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CHANGES IN THE ALKALINE PHOSPHATASE ACTIVITY IN THE LITTORAL WATER OF LAKE PIASECZNO (THE ŁĘCZNA-WŁODAWA LAKELAND) BETWEEN 1996 AND 2016 AS AN INDICATOR OF TRANSFORMATIONS IN THE WATER ENVIRONMENT IN AGRICULTURAL AREAS

Summary

Between 1996 and 2016 the activity of alkaline phosphatase in the littoral water of Lake Piaseczno was researched in five-year measurement cycles. Samples of water from the area corresponding to the agricultural sector of the lake catchment area were used as the research material. Simultaneously, the content of nitrogen and phosphorus compounds in the soils of the agricultural sector of Lake Piaseczno was investigated. Between 1996 and 2006 the activity of alkaline phosphatase in the water under study was similar and exhibited a slight increasing tendency. In the consecutive measurement cycles (2011 and 2016) the activity of the enzyme in the water increased significantly. The research also proved that every year the content of mineral forms of nitrogen and assimilable phosphorus in the soil surrounding the lake tended to increase. The enzymatic parameter under study was used as an indicator of lake eutrophication. The research revealed that during the period under analysis the trophicity of Lake Piaseczno increased.
***Key words**: alkaline phosphatase activity, water habitats, agricultural areas*

ZMIANY AKTYWNOŚCI FOSFATAZY ZASADOWEJ W WODZIE LITORALNEJ JEZIORA PIASECZNO (POJEZIERZE ŁĘCZYŃSKO-WŁODAWSKIE) W LATACH 1996-2016 JAKO WSKAŹNIK PRZEOBRAŻEŃ ŚRODOWISK WODNYCH NA TERENACH ROLNICZYCH

Streszczenie

W latach 1996-2016, w 5-letnim cyklu pomiarowym, badano aktywność fosfatazy zasadowej w wodzie litoralnej Jeziora Piaseczno. Obiektem badań były próbki wody pochodzące z obszaru odpowiadającego sektorowi rolniczemu zlewni jeziora. Równolegle badano także zawartość związków azotu i fosforu w glebach przybrzeżnych sektora rolniczego Jeziora Piaseczno. W latach 1996-2006 aktywność fosfatazy zasadowej w badanych wodach utrzymywała się na zbliżonym poziomie, wykazując niewielką tendencje wzrostową. Natomiast w kolejnych cyklach pomiarowych (2011 i 2016) zanotowano istotny wzrost aktywności tego enzymu w badanej wodzie. Wykazano także wzrastającą z roku na rok zawartość mineralnych form azotu i fosforu przyswajalnego w glebie przybrzeżnej jeziora. Opierając się na badanym parametrze enzymatycznym jako jednym ze wskaźników eutrofizacji jezior stwierdzono, że w analizowanym okresie wystąpił wzrost troficzności zbiornika Piaseczno.
***Słowa kluczowe**: aktywność fosfatazy alkalicznej, środowiska wodne, obszary rolnicze*

1. Introduction

Bodies of water in agricultural areas have important ecological, economic and recreational functions. They are particularly significant for maintenance of biodiversity as they positively modify the microclimate [9]. The two main nutrients responsible for the eutrophication of water habitats are nitrates (V) and, above all, phosphates – due to contemporary transformations in rural areas (V) [1, 7]. The imbalance between the flow of biogenic substances to the water habitat and the growth of biomass caused by the accumulation of phosphorus and nitrogen reserves in water can chiefly be observed in lakes, because the minimal flow of water and exchange of matter favour its development [3, 12]. These conditions generate anaerobic decay processes, which disorder biological life in the water environment [8, 17]. The alkaline phosphatase activity in water is an indicator of lake eutrophication [5, 7, 11]. The aim of the study was to determine the possible changes in the trophicity of Lake Piaseczno during the long-term period on the basis of the alkaline phosphatase activity in the littoral water

2. Materials and methods

The research was located in the agricultural sector of the Lake Piaseczno catchment area. The area of Lake Piaseczno is about 84 ha. Its maximum depth is about 39 m. It is located in the south of the Łęczna-Włodawa Lakeland, about 45 km east of Lublin. The Lake Piaseczno catchment area is flat and small (240 ha). It is mostly covered by podzolic soils composed of sand, characterised by low fertility and low sorption. Only in the north there are peat soils made from a low peat bog adjacent to the lake [3, 16]. Depending on the land use, the lake habitat was contractually divided into three sectors (partial catchment areas): an agricultural sector, a forest and recreation sector and a peat sector. A specific part of the shore and the littoral zone of the lake was allocated to each sector [15]. Until the 1980s the sector

of the Lake Piaseczno catchment area under study was mostly used for farming [19]. At present, due to the increasing number of holiday plots it is chiefly used for tourism and recreation. The natural tourist absorption capacity in this part of the lake catchment area has been exceeded more than 4 times [10].

Between 1996 and 2016 the alkaline phosphatase activity in the littoral water of the agricultural sector of the Lake Piaseczno catchment area was researched in five-year measurement cycles. Simultaneously the content of mineral forms of nitrogen and assimilable forms of phosphorus in the soils surrounding the agricultural sector of the shore of lake was studied. Samples of water and soil were collected three times a year (in early May, mid-July and late September) in 1996, 2001, 2006, 2011 and 2016. Water samples were collected with a 5 dm^3 Bernatowicz dipper and stored at 4°C for about 24 hours. Soil samples were collected along the surface water flow line running next to the shore. The samples under analysis were the average of 5 samples collected from the selected research stations. The alkaline phosphatase activity in the water was measured with the method developed by Jones [11]. The content of ammonium nitrogen and nitrate nitrogen [ISO 14255] and assimilable forms of phosphorus in the soil samples were measured with the method developed by Egner et al. [6].

The results were statistically analysed with Microsoft Office Excel 2003 spreadsheet and Statistica v. 10PL software. The variability of the results was estimated with the two-way analysis of variance. The significance of differences between the mean values was verified with Tukey's t-test at a significance level of $\alpha \leq 0.05$. For some parameters, the value of the Pearson correlation coefficient (r) was calculated at $p < 0.05$. A maximum 5% dispersion of measurements in the biochemical and chemical analysis was assumed in the study.

3. Results and discussion

During the twenty-year period under study alkaline phosphatase activity in the littoral water of Lake Piaseczno was characterised by high spread as it ranged from 298.1 to 2,858.6 nmol $PO_4 \cdot dm^{-3} \cdot h^{-1}$ (Table 1). The observations made between 1996 and 2006 proved that the alkaline phosphatase activity in the water under study was similar and exhibited a slight increasing tendency. In the consecutive measurement cycles (2011 and 2016) the enzyme activity in the littoral water of the agricultural sector of the Lake Piaseczno catchment area increased significantly. In 2011 the alkaline phosphatase activity was about 3-4 times greater than in 1996, whereas in 2016 it was 6-7 times greater (Table 1). The increase resulted from the amount of nitrogen and phosphorus compounds flowing to the lake and stimulating the enzymatic activity. Between 2011 and 2016 there was a significant increase in the content of mineral forms of nitrogen and assimilable phosphorus in the soil around the shore of the lake (Table 2). The flow of biogenic substances to the water environment stimulates the development of heterotrophic bacteria and fungi, which are one of the sources of phosphatase [2, 7, 14]. Our study proved a highly significant positive correlation between the alkaline phosphatase activity in the littoral water and the content of mineral forms of nitrogen and assimilable phosphorus in the soil around the shore of the lake (Table 3). It indicates the increasing trophicity of Lake Piaseczno and the eutrophication of the lake shoreline habitat, generated by the increasing anthropogenic pressure. The character of rural areas is changing – they are being transformed from the space of agricultural production into the space of multifunctional consumption, in which recreation, tourism, housing and non-productive use of natural resources are increasingly important while agriculture is in decline, both in the functional aspect and in terms of land use [4].

The alkaline phosphatase activity in the water under study was characterised by seasonal fluctuations, which were particularly noticeable in 2011 and 2016. The enzyme activity was significantly higher in July (Table 1). The study by Furczak and Bielińska [7] proved that the high phosphatase activity in the water in July was related with larger populations of heterotrophic bacteria and high inflow of biogenic substances to the littoral water of Lake Piaseczno. Other authors also observed the maximum alkaline phosphatase activity in lake water during the summer stagnation [5, 14]. In our study the decrease in the alkaline phosphatase activity in water in spring and autumn may have been caused by low temperatures and lower demand of the biocenosis for phosphates [2].

During our observations the content of mineral forms of nitrogen and assimilable phosphorus in the soil around the shore of Lake Piaseczno increased noticeably as time elapsed (Table 2). Between 1996 and 2006 the differences were not statistically significant. However, in the consecutive measurement cycles (2011 and 2016) the content of these components in the soil surrounding the shore of the lake increased several times. It was caused by the pressure of recreation, which became more intense as time elapsed. This fact is proved by seasonal changes in the content of nitrogen and phosphorus compounds in the soil under study. The content of these components in the soil around the shore of the lake was noticeably higher in summer and autumn than in spring (Table 2). Studies conducted by other authors [13, 18, 19] proved that changes in the use of land in the Lake Piaseczno catchment area from agricultural to recreational inhibited the flow of biogenic substances of agricultural origin and simultaneously increased the flow of nutrients related with tourism and recreation.

Table 1. The alkaline phosphatase activity in water (nmol $PO_4 \cdot dm^{-3} \cdot h^{-1}$)
Tab. 1. Aktywność fosfatazy zasadowej w wodzie (nmol $PO_4 \cdot dm^{-3} \cdot h^{-1}$)

Term	Year				
	1996	2001	2006	2011	2016
May	298.1a	382.8a	354.6a	780.1b	1,893.8c
July	372.4a	480.6a	569.2a	1,437.7c	2,858.6cd
September	348.9a	412.8a	512.9a	944.5b	2,204.3c
$\overline{x}$	339.8a	425.4a	478.9a	1,054.1b	2,318.9c

The values followed by the same letter in the column are not significant at $p < 0.05$, 't' - test.

Source: own work / Źródło: opracowanie własne

Table 2. The content of particular nitrogen and assimilable phosphorus forms (P) in the soil around the shore of the lake
Tab. 2. Zawartość poszczególnych form azotu i przyswajalnego fosforu (P) w glebie otaczającej brzeg jeziora

Year	Term	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	P
		$[mg \cdot kg^{-1}]$		
1996	May	24.5a	10.2a	33.2a
	July	58.1a	27.3a	40.1a
	September	41.3a	19.1a	38.6a
2001	May	18.9a	6.9a	39.8a
	July	47.6a	24.8a	42.3a
	September	33.8a	25.1a	40.9a
2006	May	44.7a	20.5a	54.5a
	July	69.4ab	42.1b	60.4a
	September	52.1a	38.9b	59.3a
2011	May	108.5b	72.1c	82.5b
	July	122.8b	83.8c	93.4b
	September	99.4b	85.6c	89.7b
2016	May	137.3b	101.4c	122.1bc
	July	148.1b	138.9c	134.9bc
	September	150.3b	144.1c	128.6bc

The values followed by the same letter in the column are not significant at $p < 0.05$, 't'- test.

Source: own work / Źródło: opracowanie własne

Table 3. The coefficients of correlation between the alkaline phosphatase activity in water and the concentration of nitrogen (NH_4^+ and NO_3^-) and assimilable phosphorus forms (P) in the soil around the shore of the lake
Tab. 3. Współczynniki korelacji pomiędzy aktywnością enzymatyczną a zawartością mineralnych form azotu (NH_4^+ i NO_3^-) oraz fosforu przyswajalnego (P) w glebie przybrzeżnej jeziora

Alkaline phosphatase	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	P
	0.91^*	0.94^*	0.95^*

* significant at $p = 0.05$.

Source: own work / Źródło: opracowanie własne

4. Conclusions

1. The significant increase in the alkaline phosphatase activity in the littoral water of the agricultural sector of the Lake Piaseczno catchment area observed over the period of twenty years (1996-2016) points to rapid eutrophication of the lake caused by the pressure of recreation.
2. The increasing content of mineral forms of nitrogen and assimilable phosphorus in the soil surrounding the shore of Lake Piaseczno points to the increasing anthropogenic pressure, which generates eutrophication of the lake ecosystem.
3. Measurements of the alkaline phosphatase activity in lake water enable determination of the rate of eutrophication of shoreline habitats.
4. The results of long-term observations point to the need to undertake renaturing and preventive actions in order to determine the optimal values of the compensational capacity of the Lake Piaseczno catchment area and the recreational capacity of this ecosystem.

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