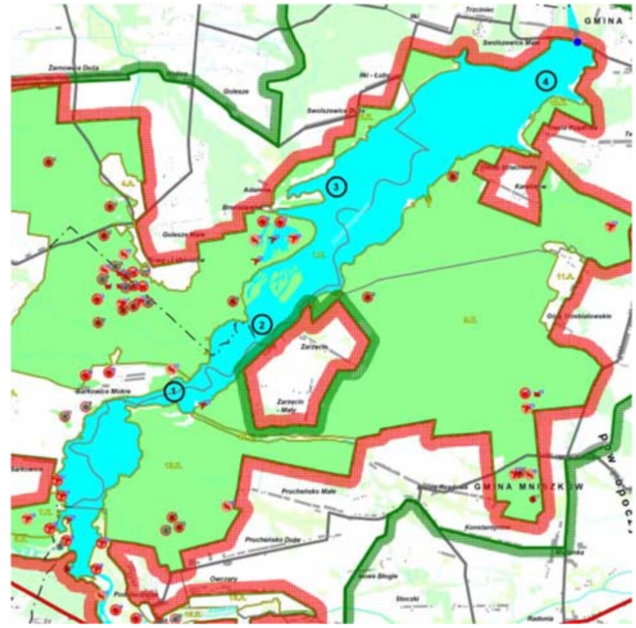


Fig. 5. The location of measuring stations in the network of water quality monitoring in the Sulejow Reservoir (Barkowice Mokre—no. 1, Zarzecin—no. 2, Bronislawow—no. 3, Tresta—no. 4). Source: [10].

for surface waters used for the supply into water intended for consumption (*Journal of Laws of the Republic of Poland* No. 204, item 1,728) [10]. According to the analysis performed, the predominant number of parameters examined at separate stations met the normative requirements of water quality class I and II. However, single indicators repeatedly had the values of higher (worse) classes. This group comprises colors, BOD_5 (class III or IV), and cadmium and those with class III standards were oxygen absorption indicators such as COD_{Mn} and COD_{Cr}. Some metals (manganese, lead, iron, and mercury) occasionally fell into class IV and V. Total Kjeldahl nitrogen indicator was also determined by high concentrations corresponding mainly to class IV. Taking into consideration that the indicator belongs to the group of nutrients which are fertilizing factors being in favor of phytoplankton growth and increase in water eutrophication, such a situation was unfavorable (Fig. 6).

Concentrations of other determined biogenic substances—nitric and phosphoric—mainly fell into the range of normative classes I–II, less often into class III. The average concentrations of phosphorus compounds in the Sulejow Reservoir are shown in Fig. 7.

The concentration of chlorophyll a differs in each part of the reservoir. The highest concentration amounting to 154.66 μg/l (class V) was recorded in Bronislawow in August. High concentrations were recorded in August and September in Tresta (45.38

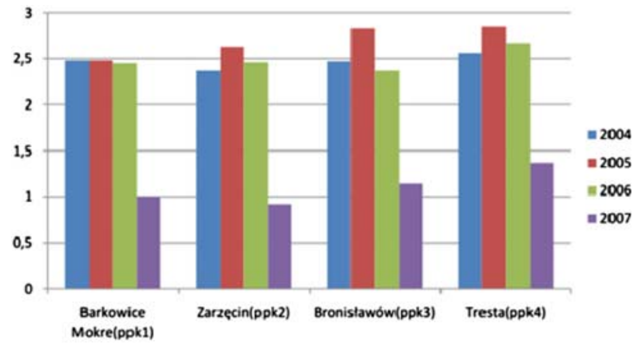


Fig. 6. The average concentrations of nitrogen compounds in the Sulejow Reservoir in 2004–2007. Source: Voivo deship Inspectorate for Environmental Protection in Lodz.

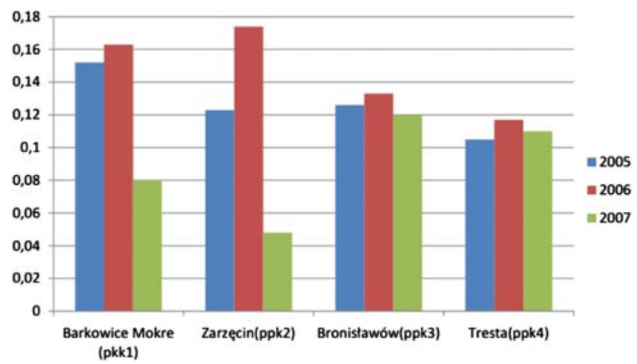


Fig. 7. The average concentrations of phosphorus compounds in the Sulejow Reservoir in the years 2005–2007. Source: Voivodeship Inspectorate for Environmental Protection in Lodz.

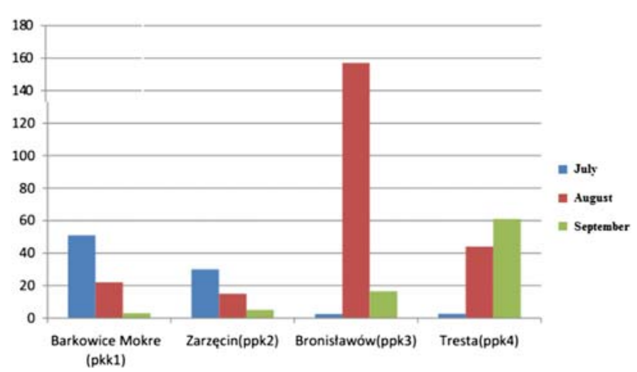


Fig. 8. The average chlorophyll a concentrations in the Sulejow Reservoir water in 2007. Source: Voivodeship Inspectorate for Environmental Protection in Lodz.

and 61.79 μg/l, respectively). In other monitoring periods the chlorophyll concentration values remained within class I and II. Chlorophyll a concentrations determined in the reservoir in 2007 are shown in Fig. 8.

The conducted analysis showed that the standards were met in neither of the stations. The analysis conducted in terms of provision of consumption water showed that water quality in the reservoir fell into II category only in the profile of Barkowice Mokre. At other stations, the water quality did not meet the requirements of either I to III classes. However, it needs to be highlighted that it was determined by the following indicators: BOD_5 (Bronislawow), mercury (Zarzecin and Tresta), and lead (Zarzecin). The overwhelming majority of parameters ranged within the values acceptable for I and II categories. According to the comparison, in 2005–2009, water quality deteriorated substantially at the Sulejow Reservoir—Tresta (4) station and a transition from class III to IV occurred. The results of the analysis show that the most significant problem concerning reservoir functioning is the poor quality of water due to the eutrophication processes. In order to enhance water quality, certain actions concerning reduction of stationary and diffuse pollution in the Pilica basin above the reservoir must be taken, particularly to reduce phosphates flowing into the reservoir [11]. Accordingly, the activities must be taken with the aim of enhancing the surface water quality by means of complex equipping the Sulejow Reservoir area with the technical infrastructure of environmental protection (sewage system and purification plants) and waste management.

The most important problems encountered in the region of the Sulejow Reservoir that need to be solved are as follows:

- construction pressure in the area surrounding the reservoir and in the Pilica valley,
- insufficient technical infrastructure development (including sewage systems), and
- insufficient ecological status of water of the Pilica River and the Sulejow Reservoir.

The above-mentioned threats and factors influence significantly the ecological status of the Sulejow Reservoir water, biological and landscape diversity, and cultural values of the area in question.

3. Materials and methods

The analysis concerning the Sulejow Reservoir environmental condition, threats and conflicts influencing the environmental pollution, makes it possible to set a list of objectives that must be achieved in order to improve the environmental condition of the region. Table 2 shows the set of objectives established by the communes of Wolborz, Tomaszow Mazowiecki, Sulejow and Mniszkow while drawing up the reparation action plans and environmental protection programs for the years 2004–2010.

The set of objectives shown in Table 2 can be used for the assessment of effectiveness of the reparation action plans and environmental protection programs outlined in the respective communes. The set indeed includes all the elements essential for the improvement of the environmental condition ranging from the issues concerning the Sulejow Reservoir protection against water pollution to environmental consciousness and the protection of cultural values.

It should be stressed that a successful accomplishment of the objectives presented in Table 2 would solve most of the problems faced by the region including the problems connected to the strong pressure for building development in the areas surrounding the reservoir and the Pilica valley, insufficient development of technical infrastructure (including sewage systems) and the unsatisfying environmental condition of the Pilica River and the Sulejow Reservoir.

In 2004–2010, the communes of Wolborz, Tomaszow Mazowiecki, Sulejow and Mniszkow specified environmental protection programs and reparation action plans whose realization aims at improvement of the Sulejow Reservoir environmental condition. Such actions are environmentally-oriented with the objectives specified in Table 3.

The set of actions and enterprises currently being realized in the respective communes is shown below along with the preliminary assessment of realization of these actions. The extent of the task realization has been assessed pursuant to the meetings and talks held with the authorities of the respective communes, investment documentation and private observations. The task realization has been assessed according to the following 4-point scale:

- the task has been completed according to the assumptions made (VG),
- the task is currently being realized and its realization is almost completed (G),
- the task is being realized, however, its realization is in the initial phase (P),
- the task realization has not been initiated yet (B).

The above-mentioned scale allows us to assess the extent of realization of the environmental protection program in the respective communes and to determine the extent of accomplishment of objectives in the region of the Sulejow Reservoir.

Based on the data on the realization extent of tasks and environmental protection programs in the respective communes, their efficacy in raising funds and managing investment undertakings can be assessed. Such an analysis enables the assessment of delays in the realization of the environmental protection programs. The table below shows the realization status of the most significant tasks arising from the programs of the respective communes in the Sulejow Reservoir [9].

The data from Table 3 show that the progress in realization of some tasks in the analyzed area is satisfactory. The tasks in question concern land use in the region of the reservoir (setting the protection zone for all the underground water intakes, building development ban in 100 m wide zone along the reservoir banks or in the areas liable to flooding) and flood control in the same area (introduction of a flood-control system for the Pilica River). There is considerable progress in the realization of the serious task of development of the commune sewage system together with local or municipal sewage treatment plants, which is crucial for water protection in the Sulejow Reservoir. However, a huge backlog and delays occur in the realization of other crucial tasks such as biological housing of watercourses and bodies of water and removing illegal sources emitting unpurified wastewater to surface water, building individual sewage neutralizing devices or septic tanks. The realization of the tasks involving introduction of farm and environmental programs or "greening agricultural production" also encounters difficulties connected with low environmental consciousness of local farmers.

In Poland, the key task in the planning process appears to be strengthening the dialog between respective authorities responsible for sectorial policies. It is also essential, in order to maintain a good ecological status for water quality, that a dialog takes places between experts and stakeholders so as to ensure a proper balance between the various methods of water use and water resource protection. A variety of tools were used which were intended to inform the public and interested groups and to collect comments and opinions. These included surveys, articles in the national and regional press, information provided in the press, on the radio, television and Internet, meetings with local authorities and seminars.

4. Risks assessment

One of the most serious threats to the environment in the reservoir's drainage basin is the insufficient development of technical infrastructure and unresolved sewage management in the areas adjacent to the Sulejow Reservoir. The average degree of cities

Table 2
Objectives established for environmental protection program and action plans concerning the Sulejow Reservoir region (according to the Environmental Protection Program established for Sulejow Landscape Park in 2006)

ID	Objectives	Wolborz	Tomaszow	Sulejow	Mniszkow
	I. Water management and water protection				
1	Surface and underground water protection, improvement of ecological status of the surface water	√	√	√	√
2	Increasing safety of areas liable to flooding			√	
3	Water balance improvement	√	√	√	√
4	Protection of peat and water ecosystems	√	√	√	√
	II. Technical infrastructure development				
5	Reduction in degradation and anthropogenic threats within the sphere of water and earth protection	√	√	√	√
6	Reduction in air and acoustic climate degradation	√	√	√	√
	III. Farm management and woodless systems protection				
7	Restoration of woodless ecosystems	√		√	
8	Shaping the diversification of agricultural landscape and its expansion	√		√	
9	Protection of traditional varieties of crop plants, trees and fruit bushes	√	√	√	√
	IV. Fishing and hunting management				
10	Protection of well-balanced species structure in waters of Pilica, Luciaza and Czarna Maleniecka	√	√	√	√
11	Making rivers passable		√	√	
12	Game protection	√	√	√	√
	V. Forest management and protection				
13	Shaping well-balanced structure of tree stands	√	√	√	√
14	Maintaining riparian forests at river beds			√	
15	Shaping new ecological junctions of the system	√	√	√	√
	VI. Flora and fauna protection				
16	Reconstruction of degraded water habitats	√	√	√	√
17	Protection of native species of plants	√	√	√	√
18	Improvement of water conditions within Bronisławow Water Intake (UE)	√		√	
19	Providing ecological continuity of corridors, removing barriers for animals	√		√	
20	Protection of endangered species of plants and animals	√	√	√	√
	VII. Nature conservation				
21	Management of protection activities in nature reserves	√	√	√	√
22	Setting up new nature reserves "Bory nad Pilica," "Pruchensko"			√	
23	Forming 3 natural and landscape complexes: "Dolina rzeki Luciazy," "Dolina Radonki", and "Dolina Czarnej Malenickiej"			√	
24	Establishment of 32 natural features of historic importance	√	√	√	√
25	Establishment of ecological use			√	
26	Establishment of documentary sites			√	
	VIII. Tourism and recreation				
27	Protection of the Park area from undesirable tourist penetration	√	√	√	√
28	Maintaining tourist trails	√	√	√	√
29	Building new trails and bicycle lanes	√	√	√	√
30	Development and promotion of farm tourism	√	√	√	√

(*Continued*)

Table 2
(*Continued*)

ID	Objectives	Wolborz	Tomaszow	Sulejow	Mniszkow
	IX. Environmental education				
31	Raising environmental consciousness of local communities particularly of children and young people	√	√	√	√
X. Protection of cultural and landscape values					
32	Establishing close conservation for Cistercian complex in Sulejow Podklasztorze			√	
33	Maintaining and restoring values of the cultural landscape			√	
34	Protection of archaeological sites	√	√	√	√
35	Maintaining buildings of historical interest			√	
36	Protection of historic spatial layouts in Barkowice Mokre, Winduga, Dabrowa and Czarna			√	
37	Protection of natural forest and valley scenery	√	√	√	√

and communities sewerage system in that area accounts for 40%. For comparison, a degree of the inhabitants' access to the sewage system is approximately 85% (Table 4). The analyzed area requires sewage management to be urgently reorganized and adapted to the developed drinking water supply system.

About 64% of the catchment area is used as agricultural land and about 30% is covered by forests. A sanitary system has not been developed completely around the reservoir, which facilitates sewage discharge and direct surface flows to the water body. Reservoir waters are marked by high oxygenation along with supersaturation in the bloom period. During the period of strong growth of phytoplankton, alkalization in the reservoir is observed. As a result, across the reservoir, nutrients are desorbed from bottom deposits, which periodically contribute to the mass growth of algae, particularly their blue-green genus.

Among other threats, land management is one of the main causes of strong anthropogenic pressure affecting biological diversity, landscape values and the environmental condition of the areas around the Sulejow Reservoir. The availability of communications and environmental attractiveness make the region susceptible to the pressure of unregulated development. Leisure centers, camping sites and catering facilities attracting increasing numbers of tourists have been widely developed.

Excessive parceling up of land into small holiday plots accompanied by high-density housing can lead to a real threat to the quality and condition of the environment in the area of the Sulejow Reservoir and the Sulejow Landscape Park. The newly-constructed facilities hardly ever meet environmental standards, additionally their scale and architectural form do not correspond to the traditional architecture of the region.

The environmental threats are also caused by farming management. The latter's impact on the environment is associated with the chemicalization of agricultural production, ill-equipped farms lacking appropriate technical infrastructure (sewage systems) and the lack of application of good agricultural practices. Another aspect of this issue is the transformation of landscape from an agricultural function to a recreational one, which leads to biodiversity reduction and increase of anthropogenic pressure in the region of the Sulejow Reservoir.

In order to maintain natural and environmental values it is essential to keep the existing, traditional character of the agricultural production in this area. Accordingly, fertilizers for plant protection must be applied, mineral fertilizing should be adjusted to local needs and as regards stockbreeding, the number and concentration of livestock should be adapted to the possibilities of manure management. It requires the reduction in or even a ban on locating large farms in this area, especially those operating in non-bedding system. It should be highlighted, however, that actions concerning farm management are environmentally and legally demanding and they can only influence the sphere of environmental consciousness.

The analysis of threats and conflicts occurring in the area allow for the construction of a matrix of pressures and impacts influencing water quality at the Sulejow Reservoir. The matrix shown in Table 5 illustrates the relationship between the environmental condition of water and factors causing deterioration of its quality and determines the objectives of environmental protection programs for the given area [11].

A very important obstacle to the correct management of the reservoir is the complex system of

Table 3
Assessment of the realization extent of selected tasks in the environmental protection programs identified by the communes surrounding the Sulejow Reservoir

	Measures/Tasks	Wolborz	Tomasz.	Sulejow	Mniszkow
	I. Water management and water protection				
1	Management of sewage system in the Basin of Pilica River and the Sulejow Reservoir	G	G	G	P
2	Building community sewer system together with local or communal sewage treatment plants	VG	G	G	P
3	Removing illegal sources emitting polluted/untreated wastewater to surface water, building individual sewage neutralizing devices or septic tanks.	P	P	P	P
4	Ban on building development at 100 m wide zone along the reservoir banks	G	G	G	G
5	Biological housing of watercourse and bodies of water which prevents their eutrophication and degradation	B	B	B	B
6	Introducing of flood-control system for Pilica River	VG	VG	VG	VG
7	Ban on building development on areas liable to flooding	G	G	G	G
8	Introducing protection and reconstruction programme of small ponds, bogs and marshes	P	P	P	P
9	Restructuring improvement devices in the scope of irrigation	B	B	B	B
10	Setting protection zone for all underground water intakes	G	G	G	G
11	Maintaining and modernizing technical infrastructure supporting water retention	P	P	P	P
12	Introducing the ban on mowing, cattle grazing and peat-bogs draining	P	P	P	P
13	Maintaining and modernizing technical infrastructure supporting water retention	P	P	P	P
	II. Technical infrastructure development				
15	Constructing community sewer system in the following areas: Barkowice, Nowa Wies, Koło, Lubiaszow, Swolszewice, Ostrow, Taraska, Stobnica	G	G	P	P
16	Building sewage treatment plant in Koło, Żarnowica, Stary Niewierszyn, Szarbsk, Skotniki, Trzy Morgi, Pociosk, Łęg Ręczyński	G	G	P	P
17	Modernization of the provincial road 8, 74, 12	P	P	P	P
18	Introduction of biological housing tract (afforestation)	G	G	G	G
	III. Farm management and woodless systems protection				
20	"Greening" agricultural production	P	P	P	P
21	Moderate grazing and natural turf mowing, cutting down the trees, bushes and sowing	G	G	G	G
22	No afforestation and no meadows draining especially forest clearings	-	-	-	-
23	New mid-field, waterside and roadside afforestation	P	P	P	P
24	Country greenery protection	-	-	-	-
25	Maintaining marginal habitats– baulks, mid-field boggy areas, small ponds	G	G	G	G
26	Maintaining and reconstruction of old orchards with traditional varieties of trees	P	P	P	P
27	Maintaining the diversity of species in agricultural usage along with traditional farming and plants cultivation	G	G	G	G
28	Implementation of farm and environmental programmes	B	B	B	B

Source: [9].

governance. This applies both to areas around the lake and to reservoir waters. In addition, an insufficient amount of funds provided for the needs of municipalities (expansion of water and sewage system, building and modernization of sewage treatment plants or building ecotone zones) significantly delays investments that are crucial for maintaining good reservoir water quality.

Numerous studies and research articles have shown that pollution is reducing the quality of water in the Sulejow Reservoir (primarily nutrients) causing secondary pollution, which is carried not only by water of the Pilica and Luciaza rivers but also by direct run-off of surface rainwater and contaminated groundwater. Especially, dangerous for the quality of the reservoir water are periods of low flows and high temperatures. In summer, the supply from groundwater increases significantly and these waters are most polluted due to the increase in the number of people vacationing at the lake.

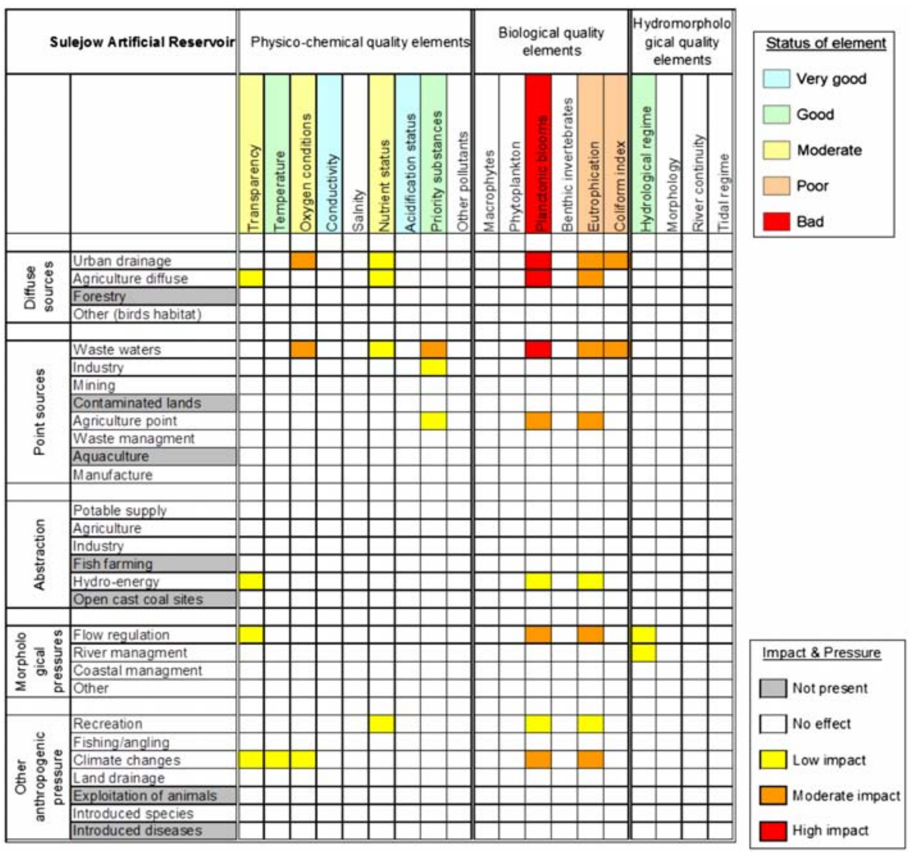
In addition to standard investment activities aimed at comprehensive wastewater management of the

Table 4
The length of sewerage and water supply network in municipalities situated around the reservoir

Community	Water supply system % and length of the water supply system		Sanitary sewer % and length of the sanitary sewer system	
Mniszkow	81.9%	100 km	23.1%	23.6 km
Sulejow	80.9%	181.2 km	22.9%	24.4 km
Wolborz	85.7%	124.2 km	40.8%	30.2 km
Tomaszow Mazowiecki	90.9%	167 km	77.9%	88.3 km

Source: Central Statistical Office of Poland, 2011.

Table 5
Matrix of pressures and impacts for the Sulejow artificial reservoir



Source: Authors' own elaboration.

surrounding municipalities and improving the conditions of land development, it would also be significant to reduce the deposition of phosphorus compounds in the areas contributing to the flow of nutrients from fields. Among the proposed activities, a set of innovative projects are highlighted [12]:

- removal of condensed algal blooms (e.g., using molecular sieves),
- digging drainage ditches in which the increased denitrification largely restricting the penetration of nitrogenous compounds into the reservoir water will occur after adding the respective components, and

- construction of ecotone zones that are communities of different types comprising a balanced selection of plants—on the edges of the reservoir. This is one of the innovative actions that significantly reduce the load of nutrients penetrating the reservoir in the critical summer period, which was included in the Conservation Program of the Sulejow Landscape Park.

5. Summary

The research presented contains the analysis of the existing water protection action plans and projects realized in the Sulejow Reservoir region. The Sulejow Reservoir was built in 1973 as a drinking water reservoir. However, currently, the reservoir is exploited for recreational and flood-control purposes. Due to the lack of full sanitary system, the area surrounding the reservoir facilitates unpurified municipal waste discharges and surface flows directly to the reservoir. A large amount of nutrients causes rapid growth of phytoplankton in the reservoir and periodically contributes to the mass algae growth particularly their blue-green genus. In the period 2004–2010, communes surrounding the Sulejow Reservoir: Wolborz, Tomaszow Mazowiecki, Mniszkow, and Sulejow, set out the environmental protection action plans aimed at improving the environmental condition of the Sulejow Reservoir. Each plan has been assessed in terms of the extent of its realization. The analysis performed shows that the progress of realization of some tasks in the analyzed area is satisfactory. Tasks in question concern the land use in the region of the reservoir (setting protection zone for all the underground water intakes, building development ban in 100 m wide zone along the reservoir banks or in the areas liable to flooding) and flood control in the same area (introduction of a flood-control system for the Pilica River). Unfortunately, some of the other crucial tasks like "Technical infrastructure development" and "Water management and water protection" have not been fully realized. The most serious delays occurred in the Mniszkow Commune. The available data indicate that the delays concern one of the most critical places at the Sulejow Reservoir—Zarzecin village. Due to the lack of the central sewage system carrying the municipal waste to the sewage treatment plant, this village becomes a serious source of nutrient emission that deteriorates the environmental condition of the Sulejow Reservoir. An investment plan developed during the implementation of the Waterpraxis project allows one of the main objectives of the Action Plan to be achieved, that is, "Water management and water protection system development and technical infrastructure development." The investments proposed in the context of Waterpraxis include connecting the Zarzecin local sewer system to the Mniszkow community sewer system, equipped with a wastewater treatment plant, by building a sewage pumping station and a local community sewer system in Zarzecin area and removing illegal sources discharging polluted/untreated wastewater into surface water from this area. As a result, the project provides a significant improvement in the level of protection of the local environment by reducing pollution in urban wastewater, thereby improving the quality of surface water and groundwater. The detailed scope of the project includes the construction of a 9.5 km gravitational sanitary sewage network, a 6.9 km pressure sanitary sewage network, nine pumping stations, and 3.7 km of sewer connections. Total investment costs are PLN 8.45 million (approx. € 1.9 million). It will contribute significantly to improving quality of life in the area and will raise the environmental awareness among both local authorities and inhabitants and will provide an impetus for the development and implementation of new projects and ideas.

ACKNOWLEDGEMENT

This study was supported by the project WATERPRAXIS of the Baltic Sea Region Programme 2007–2013 (grant #10: From theory and plans to eco-efficient and sustainable practices to improve the status of the Baltic Sea).

References

[1] A. Bednarek, M. Zalewski, Potential effects of enhancing denitrification rates in sediments of the Sulejow reservoir, Environ. Prot. Eng. 33(2) (2007) 35–43.

[2] S. Ahriz, D. Nedjraoui, N. Sadki. The impact of industrial pollution on the ecosystem of Réghaia Lake (Algeria). Desal. Water Treat. 24 (1–3) (Dec 2010) 1–6, 6p, doi: 10.5004/dwt.2010.130.

[3] B. Rakowska, M. Sitkowska, E. Szczepocka, B. Szulc, Cyanobacteria water blooms associated with various eukaryotic algae in the Sulejów Reservoir, Oceanol. Hydrobiol. Stud. XXXIV(1) (2005) 31–38.

[4] I. Wagner, M. Zalewski, Effect of hydrological patterns of tributaries on biotic processes in a lowland reservoir—consequences for restoration, Ecol. Eng. 16 (2000) 79–90.

[5] I. Wagner, K. Izydorczyk, E. Kiedrzyńska, J. Mankiewicz-Boczek, T. Jurczak, A. Bednarek, A. Wojtal-Frankiewicz, P. Frankiewicz, S. Ratajski, Z. Kaczkowski, M. Zalewski, Ecohydrological system solutions to enhance ecosystem services: The Pilica River Demonstration Project, Ecohydrol. Hydrobiol. 9(1) (2009) 13–39, doi: 10.2478/V10104-009-0042-8.

[6] H. Klapper, Control of Eutrophication in Inland Waters, Ellis Horwood, Chichester, p. 337, 1993.

[7] Z. Romanowska-Duda, J. Mankiewicz, M. Tarczyńska, Z. Walter, M. Zalewski, The Effect of Toxic Cyanobacteria (Blue-green algae) on Water Plants and Animal Cells, Pol. J. Environ. Stud. 11(5) (2002) 561–566.
[8] M. Tarczyńska, J. Mankiewicz-Boczek, Risk of microcystins occurrence in water, guidelines of WHO, Ecohydrol. Hydrobiol 5(Suppl.) (2005) 7–12.
[9] I.R. Falconer, An overview of problems caused by toxic Blue-Green Algae (*Cyanobacteria*) in drinking and recreational water, Env. Toxicol. Water Qual. 14 (1999) 5–12.
[10] Regulation of the Environment Minister of 27 November 2002 on requirements for surface waters used for the supply into water intended for consumption (in Polish). Dz.U. 2002, no. 204, item 1728.
[11] M. Imbierowicz, J. Skrzypski, A. Ziemińska-Stolarska, I. Zbiciński, Analysis of Existing Water Protection Action Plans and Realized Water Protection Projects at Sulejow Reservoir Region in Poland, Waterpraxis Project, Lodz, June 2010.
[12] Report on the state of the environment in Poland, Chief Inspectorate for, Environmental Protection, 2008.