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DIFFERENCES IN COMPOSITION AND PROPORTION OF PHOSPHORUS FRACTIONS IN BOTTOM SEDIMENTS OF LAKE GÓRECKIE (WIELKOPOLSKA NATIONAL PARK)

The spatial and vertical changes in the composition of the profundal bottom sediments of Lake Góreckie, in particular the changes in the fraction of phosphorus of different mobility and bioavailability, have been studied. The basin of this channel lake is naturally divided into two parts. The bottom sediment was collected by a Limnos sampler equipped with a device for core slicing (in situ). It was shown that in the surface layer of the sediment actively involved in the exchange of matter between the sediment and water, the content of phosphorus was rather low and only up to 24% of its pool was bound to the bioavailable fractions. However, this amount was sufficiently high to stimulate high trophy of the lake with periodical states of water hypertrophy.

1. INTRODUCTION

Usually, phosphorus is the element limiting the primary production in lakes. Its compounds, relatively easily removable from the bulk water and accumulated in the bottom sediments [1], [2], in favourable conditions can be released back to the bulk. Many times, this secondary, inner source of this element determines the trophic status of lakes [3]–[5] and other inland water bodies [6]. The total content of phosphorus in the surface layer of the bottom sediment – the layer directly involved in the sediment–bulk water exchange – does not reflect the full scale of the lake status. Much more information on the current state of the lake can be obtained by the fractionation of phosphorus [2], [5], [7] which illustrates the ability of its release.

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2. STUDY AREA

Lake Góreckie, localised in the Wielkopolska National Park, is a large and rather deep channel-moraine type reservoir (the area of 103 ha, the maximum depth of 17 m) with no outflows, almost totally surrounded by hilly forested banks. The area at the bank is agriculturally used only in the north-western part. The lake basin is naturally divided into two subbasins: a deeper southern one and a shallower (the maximum depth of 10 m) north-western one. The lake, classified into category II in susceptibility to degradation [8]–[10], presently reveals the signs of advanced degradation. The main reason is that for many years the lake received the untreated wastes from the nearby sanatorium. Despite the fact that the inflow of the wastes to the lake was totally cut off in the end of the 1990s, the lake water was in the hypertrophic state [9], [11].

3. MATERIAL AND METHODS

Sediment samples were collected in May 2008 from a profundal zone in both basins of the lake. According to the earlier tests, the sediments on the slopes of the lake basin have more mineral character and contain small amounts of phosphorus [12]. The samples were collected by a cores sampler (Limnos) with a device for core slicing. The core was sliced into 5-cm layers directly after collection; each 5-cm thick layer was treated as a separate sample. At nine sites labelled with numbers 1–9, the sediment samples were collected from a 10-cm thick layer directly involved in the exchange of matter between the sediment and the bulk water [5]. In order to analyse the changes in the chemical compositions in the deeper layers, the cores at two sites (no. 10 and 13) were 30 cm thick.

The degree of sample hydration was determined directly after their collection. Next, the fractionation of phosphorus was performed by sequential extraction according to the scheme proposed by PSENNER [13], who separated 5 fractions: P-NH_4Cl – loosely bound phosphorus, P-Fe – iron-bound phosphorus, P-NaOH – phosphorus bound to aluminium and organic matter, P-HCl – phosphorus bound to calcium, P-Rez. – phosphorus permanently bound to the matrix. After drying, the content of organic matter as loss on ignition at 550 ºC was analysed in the air-dry samples. The total phosphorus was determined at 850 nm using a UV-1610 (Shimadzu) spectrophotometer (molybdate method) after sample ashing at 550 ºC and mineralization in HNO_3 and H_2SO_4 [14]. Calcium, iron and aluminium were analysed using FAAS technique in AAnalyst 300 (Perkin Elmer) after sample mineralization in HNO_3 and H_2O_2 [15] (Ca, Al – atomization in N_2O-C_2H_2 flame). Determination of metals from the acidic extract enabled determination of the aluminium fraction soluble in acids that can be involved in the phosphorus binding.

4. RESULTS AND DISCUSSION

The lake sediments in the surface layer (0–10 cm) were red-brown in colour and of semi-liquid consistence. The deeper layer was darker, the colour ranging from brown to black, and the hydration degree of the sediment clearly decreased with its increasing depth. The sediments collected from the surface layer (down to 10 cm) were characterised by a similarly high degree of hydration and similar content of organic matter (table 1). The sediment collected from the south basin contained more calcium and iron. The content of phosphorus was also higher in the south basin, which is related to the discharge of the untreated domestic sewage from the nearby sanatorium. This fact has been already confirmed in the earlier studies [12]. In general, the content of total phosphorus in the surface layer of the sediment was relatively low. Much higher content of phosphorus was determined in other lakes in the Wielkopolska National Park, the area subjected to strong anthropogenic pressure [16], and in a several dozen lakes studied by KENTZER [2].

Table 1

Physicochemical characteristics of bottom sediments of stations No. 1–9

Parameter	Unit	Station No								
		1	2	3	4	5	6	7	8	9
Hydration	%	88.1	89.6	87.0	91.9	89.7	88.3	89.7	88.8	90.2
Organic matter	% d.w.	28.1	27.1	27.1	26.3	27.2	26.2	27.1	26.4	27.2
Calcium	g kg^{-1} d.w.	75.0	83.0	71.0	122	120	128	114	88.0	112
Iron	g kg^{-1} d.w.	6.77	5.97	3.56	5.21	6.53	4.96	10.2	11.5	10.7
Aluminium	g kg^{-1} d.w.	4.95	5.10	3.70	3.69	3.53	3.02	4.37	6.12	6.88
Phosphorus	g kg^{-1} d.w.	1.09	1.15	1.03	1.17	1.26	1.06	1.27	1.01	1.26

The fractional analysis of phosphorus proved that the most bioavailable fractions, that is P-NH_4Cl and P-Fe, made together from 15% to 24% of the pool of this element (figure 1). Much greater content of phosphorus was found in its fraction bound to organic matter and aluminium (P-NaOH), which is less bioavailable. The lowest content of phosphorus was observed in the residual fraction (P-Rez.), which is practically biologically unavailable. A similar fractional distribution of phosphorus was characteristic of many Polish lakes [2].

As expected, in all deep cores of the sediment (table 2), both hydration and the content of organic matter decreased with increasing depth. In the shallower layers of the sediment, calcium was found in high concentration, which can be related to the progressive eutrophication of the lake, leading to periodical strong alkalinity of the water. In the polar cores collected from the southern basin, a characteristic vertical distribution of iron content was established. From the surface to the depth of 20 cm, the concentration of iron increased with the depth, but in the deeper layers it decreased. This pattern of changes can be related to the above-mentioned discharge of sewage from the sanatorium, which had been taking place for a few years in the past.

In the north-western basin subject to anthropogenic pressure only from scattered sources, the content of iron also increased with the depth of the sediment, but the gradient of concentrations was much smaller (table 2).

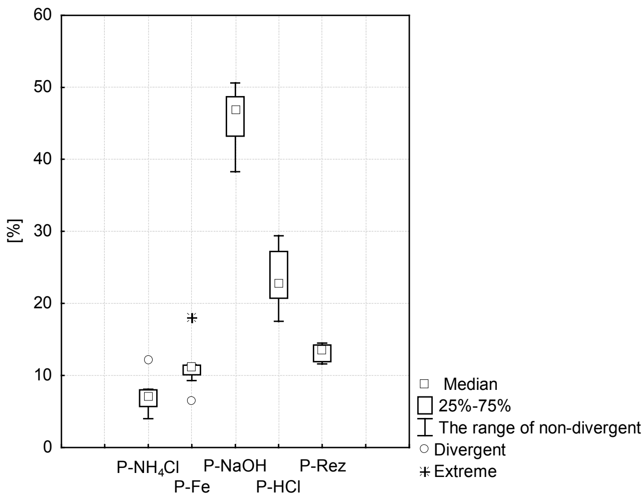

Fig. 1. Phosphorus fractions in surface layer of bottom sediments (0–10 cm) in stations 1–9

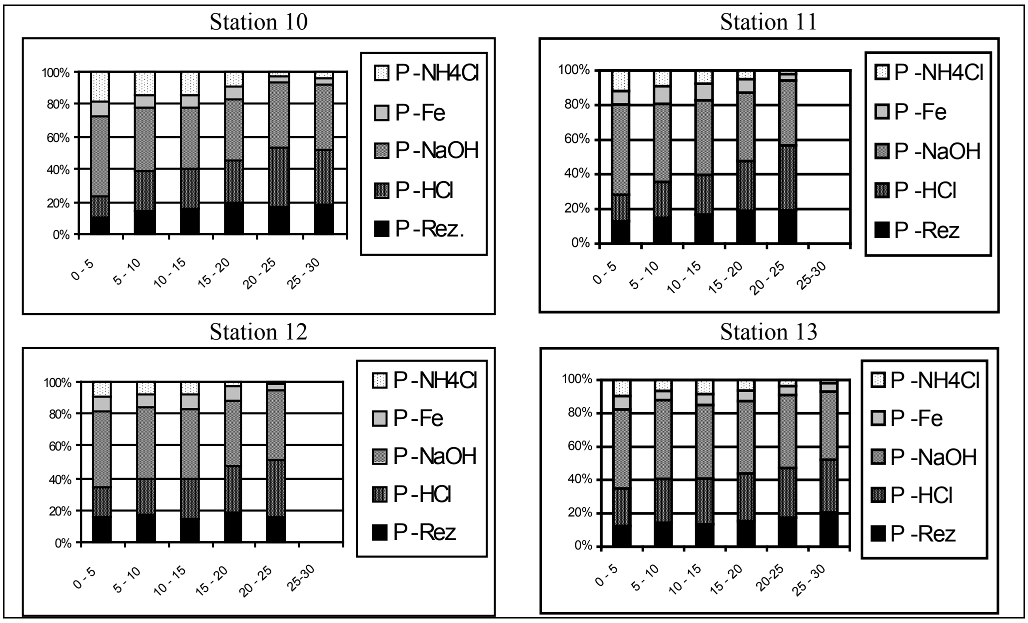

Fig. 2. Vertical changes of percentage proportion of phosphorus fractions in bottom sediments of Lake Góreckie

Table 2

Spatial and vertical changeability of physicochemical parameters of bottom sediments

Parameter	Layer (cm)	0–5	5–10	10–15	15–20	20–25	25–30
				Station 10			
Hydration	%	95.4	89.8	88.6	86.1	84.2	83.6
Organic matter	% d.w.	33.6	28.2	27.7	24.8	23.9	21.8
Calcium	g kg^{-1} d.w.	143	121	114	107	107	107
Iron	g kg^{-1} d.w.	6.79	11.6	12.6	14.8	11.7	6.74
Aluminium	g kg^{-1} d.w.	4.97	5.77	6.64	4.90	4.79	4.16
Phosphorus	g kg^{-1} d.w.	1.50	1.12	1.09	0.95	1.16	0.91
				Station 11			
Hydration	%	96.6	86.4	84.5	82.5	80.1	–
Organic matter	% d.w.	29.8	28.0	25.3	23.3	23.5	–
Calcium	g kg^{-1} d.w.	143	121	86.0	107	100	–
Iron	g kg^{-1} d.w.	5.13	6.26	12.1	15.1	8.01	–
Aluminium	g kg^{-1} d.w.	3.40	5.40	10.2	4.11	6.19	–
Phosphorus	g kg^{-1} d.w.	1.62	1.33	0.91	1.00	0.99	–
				Station 12			
Hydration	%	96.0	89.0	86.9	84.3	82.8	–
Organic matter	% d.w.	26.3	23.3	22.1	20.3	17.9	–
Calcium	g kg^{-1} d.w.	89.0	86.0	68.0	64.0	57.0	–
Iron	g kg^{-1} d.w.	5.12	5.27	6.03	5.31	7.22	–
Aluminium	g kg^{-1} d.w.	3.71	4.54	8.70	6.40	7.56	–
Phosphorus	g kg^{-1} d.w.	1.35	1.20	0.99	0.78	0.74	–
				Station 13			
Hydration	%	91.2	87.2	84.9	82.0	78.9	78.7
Organic matter	% d.w.	25.6	23.9	22.6	20.6	20.0	18.6
Calcium	g kg^{-1} d.w.	100	86.0	71.0	50.0	43.0	43.0
Iron	g kg^{-1} d.w.	8.09	8.02	9.09	10.4	10.6	11.1
Aluminium	g kg^{-1} d.w.	5.19	3.55	5.10	5,23	4.75	5.20
Phosphorus	g kg^{-1} d.w.	1.22	1.16	1.04	0.93	0.82	0.67

The analysis of the content of phosphorus along the vertical profile of the sediment showed its highest concentration in the layer at the depth of 0–5 cm (table 2). In the deeper layers – already from 5–10 cm – the content of phosphorus systematically decreased (figure 2). With the increasing depth, the contribution of individual fractions of phosphorus also changed.

In all samples, the contribution of bioavailable phosphorus forms (the sum of P-NH_4Cl and P-Fe fractions) decreased with the depth, and the decrease of the most readily bioavailable fraction of P-NH_4Cl was much faster. The content of the fraction bound to aluminium and organic matter (P-NaOH) also decreased with the depth, but the decrease was smaller. As a result of the chemical transformations taking place in the sediments, with increasing depth and, consequently with prolonged time of deposition, the content of the phosphorus fraction bound to calcium (P-HCl) increased.

This increase was observed despite the fact that the content of calcium in the deeper layers of the sediment decreased. In the older layers of the sediment, the content of the residual fraction, practically biologically unavailable, was found to increase. However, in general, the contribution of P-Rez. was not high (table 2).

5. CONCLUSIONS

In the bottom sediment of Lake Góreckie, the greatest amounts of phosphorus, especially in the bioavailable fractions, were found in the surface layer of 0–5 cm. With increasing depth of the sediment, the content of the bioavailable fractions of phosphorus decreased, while the content of the hardly bioavailable species increased.

Higher content of phosphorus was found in the sediments form the southern basin, to which the untreated domestic sewage had been discharged for a few years in the past. In the pool of phosphorus accumulated in the surface layer, maximum 24% occurred in biologically available fractions. As follows from the observations of the aquatic environment, even this relatively low amount of phosphorus prompted intense algal bloom throughout the vegetation season, leading to the unclassifiable high concentration of chlorophyll *a* and to deoxygenation of the bulk water below the water surface layer.

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ZRÓŻNICOWANIE SKŁADU I UDZIAŁU FRAKCJI FOSFORU W OSADACH DENNYCH JEZIORA GÓRECKIEGO (WIELKOPOLSKI PARK NARODOWY)

Analizowano przestrzenne i pionowe zmiany składu profundalowych osadów dennych Jeziora Góreckiego, ze szczególnym uwzględnieniem frakcji fosforu, różniących się mobilnością i biodostępnością. Misa tego rynnowego jeziora jest naturalnie podzielona na dwa odmienne baseny. Osad pobierano czerpaczem z systemem cięcia rdzenia na warstwy (*in situ*). Wykazano, że w powierzchniowej warstwie osadu, biorącej czynny udział w wymianie materii osad–woda, zawartość fosforu nie była szczególnie wysoka, z czego tylko do 24% całkowitej jego puli było związane we frakcjach biodostępnych. Ilość ta była jednak wystarczająca do stymulowania wysokiej trofii jeziora z okresowymi stanami hypertrofii.