

ESTIMATION OF POTENTIAL LOAD OF EUTROPHICATING
COMPOUNDS OF RECREATIONAL ORIGIN PENETRATING
INTO THE MESOTROPHIC LAKE PIASECZNO
AND OF THE TOURIST CAPACITY OF THE LAKE
IN THE SUMMER SEASONS OF 2008 AND 2010

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Summary. Lake Piaseczno, an element of the Łęczna-Włodawa Lakeland, included in the network of area protection as an ecological use land due to its exceptional nature-landscape values, is under strong tourism-recreational pressure. The objective of the study was to estimate the degree of environmental impacts concerning the lake in the aspect of the amounts of introduced biogenic substances and the tourist capacity, related with analysis of the numbers of tourists within the shore line in the summer seasons of 2008 and 2010. During the period of the study the numbers of tourists in the shore zone of the lake did not determine the considerable potential influx of biogenic compounds of recreational origin to the lake, and it did not result in exceeding the physical carrying capacity index, the natural capacity of the lake, nor the index for open bathing zones. A larger number of tourists was noted in the summer season of 2010.

Key words: lake, biogens, tourist capacity, recreation, tourism

INTRODUCTION

Lakes are ecological systems whose condition depends on the influx of matter, including contaminants, from the drainage basins, and its accumulation in the reservoirs. Those processes, taking place at various ranges and rates, depend largely on the physical-geographical conditions of the drainage basins, methods of their use, and the hydrological-morphometric parameters of the reservoirs, with varied effects on the mobilisation of biogenic compounds and on the supply of lakes [Bajkiewicz-Grabowska 2002].

Excessive influx of biogenic compounds to lake waters causes an intensification of the process of eutrophication, which results in a deterioration of the living conditions of numerous living organisms, and also in reduced possibilities of economic utilisation of the waters. Therefore, correct identification of the sources and limitation of the influx of those compounds to lakes is of great importance for the improvement of water quality and for counteracting their further degradation [Ławniczak *et al.* 2010].

The diversity of area forms of nature conservation in the territory of the Łęczna-Włodawa Lakeland, related with the high nature-landscape values, significantly enhance the tourist-recreational attractiveness of the region [Krukowska and Krukowski 2009, Krukowski and Krukowska 2013].

The tourist-recreational activity related with intensification of non-organised tourism, combined with the effects of the present increasingly extensive agriculture, with transformations of the hydrological status of the Lakeland determined by the functioning of the melioration system of the Wieprz-Krzna Canal and the probable effect of the Lublin Coal Mining Basin, have an effect on the changes in the natural environment of the Lakeland [Serafin 2009].

The mesotrophic lake Piaseczno – the deepest and one of the most valuable – in terms of nature values – lakes of the Lakeland, included in the network of protected areas as an ecological use area, due to diverse anthropopressure has been subject, since the beginning of the 1970's, to a considerable influence of biogens affecting its ecological status [Wojciechowski 1976, Wojciechowski *et al.* 1995, Serafin and Czernaś 2003, Czernaś and Serafin 2007].

The sources of nutrients initiating the phenomenon of eutrophication of waters, and thus affecting the ecological status of lake Piaseczno, are mainly agriculture and intensive tourism, organised as well as non-organised [Serafin and Czernaś 2003, Czernaś and Serafin 2007].

The agriculture, though rather low-intensity in character, due the low quality of the permeable podzolic soils plays a fundamental role in the enrichment of the ground waters of the lake drainage basin in biogenic elements [Misztal and Smal 1995].

The low production quality of the permeable soils in the drainage basin of the lake, combined with the attractiveness of the region of Piaseczno, results at present in changes in the land use of the drainage basin from agricultural towards the recreational-tourist one. For this reason the lands near the eastern shore of lake Piaseczno, still under agricultural use at the beginning of the 1990's, have been divided into recreational plots and covered with over a thousand recreational houses, and the sewage from the area, due to the leaky cess-pools, have been largely penetrating into the ground [Misztal and Smal 1995].

The excessive recreational use of the reservoir, above its tourist capacity, has also been related with non-organised recreational activity. In this respect, as early as mid-2000's lake Piaseczno was among the most crowded lakes of the

Lakeland, and on the weekends the number of people taking their rest on its beaches exceeded 7000 [Chmielewski 2001].

The specific topographic and hydrometric features of lake Piaseczno, the quality of its waters and the character of land use of its drainage basin cause, however, that in the Lake Quality Assessment System (SOJJ) acc. to Kudelska *et al.* [1983, 1997] that reservoir has been classified for many years in water purity classes I or II, and in category I or II of lake susceptibility to degradation (Reports on the status of the environment of the Lublin Province in the years 1992–2011), and thus as a reservoir with good natural conditions, resistant to environmental transformations. In spite of that, a number of changes are observed here, e.g. fluctuations in the productivity of the lake ecosystem [e.g. Wojciechowski *et al.* 1995, Serafin 2009], or fluctuations in biogen retention by psammon algae communities [Czernaś 2001], that may indicate temporary destabilisation of the trophy of the reservoir, which can cause changes in its ecological status and deterioration of its recreational values.

Although many hydrobiological studies emphasise the effect of tourism and recreation on excessive fertilisation of water reservoirs [Vollenweider 1971, Kajak 1979, Bajkiewicz-Grabowska 1987, Lossow 1995a, b, Kalf 2001, Kubiak and Tórz 2005], the analyses usually do not include the pressure of the beach recreation, concentrating primarily on the influx of biogenic compounds from areas under recreational development, stressing their relatively low contribution to the nutrient balance [e.g. Ławniczak *et al.* 2010].

However, taking into account the specific nature of lakes resulting from their nearly system, determining the inclusion of contaminants introduced even once into the cycle of matter, permanent supply of even small amounts of biogens affects the quality of the waters and may destabilise the littoral elements of the lake biocenosis, e.g. macrophytes of invertebrate macrofauna [Soszka 2010].

The objective of this study was analysis of tourist movement on Lake Piaseczno in the aspect of the amounts of biogenic compounds and organic secretions introduced into the ecosystem, and on the tourist capacity, based on the numbers of tourists in the shore zone of the lake in the summer seasons of 2008 and 2010.

MATERIALS AND METHODS

Lake Piaseczno is situated in the south-western part of the Łęczna-Włodawa Lakeland, in the commune of Ludwin, about 13 km to the north-east of the main town of the region – Łęczna, and in close vicinity of the localities of Rozpłucie, Kaniwola and Piaseczno.

In terms of limnology it represents the dymictic, b-mesotrophic type of reservoir, with maximum depth of 38.8 m and an area of 85 ha [Wilgat *et al.* 1991]. The lake is surrounded by a narrow belt of sandy beach, at present notably reduced

due to a high water level, and on the north-west and the western shore the lake neighbours a formerly active but currently degraded transitional moor [Serafin 2009].

A Resolution of the Council of the Commune of Ludwin (No. XX/114/93), to preserve the unique nature-landscape values of lake Piaseczno and the adjacent areas, created the ecological land use unit „Lake Piaseczno and its neighbourhood” with an area of 1534 ha including the lake itself, which may have had an additional impact on enhancing the tourist attractiveness of the region, as it is now one of the most recreationally frequented lakes of the Lakeland [after Krukowska and Krukowski 2009].

The assessment of the tourist traffic pressure on the waters of lake Piaseczno was performed in the summer seasons of 2008 (8 dates between 28th June and 12th July) and 2010 (8 dates between 6th and 20th July) on the basis of numerical analysis of the presence of tourists in the shore zone in the area of the three main beaches: RESORT (current name) – south-western bank of the lake, Didactic-Sailing Station of ULS Lublin – north-eastern bank of lake Piaseczno, and the Divers’ Base – on the south-east bank. The tourists were counted on each date of survey, between the hours of 10–12 and 15–17, and the results were averaged for the day, for the whole study season, and for all the beaches.

The number of tourists was converted to the amount of biogens introduced in the lake waters. In the study we used materials from the Project of Twin Cooperation between the EU and Poland (PL 2005/IB/EN/03) within the framework of the module „Extension of the System of Sanitary Supervision in the area of the Quality of Waters”. Based on those materials it was assumed that 100 bathers potentially introduce to the waters 0.1 kg of nitrogen, 5 dm³ of urine, 30 dm³ of sweat, 50 g of insoluble organic contaminants and 400 g of soluble organic contaminants expressed as the use of KMnO₄ [Prędotą 2007].

For the amount of phosphorus getting into the water the index of Szyper and Zaniewska [1984] was adopted, equal to 0.457g of P introduced by a single bather.

The results concerning the numbers of tourists were subjected to simple statistical analysis, taking into account the mean value, standard deviation (*SD*), and the coefficient of variation (*V*) as a measure of the scatter of the results.

For further stages of analysis of the environmental pressure on the lake waters the index of physical carrying capacity (*PCC*) for lake Piaseczno was calculated according to the formula of Ciefuentes Arias [1992], after Kowalczyk and Derek [2010]:

$$PCC = A \times V/a \times Rf,$$

where:

A – area available for the tourists (beach);

V/a – number of tourists per 1 m², resting comfortably [Tran Nghi *et al.* 2007]; for lake Piaseczno beaches the value adopted was 5 m² per tourist, i.e.;

$$V/a = 0.2 \text{ person/m}^2;$$

Rf – coefficient – a quotient of time during which the area is made available for the tourists and the mean duration of stay of a tourist; the adopted time of accessibility to the beaches was 16 hours, and the mean duration of stay of one tourist 5 h, therefore $Rf = 3.2$.

Index PCC defines the largest possible number of tourists on a given area in any specified time, that does not cause devastation and degradation of the natural environment [Pawlikowska-Piechotka 2009].

The additional index applied was the index of tourist capacity for open bathing areas, at 20 m²/person, above which value there appears excessive tourist pressure on the lake ecosystem [Owsiak *et al.* 2003]. The water area for the bathers was obtained on the basis of counting the tourists within a 30 m belt into the shore water surface of the lake, along the whole shoreline of the lake (area of approx. 113,340 m²). The calculations took into account the average number of tourists on the lake during a day, assuming that each sunbather on the beach was also a bather during his/her stay.

RESULTS AND DISCUSSION

In the summer season of 2008 the mean diurnal number of tourists on the three main beaches of lake Piaseczno was 724.5 persons and it was nearly twice lower than in the summer season of 2010 (Tab. 1). In the summer season of 2010 the maximum number of tourists was 2603 (Tab. 1), which was about one half of the number of tourists within the shoreline of lake Piaseczno in the 1990's, when that number attained even the level of 5000 persons per 4 day [after Radwan, Kornijów 1998]. With the assumption that a short non-organised rest visit does not generate significant costs, that situation could have been caused by the social and economic changes in Poland, determining a rise in the material status and level of living of a part of the families, which – in consequence – could be reflected in other choices for the recreational destinations, e.g. attractive trips abroad.

Both in 2008 and in 2010 significant differences were noted in the numbers of sunbathers for the successive dates of survey, which is reflected in the high values of the coefficient of variation (Tab. 1). As expected, lower numbers of tourists were observed on the week days – in 2008 a mean of 394 persons, and in 2010 – 1086 persons. Considerably more tourists visited lake Piaseczno on weekends, though that tendency was somewhat less pronounced in the summer season of 2010 (1274 persons in 2008 and 2397 in 2010, respectively). This fact may support the observable trend towards shift in the proportions of tourist traffic from the weekend one to the week days, noted already since the end of the nineteen eighties [Chmielewski 2001].

Table 1. Mean diurnal numbers of tourists on beaches of lake Piaseczno, with oscillation graphs and total numbers in the summer seasons of 2008 and 2010

Piaseczno Lake	2008	2010
Range	103–1956	750–2603
Mean daily	724.5	1413.8
<i>SD</i>	720.7	725.5
<i>V</i> , %	99.48	51.32
Total	5796	11311

The balance and the distribution of sources of biogens entering the lake depend on the manner of drainage basin use, and in the case of lakes the largest share in the influx of nutrients is that of tributaries and transit water courses, and somewhat lesser that of agriculture. Scattered sources, from which nutrients of recreational genesis originate, usually constitute a small contribution in the balance of substances fertilising a lake [Ławniczak *et al.* 2010].

With relation to their numbers, the tourists could potentially introduce twice the amount of nutrients (N and P) and organic substances (urine, sweat, organic compounds: soluble and insoluble) in the summer of 2010 (Fig. 1, 2, 3).

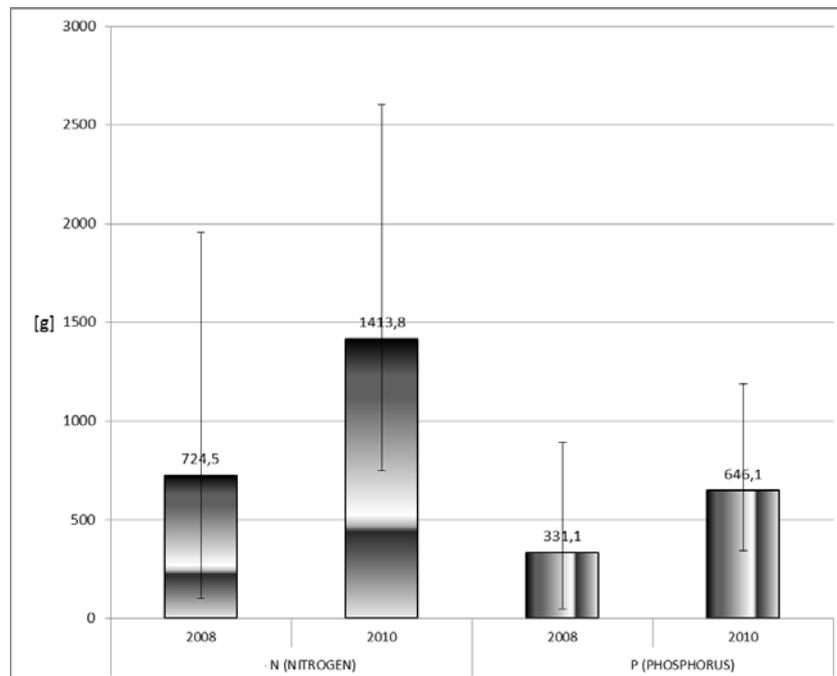


Fig. 1. Mean diurnal values of biogens potentially introduced by bathers on the beaches into the waters of lake Piaseczno, with variation ranges in the summer seasons of 2008 and 2010

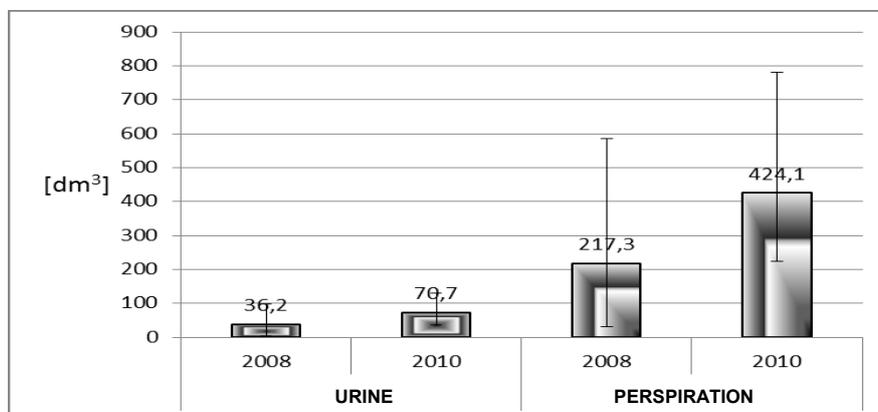


Fig. 2. Mean diurnal values of organic secretions potentially introduced by bathers on the beaches into the waters of lake Piaseczno, with variation ranges in the summer seasons of 2008 and 2010

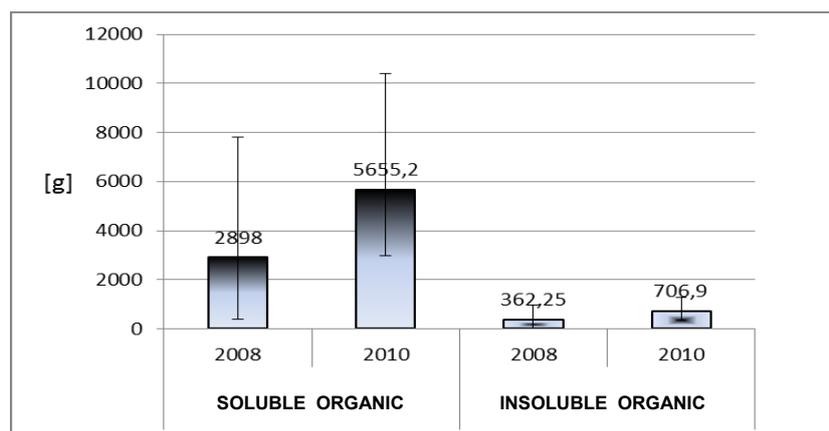


Fig. 3. Mean diurnal values of organic compounds, soluble and insoluble, potentially introduced by bathers on the beaches into the waters of lake Piaseczno, with variation ranges in the summer seasons of 2008 and 2010

The estimated total amount of nitrogen introduced by the sunbathers in that time was 11.3 kg, that of phosphorus – 5.1 kg, urine – 565.5 dm³, sweat – nearly 3393.5 dm³, and over 45.2 kg of soluble organic compounds and 5.65 kg of insoluble organic compounds. The tourists could have introduced into the lake waters also undetermined amounts of other organic contaminants, e.g. hair, epidermis, residues of alimentary track excretions, saliva, mucus, vomit residues, parasites, microorganisms, and also residues of cosmetics, detergents, textile fibres, and dust [after Prędotła 2007].

Extrapolating directly, with a large error margin, the mean diurnal amount of biogenic substances for all the dates of survey over the whole summer season of 2010 (due to the lack of analysis of weather conditions, without the division for weekend tourism and the week days the arithmetic mean was multiplied by 90 days) we obtain over 127.2 kg of nitrogen, nearly 58.1 kg of phosphorus, over 44.5 thousand dm³ of physiological secretions (urine and sweat), as well as over 572 kg of organic compounds potentially introduced into the lake waters as a result of the beach tourism. In 2008, due to the smaller number of tourists using the beaches of lake Piaseczno, that balance was lower by one half.

Comparing the data obtained as above, concerning the potential load of N and P originating from the beach tourism in the study seasons, with adopted after Soszka [2010] unit coefficients of export relating to area loads of nutrients from drainage basin areas under use of various character (kg·ha⁻¹·year⁻¹), one can arrive at the following conclusions. The total estimated load of nitrogen from the beach tourism on lake Piaseczno in 2010 was higher by ¼ from the estimated amount of nitrogen introduced per year by the forest areas of the drainage basin of the lake (coefficient of 1.5 kg N·ha⁻¹·year⁻¹ at 67.5 ha), while the amount of phosphorus was over 50% greater than that potentially generated by the arable fields in the basin, with area of 82.15 ha (coefficient of 0.3 kg P·ha⁻¹·year⁻¹). The data concerning the areas of the cited elements of the drainage basin of lake Piaseczno are given after Furtak and Sobolewski 1998. Nevertheless, in the analysis of the balance of nutrients in the lake we take into account all possible area and point sources of the load of N and P that, in total, are far in excess of the amounts of biogens potentially generated by the beach tourism.

The physical carrying capacity index (*PCC*) calculated for the three main beaches of lake Piaseczno was within the range from 1382.4 to 2580.5 persons·day⁻¹ and assumed the total value for the whole lake $PCC_{tot} = 5683.2$ persons per day that could stay within the shoreline zone of the lake without detrimental effects on its ecosystem. Neither the number of beach tourists for the successive dates of research nor the mean diurnal number of tourists noted during the study period exceeded the *PCC* index value for lake Piaseczno.

The value of the *PCC* index calculated above exceeds nearly 3.5-fold the unit of natural tourist capacity index calculated for lake Piaseczno towards the end of the 1990's, that according to Radwan and Kornijów [1998] equalled 1700 persons·day⁻¹. However, even for that index the mean number of tourists per day on the beaches and in the bathing zones of lake Piaseczno during the study period did not exceed the limit value that would have an effect on the degradation of the ecosystem.

Similarly, the index of tourist capacity calculated for open bathing zones according to Owsiak *et al.* [2003], both for the summer season of 2008 (0.128 person·20 m⁻²·day⁻¹) and for the summer of 2010 (0.249 person·20 m⁻²·day⁻¹) did not exceed the sensitive value for the lake ecosystem, of 1 person·20 m⁻²·day⁻¹.

CONCLUSIONS

1. During the study period the numbers of tourists taking their rest on the beaches of lake Piaseczno were notably lower than in the 1990's, moderately confirming the tendency towards an increase of week-day rest and recreation at the expense of weekend tourism.

2. The relatively small number of tourists taking their rest on the beaches of lake Piaseczno was reflected in correspondingly lower amounts of biogenic compounds potentially introduced into the lake waters.

3. In the summer seasons of 2008 and 2010 the threshold levels of the tourist capacity index and the physical carrying capacity index of lake Piaseczno and of the index calculated for its open bathing zones were not exceeded.

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OCENA POTENCJALNEGO ŁADUNKU ZWIĄZKÓW EUTROFIZUJĄCYCH
POCHODZENIA REKREACYJNEGO DOSTAJĄCYCH SIĘ DO JEZIORA PIASECZNO
ORAZ JEGO CHŁONNOŚCI TURYSTYCZNEJ W SEZONACH LETNICH 2008 I 2010

Streszczenie. Jezioro Piaseczno, element Pojezierza Łęczyńsko-Włodawskiego, włączone w sieć ochrony obszarowej jako użytek ekologiczny ze względu na wyjątkowe walory przyrodniczo-krajobrazowe znajduje się pod silną presją turystyczno-wypoczynkową. Celem pracy było określenie stopnia oddziaływań środowiskowych dotyczących jeziora pod kątem potencjalnych ilości wprowadzonych substancji biogenych i chłonności turystycznej związanych z analizą liczebności turystów w linii brzegowej w sezonie letnim 2008 i 2010 r. W okresie badań liczebność turystów w strefie brzeżnej jeziora Piaseczno nie zdeterminowała znacznego potencjalnego dopływu związków biogenych pochodzenia rekreacyjnego do jeziora i nie wpłynęła na przekroczenie wskaźników turystycznej chłonności fizycznej, chłonności naturalnej jeziora i indeksu dla stref kąpielisk otwartych. Wyższą liczebność turystów zanotowano w sezonie letnim 2010.

Słowa kluczowe: jezioro, biogeny, chłonność turystyczna, rekreacja, turystyka