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Research Article

THE ASSESMENT OF LAKES' VULNERABILITY TO DEGRADATION IN THE CITY OF SZCZECIN

Piotr Daniszewski[1]

[1] Faculty of Biology, Department of Invertebrate Zoology and Limnology, University of Szczecin, 13 Waska Street, 71-415 Szczecin, Poland, e-mail: daniszewski73@gmail.com

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ABSTRACT
The purpose of the work was to determine the impact of using quality test on the evolution of water quality in Lakes Basin. The studies covered three tanks along with their drainage basins (the direct and total) in the city of Szczecin. In order to determine the impact of the estimated load of nitrogen and phosphorus compounds, reaching the Lake from the direct catchment area (as rafting area) and the total (as the supply of courses). The received loads of phosphorus were compared with the limit and dangerous cargoes for the test tanks. The work also assessed the impact of the natural resistance of the water catchment area of the lakes to the degradation caused by the pace of delivery to them.

Keywords: land use, lake catchments, nitrogen compounds, phosphorus compounds, water quality.

INTRODUCTION

Vulnerability assessment of the lakes to the degradation of water status parameters is the determining factor of any lake. Indicates whether the lake is prone to influences from the outside, which can be a drain of water or waste water discharges into the tank [1, 3, 4, 6, 9, 12, 24].

The adopted procedure consists of determining the impact on the quality of lake waters caused by anthropogenic factors, understood as the use of catchment area, in conjunction with the natural factors that can potentially increase or decrease the size of this impact [4, 6, 9, 14, 15, 16, 19, 20, 22, 23]. Natural factors affect susceptibility to degradation of the lakes and their resistance to the supply of matter from the catchment area [2, 3, 5, 13, 14, 16-18, 21, 23, 24].

This work shows the influence of catchment areas on water quality using the load of nitrogen and phosphorus to lakes and on getting tributaries of the confluence of the surface [7, 8, 12, 14, 15, 18, 20, 22, 23]. On the basis of the size of the cargo and lakes' natural susceptibility the resistance of the tank was established. It may result from the use of the seven Lakes Basin city of Szczecin with its natural context.

EXPERIMENTAL CONDITIONS

Szczecin is situated in North-Western Poland, in the western part of West Pomeranian Voivodeship at the Polish-German border [11].

Glebokie Lake is classified as an eutrophic lake, shallow type. Catchment area of the lake is almost entirely forested. The area to the east lake is developed with buildings. The Lake is a basin reservoir for the endorheic river, with only a small periodical outflow. Lake morphometric data: area 31.3 ha, length – 1550 m, 300 m, maximum depth – 6.0 m, volume – 751 thousand m^3 [11].

Rusalka Lake, also called the Sea Eye, is located in Szczecin Kasprowicz Park in Niebuszewo district. This is the reservoir formed by a medieval Mill River House Osówka [11]. Lake morphometric data: Length – 670 m, width – 70 m, the height of the mirror – 16 m above sea level, type of lake: prohibitive [11].

The Szmaragdowe Lake – the origin is artificial in the Beech Forest, it was formed on 26 July 1925 as a result of flooding the mines existing there before the World War I. The water colour owes its name to lake's origin (the effect of the content of calcium carbonate) [11]. Lake morphometric data: area – 4.5 ha, average depth – 8.2 m, maximum depth – 15.8 m [11].

The research was carried out in the years 2008–2012. The total catchment management and the direct way were found using GIS (Geographical Information System) andland-use maps [7]. Individual levels of use according to the classification adopted for Poland were extracted. On the basis of the maps drawn up about the way of spatial surfaces and their shares in the total divisional catchment area were calculated. Natural susceptibility to degradation was specified by Kudelska et al. [1994], and the role of the drainage area in the provision to them by Bajkiewicz-Grabowskiej (2002) [16].

The size of the load of nitrogen and phosphorus in the water carried by water course (momentary load) was calculated as the product of their concentrations and the instantaneous flow volume. Instantaneous load of phosphorus getting into the tank became a starting point of the calculation of the courses of its annual value.

Based on the equation proposed by Giercuszkiewicz-Bajtlik [1990] the annual load of nitrogen and phosphorus compounds derived from surface runoff were estimated [16].

Coefficients of annual nitrogen and phosphorus loads from the areas of different land cover, atmospheric inputs and their retention have been averaged to coefficients on the basis of the information contained in the work of the Skipper, Zaniewska [1984], Likens [1975], Kayak [1994], Jensen et al. [1992], Uchmański, Szelegiewicz [1988] (Table 1) [16].

The total load of phosphorus introduction spot were recalculated by the rafting Lake and adopted for the annual load of phosphorus from the drainage area with the use of sources. The value of the cargo was laden with dangerous compounds, calculated on the basis of Vollenweider's criterion of maximum [1976], and then the categories of threat tanks were set out according to Hillbricht-Ilkowska and Kajak [1986] [16].

RESULTS AND DISCUSSION

The results of the three Lakes Basin in the city of Szczecin in tables 2 to 6.

On the basis of the research, it can be concluded that the land use affects the quality of waters in the lake catchment (direct and total) and its natural conditions. The waters of the Glebokie, Rusalka, Szmaragdowe Lakes have a high ability to deliver. A significant load of nitrogen and phosphorus compounds reaching the courses and boat ride, combined with natural surface determinants of these tanks may contribute to the deterioration of the quality of their waters (Table 2 and 3).

The conclusions about the impact of the use of water reservoirs on the quality of their water were based primarily on identifying the risks of excessive phosphorus supply on the confluence of the spell/Rune and the tributary of the courses. The annual phosphorus load from the sources related to the use of the waters in the catchment area for trips into the Lakes of the worst quality

Table 1. Coefficients of annual nitrogen and phosphorus loads from the areas of different land cover, atmospheric inputs and their averaged retention coefficients [23]

Coefficients		Nitrogen	Phosphorus	Data source
		kg·ha^{-1}		
Surface runoff from:	forests	3.92	0.225	Szyper et al. [1984]
	meadows and pastures (grasslands)	8.5	0.17	Likens [1975]
	arable lands	7.84	0.45	Szyper et al. [1984]
	built-up lands (urban) areas	2.5	0.1	Szyper et al. [1984]
Atmospheric input		–	2.0	0.2
Retention		–	0.41	–
		–	–	0.57

Table 2. The vulnerability of analysed lakes to degradation

Paramenters	Glebokie		Rusalka		Szmaragdowe	
	value	score	value	score	value	score
Mean depth [m]	3.3	3	2..1	3	6.8	2
The ratio of lake volume, thous. [m^3] to the length of the shoreline [m]	0.3	3	0.1	3	0.9	3
Water stratification [%]	31.4	2	23.9	2	23.7	2
The quotient of active lake bottom [m^2] and epilimnion volume [m^3]	0.08	1	0.03	1	0.05	1
Annual water exchange [%]	73.6	2	69.1	2	53.8	2
Schindler's coefficient [$m^2 \cdot m^{-3}$]	6.4	2	4.8	2	5.2	2
Land use type in the direct catchment [%]	75.3 f	1	51.6 f	1	93.7 f	1
Result	2.00		2.00		1.85	
Vulnerability	II		II		II	

Explanations: f – forests

Table 3. The assessment of catchment as a source of matter input to analysed lakes

Paramenters	Glebokie		Rusalka		Szmaragdowe	
	value	score	value	score	value	score
Lake coefficient	63.9	2	67.2	2	49.7	2
Balance type of lake	t-fl	3	t-fl	3	t-fl	3
Catchment morphometry:						
• river network density [$m \cdot km^{-2}$]	0.2	1	0.2	1	0.1	1
• mean slope of the catchment [$m \cdot km^{-2}$]	34.1	3	38.5	3	14.6	2
• areas without drainage [%]	7.9	3	12.6	3	14.9	3
Geological structure	s	3	s	3	l	0
Land use type	f	1	f	1	f	1
Result	2.28		2.28		1.71	
Vulnerability group	4		4		3	

Explanations: t-fl – through-flow lakes, l – loamy, s – sandy, f – forest.

Table 4. Approximate annual nitrogen (N) and phosphorus (P) loads ($kg \cdot ha^{-1}$) from surface runoff per area of the analysed lakes

Catchment	Glebokie		Rusalka		Szmaragdowe	
	N	P	N	P	N	P
Direct	39.5	1.7	26.8	0.8	3.2	0.2

Table 5. Annual unit phosphorus load to the analysed lakes ($mg \cdot m^{-2}$) resulting from land use type in their catchments

Type of phosphorus load input	Catchment		
	Glebokie	Rusalka	Szmaragdowe
Surface runoff	179.5	71.9	35.9
River input	95.2	19.6	5.8
Total	274.7	91.5	41.7

Table 6. Risk levels of the analysed lakes

Phosphorus load [mg·m⁻²]	Catchment		
	Glebokie	Rusalka	Szmaragdowe
Permissible load	162.9	58.3	124.9
Excessive load	241.8	116.6	249.8
Load resulting from the catchment land use	274.7	91.5	41.7
Risk level	III	III	II

(Glebokie) exceeds the value of the dangerous load (Table 5 and 6).

This is the evidence of the threat caused by the use of catchment area, of the receipt of the cargo of the phosphorus which causes deterioration of the quality of these lakes and a large likelihood of progress of their eutrophication. The pace of this process may be different, but the load of phosphorus is higher than dangerous, what does not guarantee the maintenance of the trophic constant.

The explored lakes belong to the tanks moderately susceptible to degradation (II category of vulnerability) (Table 2). The least resistant to degradation are Glebokie and Rusalka Lakes (2.0 points). The resistance of the tank lowers the volume ratio to above all the length of the shoreline and the way the management of catchment areas (Table 2).

The largest loads, both nitrogen and phosphorus, are introduced by run-off from the direct catchment area to Głębokie and Rusalka Lakes. Nitrogen and phosphorus load in the case of the direct catchment area of Głębokie and Rusalka Lakes exceeds those that reach the direct catchment area to Lake Szmaragdowe even by 8–12 times (Table 4).

By taking temporary charge of phosphorus getting into the major tributaries in summer for the annual average, extrapolated it for a period of 10 months (no freezing period) and was considered to be the value of the annual load of phosphorus transferred to Lake tributaries. The size of this should be treated as an estimate, low, and even the minimum value of the annual inflow of phosphorus, because the courses in the calculation do not include seasonal changes of phosphorus concentration , which in summer, takes the smallest value, and also changes the flow, for example, during the melting or the life and struggles of precipitation.

Aggregate phosphorus loads coming to the container (i.e., from the confluence of its tributaries and surface) was considered the annual cargo phosphorus from sources associated with the operation sub-basins (Table 5).

The largest annual cargo phosphorus originating in the use of the catchment area reaches Glebokie Lake.

The calculated phosphorus loads were brought to Vollenweider criterion [1976] hydraulic model, adopted for the flow rate of the water of the Lakes, taking into account the yearly exchange, and so were compared with the calculations for cargo tanks and hazardous wastes under consideration limit. So you can tell if the estimated annual phosphorus load associated with the use of catchment areas can be a potential threat to the Lakes, even when given its minimum value that comes from its tributaries.

Knowing the loads of phosphorus and dangerous compounds entering the lakes as a result of the use of their catchment area, categories of their risk were determined as defined according to Hillbricht-Ilkowska and Kajak [1986] (Table 6) [16].

Only in the case of the load of phosphorous from Lake Rusałka annual use of the catchment area is greater than the acceptable level, but less than dangerous (III category of danger). The annual phosphorus load from source stated the use of catchment areas reaching the Lake Glebokie is larger (2-fold) than the dangerous one for the tank (III category) (Table 6).

CONCLUSIONS

1. Lakes Glebokie and Rusalka can be counted as the tanks of water quality and class III category III susceptibility to degradation. The status of morphometric and basin properties affect the tank.
2. Lake Szmaragdowe can be counted as the tanks of water quality and class II category II susceptibility to degradation.
3. In order to protect the lakes from excessive increases in trophic you should first of all limit the supply of nutrients to the lakes.

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