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Original Research Article

EUTROPHICATION OF THE STRZESZYŃSKIE LAKE: SOURCES, CONSEQUENCES AND REMEDIES

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Abstract

The paper presents history and recent review of investigations on ecological status of the Strzeszyńskie Lake, located within borders of town Poznań. The lake is a popular rest place, also for bathing and angling, therefore its state concerns many institutions and inhabitants. Recently, a deterioration of its ecological state has been observed due to pollution from a tributary catchment (Row Złotnicki), lake's direct catchment, precipitation and fallen leaves. Phosphorus balance for an average year was estimated. A review of applied remedies was provided but an assessment of their effectiveness was unfeasible due to simultaneity and relatively short duration of their application.

Keywords: eutrophication, phosphorus balance, diffuse pollution.

1. INTRODUCTION

A general requirement for ecological protection of all surface waters and a general minimum chemical standard were introduced by the Water Framework Directive (2000). These are the two elements called "good ecological status" and "good chemical status", respectively. Good ecological status is defined in terms

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of quality of biological community, hydrological characteristics and chemical parameters. It should be achieved till the end of the year 2015. Unfortunately, recent investigations and studies [7] indicate that this goal is not fully achievable in Poland, especially in the case of lakes. Monitoring of 208 Polish lakes in the years 2007-2008 has shown that 53% of them were in moderate or worse ecological state [1]. In many cases the desirable good ecological state can be achieved in 10-15 year only, provided that special measures against eutrophication are undertaken.

The aim of this case study was to identify sources of phosphorus compounds crucial to eutrophication of the Strzeszyńskie Lake in Poznań [13], to estimate their significance and to appraise effectiveness of applied remedies to recover a good ecological sate of the lake.

2. STRZESZYŃSKIE LAKE

2.1. General characteristics

The Strzeszyńskie Lake (Fig. 1) is a flow-through lake. Its main tributary is a small stream of catchment area 756 ha, called Rów Złotnicki. The outflow from the lake is called the Bogdanka River, left tributary to the Warta River. The lake itself and the Bogdanka River are located within administrative borders of Poznań municipality. Direct catchment of the lake of area 180 ha is covered by woods with mainly deciduous and pine- trees. From the western side the lake direct catchment is delineated by the railway Poznań-Krzyż and from the eastside by the Koszalińska Street (linear sources of pollution).

Mean yearly inflow from the Rów Złotnicki has been roughly estimated as Q_m = 18 dm^3/s, on the base of multi-year specific runoff in the Central Great Poland region.

The lake water surface area of approximately 33.5 ha is located on average at 77.0 m a.s.l. Mean water depth at that water level is equal to 8.3 m, providing water volume V = 2.5 mln m^3, and the maximum depth reaches about 17 m [2]. The mean residence time can be therefore approximately calculated as $T_r = V/Q_m$ = 4.4 years. However, due to asymmetric locations of the main inflow and outflow, a channeling is highly probable along the lake's eastern bank, leading to an asymmetry (positive skewness) in residence time distribution.

2.2. Lake status and state

Investigations made in 1994 showed the second (good) class of water quality on the base of chemical and microbiological parameters, but the visibility of the Secchi disc in the summertime in lake water at the municipal bathing beach was within range 0.45-1.1 m only. Fig. 2 shows the course of changes of the Secchi

disc visibility during one season. It can be seen that the results have dramatically changed due to mixing by storm events and probably due to a mobile aeration/pulverization with phosphorus inactivation, described in details in chapter 3.

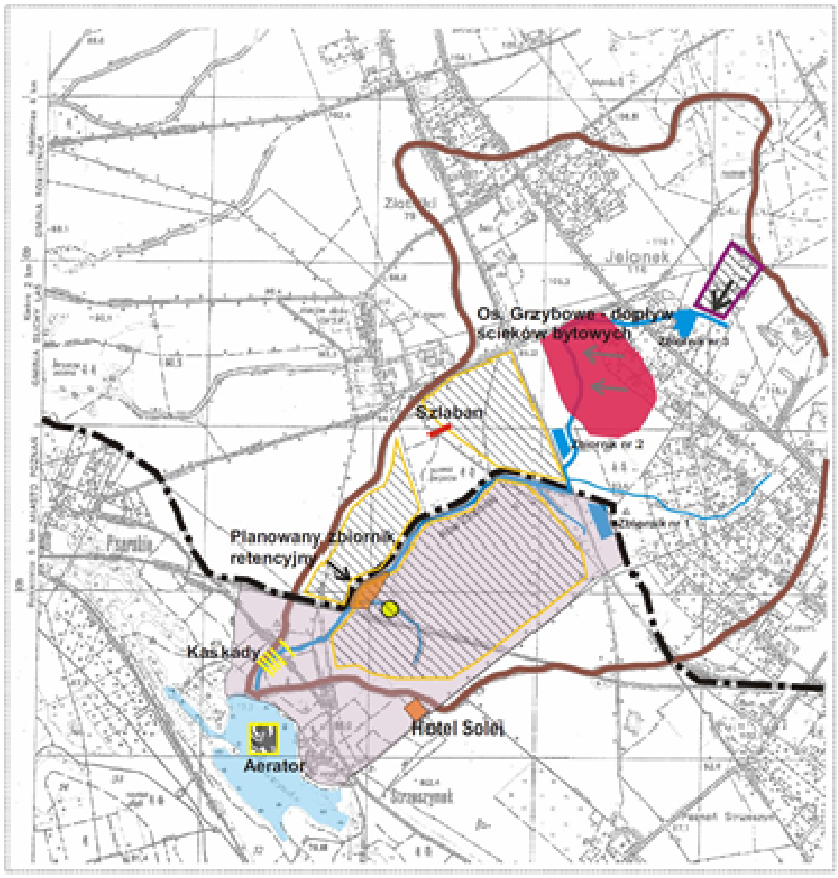

Fig. 1. Map of the Strzeszyńskie Lake and its catchment: square side of the network is equal to 1 km [9]

Data on the Secchi disk visibility, published on the website of Poznań municipality [10], have shown that it has systematically increased from the minimum value 0.95 m in 2011 to the minimum value of 2.0 m in the year 2014. In spite of this improvement, activists of the Polish Ecological Club claims that a deterioration of its ecological state has been observed mainly due to pollution from a tributary catchment (Rów Złotnicki). One of the main sources of pollution is probably sewage from a sewerage system in the housing development Osiedle Grzybowe, which is hydraulically overloaded during

storm events and the diluted sewage from the sanitary network flows to its stormwater system and further to the lake through the Rów Złotnicki.
Obviously, there are also other sources of pollutants: lake's direct catchment, precipitation, bathing people, fish baits introduced by anglers, organic mud on the bottom of the lake (of depth 30-70 cm, according to [4]), etc.. Some of the pollution sources are even not yet recognized, e.g. fish ponds or fallen leaves.

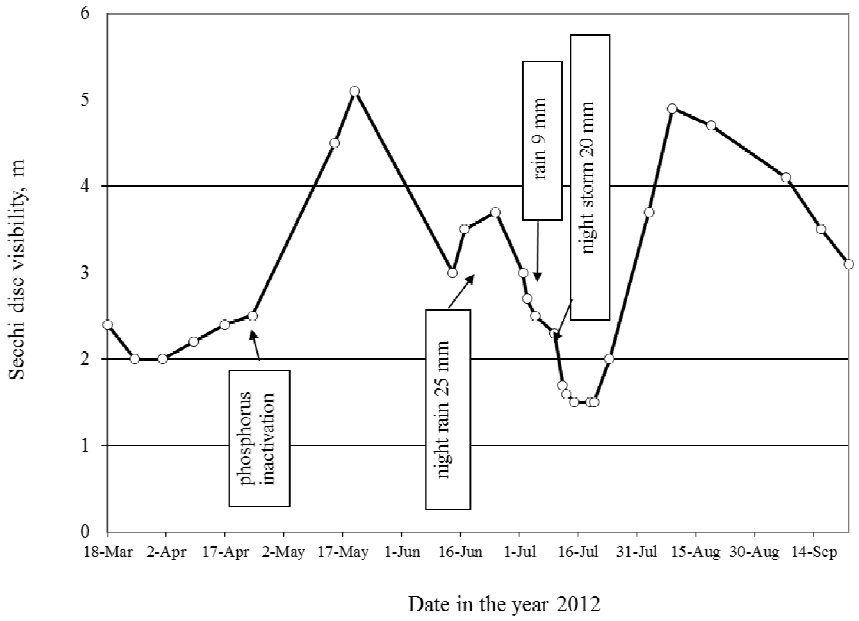

Fig. 2. Visibility of the Secchi disk in the water of the Strzeszyńskie Lake close to the public beach; measurements made by J. Juszczyński [5]

As a result of pollution some algae blooms in the lake have been observed and *E. coli* content was the reason of ban on bathing in the 2012. As the lake is a popular rest place, also for bathing and angling, many associations like Polish Ecological Club, "My-Poznaniacy" Association ("We - The Citizens of Poznań"), Association "Green Strzeszyn" borough of Strzeszyn, borough board of Osiedle Grzybowe in commune Suchy Las have recently protested and demanded actions to improve the situation.

3. LAKE MANAGEMENT PLAN

Among protection measures the following ones seem to be the most important:

- Estimation of water balance and nutrients' (especially - phosphorus) balance,
- Identification of main sources of the nutrients,
- Creation and implementation of sustainable lake management plan [8].

Great Poland's Voivodship Inspectorate of Environmental Protection and Municipality of Poznań created and implemented a management plan [9] which in the year 2012 covered:

- Construction of 6 small cascades (drops 0.2 m every 23 m) on Rów Złotnicki to slow down the runoff (Fig. 3);
- Performance of 7 series of mobile aeration/pulverization with phosphorus inactivation, using coagulant $MgCl_2$ - as a result the phosphorus concentration in the lake water has locally dropped to ≤ 0.15 mg P/dm^3;
- Construction of 4 barriers from Sinobent (bentonite medium, salts of Fe and Mg, nitrates) to bind phosphorus in the flowing waters of the Rów Złotnicki and a tributary from Solei Hotel (Fig. 3).

In the year 2013 the following measures we introduced:

- Installation of a stationary, wind-driven aeration station with chemicals ($Fe_2(SO_4)_3$ + $MgCl_2$) dosing to bind phosphorus,
- Mobile aeration/pulverization with phosphorus inactivation,
- Construction of a road barrier to prevent septage discharges from hauling trucks.

Total costs of the remediation measures undertaken in the years 2011-2013 reached 466 thousands PLN in which capital costs of the wind aeration station composed 64% [9].

There are also plans to construct a small reservoir (volume 9,000 m^3, water surface area 1.4 ha) with a vegetated soil filter on the Rów Złotnicki and to apply bio-manipulation to increase the number of prey fish and - as a consequence - zooplankton population which could control the phytoplankton growth.

4. PHOSPHORUS BALANCE

4.1 Methodology

The phosphorus balance was compiled for the year 2012 using a slightly modified methodology proposed firstly by Giercuszkiewicz-Bajtlik [3]. General form of the phosphorus mass balance was expressed as:

$$\textit{Inputs - Outputs = Change in storage} \quad (4.1)$$

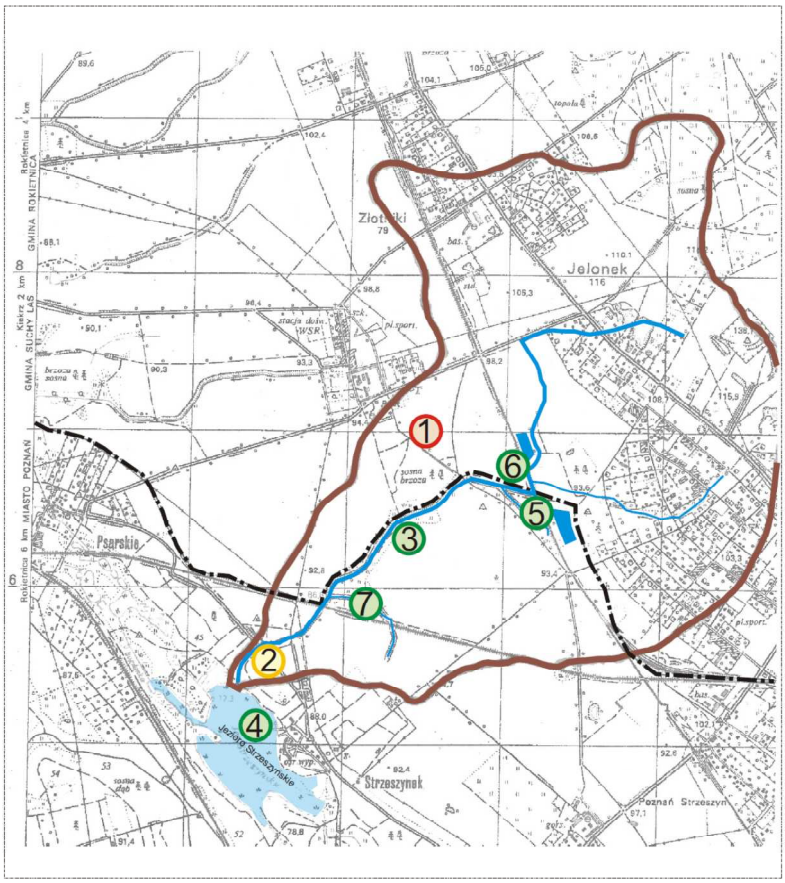

Fig. 3. Measures to protect the Strzeszyńskie Lake: 1 - road barrier, 2 - six cascades, 3, 5, 6 - Sinobent barriers on the Rów Złotnicki, 4 - aeration and chemical phosphorus inactivation in the Strzeszyńskie Lake, 7 - Sinobent barrier on the tributary from the Solei Hotel [9]

The balance embraces the following five input elements:

$$\boldsymbol{L_{Ptot} = L_{Pd} + L_{Pp} + L_{Pt} + L_{Pb} + L_{Pl}} \tag{4.2}$$

where: L_{Pd} - yearly P-load from diffused sources, kg P/a,
L_{Pp} - yearly P-load from precipitation on the lake water surface, kg P/a,

$\boldsymbol{L_{Pt} = 365\, L_r\, W\, S 10^{-4} l_U}$ early P-load from transport sources, kg P/a,
where: L_r - road length, km; W - road width, m; S - traffic intensity, vehicles per day; l_U - unit P-load in runoff, equal to 0.0003 kg P/(ha a) per 1000 vehicles.
L_{Pb} - yearly P-load from bathing, kg P/a,

L_{Pl} - yearly P-load from organic fall in neighbouring woods, kg P/a.

The phosphorus load from ground fish baits and introduction of fish stocking was equalled to the output by angling, according to estimations made by Wołos and Mioduszewska [14].

4.2 Input data

P-load from diffused sources was estimated on the base of total phosphorus concentration in the water inflowing to the lake from Rów Złotnicki (0.2±0.03 mg P/dm^3) and mean multi-year flow discharge (Q_m = 18 dm^3/s). Sampling on the following nine dates: 16. 08. 2011, 30. 11. 2011, 13, 15, 17, 19, 21, 24 and 31. 08. 2012 and chemical analyses were performed by the Great Poland's Voivodship Inspectorate of Environmental Protection [9].

Mean yearly P-load in precipitation 0.3 kg P/(ha a) was taken to the balance after Sapek and Sapek [11].

To estimate P-load from traffic the following parameters of the Koszalińska St. were taken into account: L_r - road length: 1.3 km; W - road width: 6 m; S - traffic intensity: 2500 vehicles per day.

P-load from bathing was estimated assuming the number of baths equal to 7200 during bathing season and unit load 0.05 g P/bath.

Organic fall in woods was assumed to be similar to that in Wigry National Park, i.e. 1.65 kg P/(ha a), according to multi-year investigations [6]. A belt of width 3.0 m around the lake circumference 4500 m long as well as a belt along the Rów Złotnicki of area 4050 m^2 were treated as the area generating the organic fall.

5. RESULTS AND DISSCUSSION

Calculations were accomplished according the above described methodology (Eq. 4.2) and the following results were obtained:

$$\boldsymbol{L_{Ptot} = L_{Pd} + L_{Pp} + L_{Pt} + L_{Pb} + L_{Pl} == 113.5 + 10.0 + 0.2 + 0.4 + 2.9 = 127\ kg\ P/a}$$

Unit surface load was estimated as 127,000 g/335,000 m^2 = 0.4 g P/(m^2 a). It can be seen that the first source (diffuse pollution carrying by the waters of the Rów Złotnicki) generated in the year 2012 almost 90% of the total yearly P input. Therefore the diagnosis made by the Polish Ecological Club was correct. However, it is known from the literature [12, 13] that the yearly surface load of phosphorus 0.4 g P/(m^2 a) is sufficient to initiate an algal bloom.

In April 2013 two analyses of the lake water sampled at the bathing pool, were done giving P concentrations 0.05 mg P/dm^3 and 0.08 mg P/dm^3. In spite of the

values complying requirements of the Ist quality class, they were still hazardous to the lake; according to Wang [13] the safe P concentration is not higher than 0.03 mg P/dm^3 only.

6. CONCLUSIONS

- The Strzeszyńskie Lake has been for a long time under anthropogenic pressure, mainly due to phosphorus loads from its tributary Rów Złotnicki. Undertaken lake management plan is correct and it has brought about some improvements in the lake water quality. However, because of many actions undertaken simultaneously, it is hard to point out the most effective one.
- To optimize the lake management plan, its water and phosphorus balances have to be elaborated. However it is hard and/or expensive to accomplish a phosphorus balance, especially in cases of short water quality monitoring and scarce hydrological data; therefore the errors in the balance may generate erroneous management decisions.

REFERENCES

1. Chief Inspectorate of Environmental Protection. *Report on the state of the environment in Poland 2008*. Environmental Monitoring Library. Warsaw (2010) www.gios.gov.pl
2. Choiński A.: *Katalog jezior Polski* (*Catalogue of Polish lakes* - in Polish). Poznań: Wydawnictwo Naukowe UAM, 2006
3. Giercuszkiewicz-Bajtlik M.: (1990); *Prognozowanie zmian jakości wód stojących.* (*Forecasting quality of standing waters* - in Polish). Instytut Ochrony Środowiska. Warszawa
4. Gołdyn R., Jankowska B., Kowalczak P., Pułyk M., Tybiszewska E. Wiśniewski J.: *Wody powierzchniowe m. Poznania*. (*Surface waters of Poznań* - in Polish) W: Środowisko naturalne m. Poznania, cz. I, pod red. L. Kurka, UM, Wydz. Ochr. Środowiska, Poznań 1996
5. http://ratujmy-strzeszynek.pl/ Access: July 23, 2015
6. Krzysztofiak L.: (red.) 2014 *Raport o stanie środowiska przyrodniczego Stacji Bazowej Wigry w roku hydrologicznym 2013*. WPN, Krzywe
7. MGPP, IOŚ (2010) *Sformułowanie - w warunkach korzystania z wód regionu wodnego ograniczeń - w korzystaniu z wód jezior lub zbiorników oraz w użytkowaniu ich zlewni.* (*Formulation of restrictions on lake and reservoirs water use and land use in their catchments* - in Polish) Kraków, Warszawa
8. Murat-Błażejewska S., Błażejewski R.: (2012). *Creation and implementation of sustainable lakes management plans*. Int. Lim. Conf.

„Natural and Anthropogenic Transformations of Lakes" IMGW, Łagów Lubuski.
9. Poznan* Miasto know-how (2013) http://osiedlegrzybowe.zlotniki.com/wp-content/ uploads/2013/06/j_strzeszynskie wersja uzupełniona 1.pdf Access: July 23, 2015
10. http://www.poznan.pl/mim/main/widzialnosc-krazka-secchi-ego,p,30353,30360,30363.html
11. Sapek A., Sapek B.: (2011) *Fosfor w opadzie atmosferycznym* (*Phosphorus in rainfall* - in Polish). Ochr. Środ. i Zas. Nat., 50, 122-133
12. Schindler D. W.: (1974) *Eutrophication and recovery in experimental lakes: implications for lake management*. Science 184, 897-899
13. Wang H.: (2009) *Mitigation of lake eutrophication: Loosen nitrogen control and focus on phosphorus abatement*. Progress in Natural Science. 19, 1445-1451
14. Wołos A., Mioduszewska H.: *Wpływ stosowania przez wędkarzy zanęt na efekty wędkowania i bilans biogenów ekosystemów wodnych*. (*Impact of ground fish baits on angling effects and nutrients balance in aquatic ecosystems* - in Polish). Komunikaty Ryb.1, 2003. 23-27

EUTROFIZACJA JEZIORA STRZESZYŃSKIEGO: ŹRÓDŁA, KONSEKWENCJE I ŚRODKI ZARADCZE

S t r e s z c z e n i e

Artykuł przedstawia historię i aktualne podsumowanie badań stanu ekologicznego Jeziora Strzeszyńskiego, położonego w granicach miasta Poznania. Jezioro to jest popularnym miejscem rekreacyjnym, w tym kąpieliskiem i akwenem wędkarskim, stąd też jakość jego wód jest przedmiotem troski i zainteresowania wielu instytucji oraz mieszkańców. Ostatnimi laty zaobserwowano pogarszanie się stanu ekologicznego wód, czego przyczynami były głównie zanieczyszczenia obszarowe i rozproszone w zlewni dopływu (Rowu Złotnickiego) oraz w zlewni bezpośredniej jeziora, opady atmosferyczne oraz liście drzew. Sporządzono bilans zanieczyszczeń związkami fosforu dla roku średniego (2012). Zamieszczono przegląd zastosowanych sposobów poprawy jakości wody w jeziorze, jednak ocena ich efektywności okazała się niewykonalna z uwagi na jednoczesność stosowania kilku metod i stosunkowo krótki czas ich stosowania.

Słowa kluczowe: eutrofizacja, bilans fosforu, zanieczyszczenia obszarowe.

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