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CHANGES OF THE CHEMICAL COMPOSITION OF BOTTOM SEDIMENTS IN A DYSTROPHIC LAKE SMOLAK TWENTY YEARS AFTER THE END OF A LIMING AND MINERAL FERTILISATION EXPERIMENT

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A B S T R A C T. Bottom sediments of Smolak Lake twenty years after the end of liming and mineral fertilisation experiment contained 59-84% of organic matter, 14-55% of silica, 0.05-1.8% CaO, 0.1-0.7% Fe_2O_3, and 0.1-0.5% P_2O_3. Organic mater content increased by 26%, P_2O_3 - 28%, CaO content decreased by 24%, and Fe_2O_3 - 74% compared to the period immediately post mineral fertilisation and liming (1975). Phosphorus and iron accumulated in surface layer (0-5 cm), and calcium in deeper layers of the sediments (26-40 cm).

Key words: DYSTROPHIC LAKE, BOTTOM SEDIMENTS, CHEMICAL COMPOSITION

INTRODUCTION

Dystrophic Smolak Lake, situated in north-east part of Mazurian Lakeland, is a small, closed forest-surrounded water body, of 5.3 ha area, maximum depth 5.7 m, and mean depth 2.4 m. Its catchment area is overgrown with pine and spruce forest. South shore is covered with sphagnum changing into a 7-8 m wide peatbog, marsh birch growth, and marsh pine forest. East shore is composed of a 3-4 m wide peat-bog. At the north shore, patches of reed and cattail are present. North part of the west shore contacts marsh birch growth.

In 1971-1974 the lake was fertilised and limed. It was supplied with 19.5 kg ha^{-1} of phosphoric fertilisers, and 48.2 kg ha^{-1} of nitric fertilisers, applied three times a year. Once a year potassium fertilisation was applied (245.0 kg ha^{-1}), as well as liming (3960 kg ha^{-1} of $CaCO_3$). Each fertiliser dose should have increased calcium concentration in lake water to 45 mg dm^{-3}, potassium concentration – to 4 mg dm^{-3}, nitrogen – to 1.0 mg dm^{-3}, and phosphorus – to 0.1 mg dm^{-3} (Zdanowski 1976, Niewolak, Korycka 1976). Taking into consideration large amount of the introduced nutrients, efficiency of the treatment was low, although chemical composition of lake water changed considerably. Calcium concentration in the second year of the experiment exceeded 16 mg dm^{-3}, i.e. the treshold value for dystrophic waters (Stangenberg 1936), and in the fourth year it attained a maximum – 31 mg dm^{-3} at the surface and 34 mg dm^{-3} at the bottom. Average pH increased from 4.4 to 8.3 at the surface, and 7.3 at the bottom. Only maximum potassium concentration (9.3 mg dm^{-3}) became twice higher than the previsted level (Zdanowski 1976, Zdanowski et al. 1978).

Fertilisation and liming resulted in an almost seventeen fold increase of calcium content in the bottom sediments, and a three fold increase of potassium. Mineralisation degree in the sediments also increased. Organic matter content dropped by 12%, nitrogen – by 29%, and phosphorus – by 30% (Bnińska, Zdanowski 1978, Zdanowski et al. 1977, 1978).

Over twenty years from the end of the experiment, there was a gradual decrease of calcium, potassium and bicarbonate concentration in water, as well as a drop of electrolytic conductivity (Zdanowski, Hutorowicz 1988). The present study discusses changes in the chemical composition of bottom sediments.

METHODS

Bottom sediments were sampled using a pipe sampler „Nurek", in October 1990, and once a month in 1994 from April to September. Samples were taken from the central part of the lake, at the depth of 5 m (station I), in the north part at 2.5 m (station II), and near the north shore, at the bottom slope, at 1.5 m depth (station III). Sampling stations are shown on the bathymetric map of the lake (Fig. 1). Three layers of sediments were sampled: 0-5, 6-10, and 11-15 cm. In 1990, sediments were sampled every 5 cm down to 45 cm depth at station I, to 30 cm at station II, and to 40 cm at station III.

Organic matter content was calculated from the sediment weight loss after calcination in 550°C. The sediments were mineralised using a mixture of concentrated acids: perchloric, nitric, and sulphuric. The samples were filtered, the residue calcinated in 900°C, and silica content was determined. Calcium and potassium content was measured in the filtrate using flame photometry. Total iron was measured colorimetrically with ammonium rhodanate, and total phosphorus with the molybdenum method. The results were calculated as % of dry weight.

RESULTS

The sediments of Lake Smolak belong to an organic type according to Stangenberg's (1938) classification. Semi-liquid sediments in central part of the lake contained 59-84% of organic matter. A similar range was observed at station II. There was less organic matter at the shallow station III (Tab. I). Organic matter content was

TABLE 1

Chemical composition of the surface layer of bottom sediments, 0-15 cm (mean and range in % of dry mass) of Smolak Lake (data obtained in 1990 and 1994)

Parameters	Layer [cm]	Depth		
		1,5 m	2,5 m	5,0 m
Organic matter	0-5	56	70	75
		40-79	54-80	59-80
	6-10	64	72	76
		47-78	59-82	71-80
	11-15	67	74	77
		45-78	64-86	72-84
Silica	0-5	37	27	20
		14-52	15-45	12-39
	6-10	31	20	19
		16-52	12-24	12-25
	11-15	27	19	19
		15-44	13-25	15-25
CaO	0-5	0.90	0.51	0.52
		0.05-1.77	0.27-1.01	0.19-0.88
	6-10	0.78	0.60	0.58
		0.26-1.04	0.25-0.90	0.21-0.87
	11-15	0.59	0.45	0.49
		0.12-0.88	0.16-0.85	0.14-0.86
P_2O_5	0-5	0.25	0.23	0.31
		0.08-0.43	0.07-0.54	0.15-0.42
	6-10	0.24	0.16	0.24
		0.06-0.41	0.07-0.24	0.13-0.39
	11-15	0.23	0.21	0.25
		0.08-0.40	0.07-0.43	0.09-0.39
Fe_2O_3	0-5	0.16	0.28	0.28
		0.04-0.43	0.16-0.42	0.03-0.50
	6-10	0.17	0.11	0.18
		0.02-0.37	0.01-0.31	0.06-0.36
	11-15	0.13	0.22	0.20
		0.02-0.43	0.03-0.49	0.07-0.36

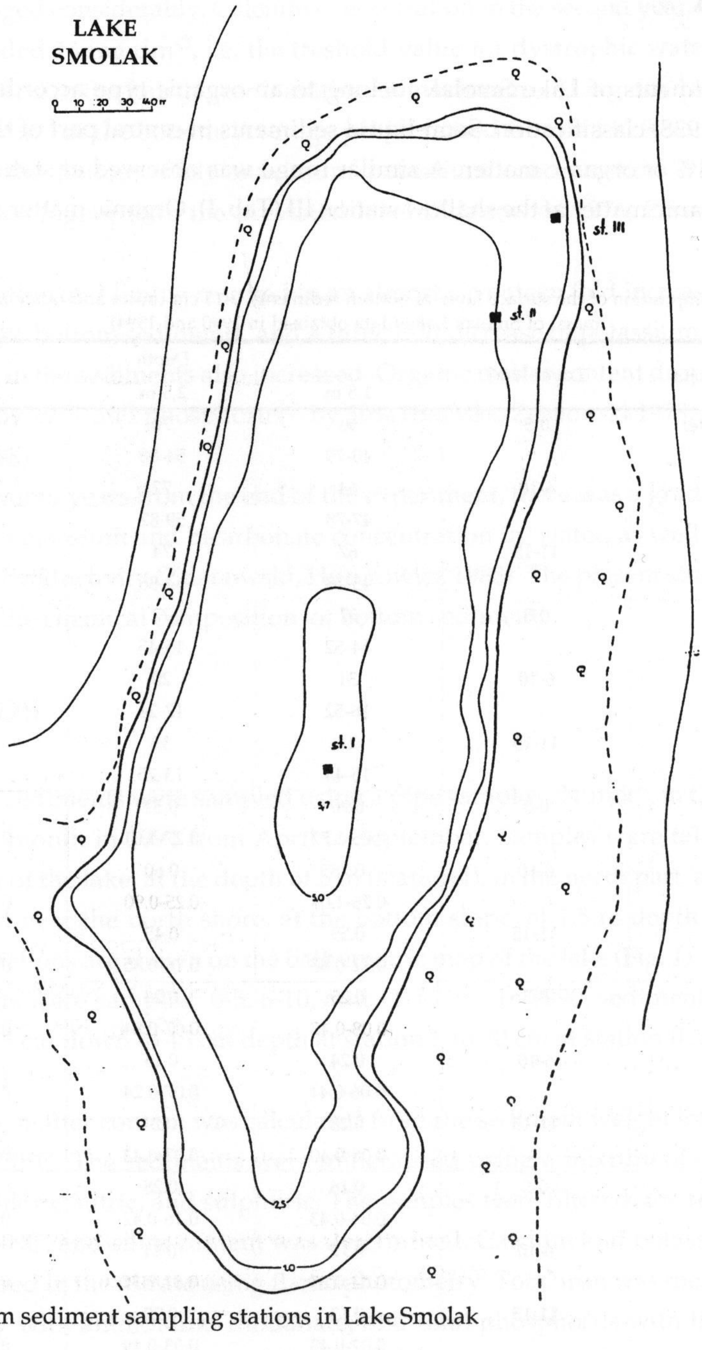

Fig. 1. Bottom sediment sampling stations in Lake Smolak

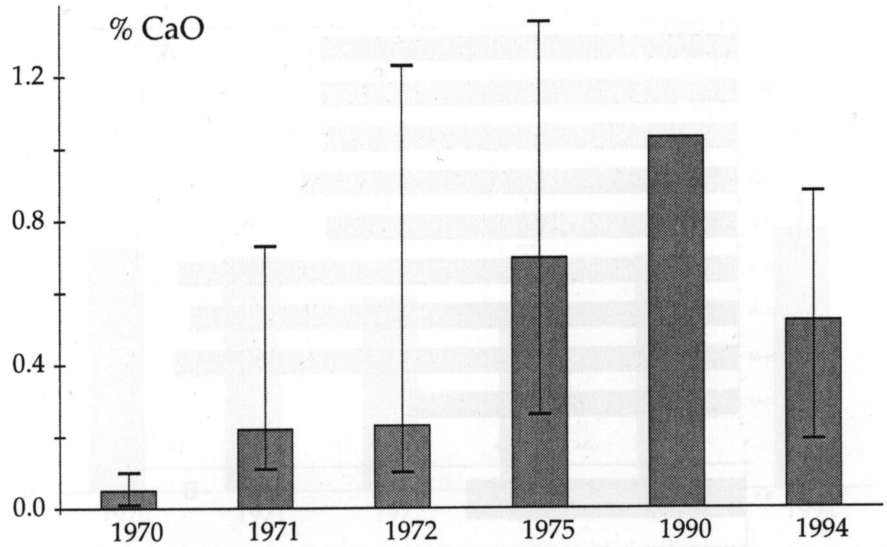

Fig. 2. Calcium content (avarage and range) in surface layer (0-5 cm) of the bottom sediments before liming and fertilization (1970), during the experiment (1971-1972), immediately after the experiment (1975), and in 1990 and 1994. Data for 1970-1975 according to Zdanowski et al. (1977)

similar to that in other dystrophic lakes. Stangenberg (1938) observed 61-90 % of organic matter in humic reservoirs near Wigry Lake, and Marek (1983) 88-94%. Similar results (77-83%) were obtained by Rybak (1969) in several dystrophic Mazurian lakes. Organic matter content increased by 26% (from 60% to 75% on the average) compared to the period immediately post liming and fertilisation.

Bottom sediments of Smolak Lake were rich in silica. Station III was the richest one in this respect (Tab. I). Silica content ranged there from 14% to 55%, while at station II it ranged from 12% to 32%, and at station I – from 12% to 39%. Silica content decreased by 48% during the twenty years post the fertilisation experiment.

The sediments contained very little soluble mineral compounds. Calcium content (as CaO) ranged from 0.05 to 1.8%. These values are slightly lower compared to some other dystrophic lakes (0.3-3.9%) of Mazurian Lakeland (Rybak 1969). Higher calcium content in humic reservoirs of Suwałki Lakeland (0.8-2.0%) was observed by Stangenberg (1938), and Marek (1983) (1.9-2.6%). Calcium content in the surface sediment layer decreased by 24% on the average, from 0.7 to 0.5% (Fig. 2) compared to the period just post the experiment. The results obtained in 1990 indicate that cal-

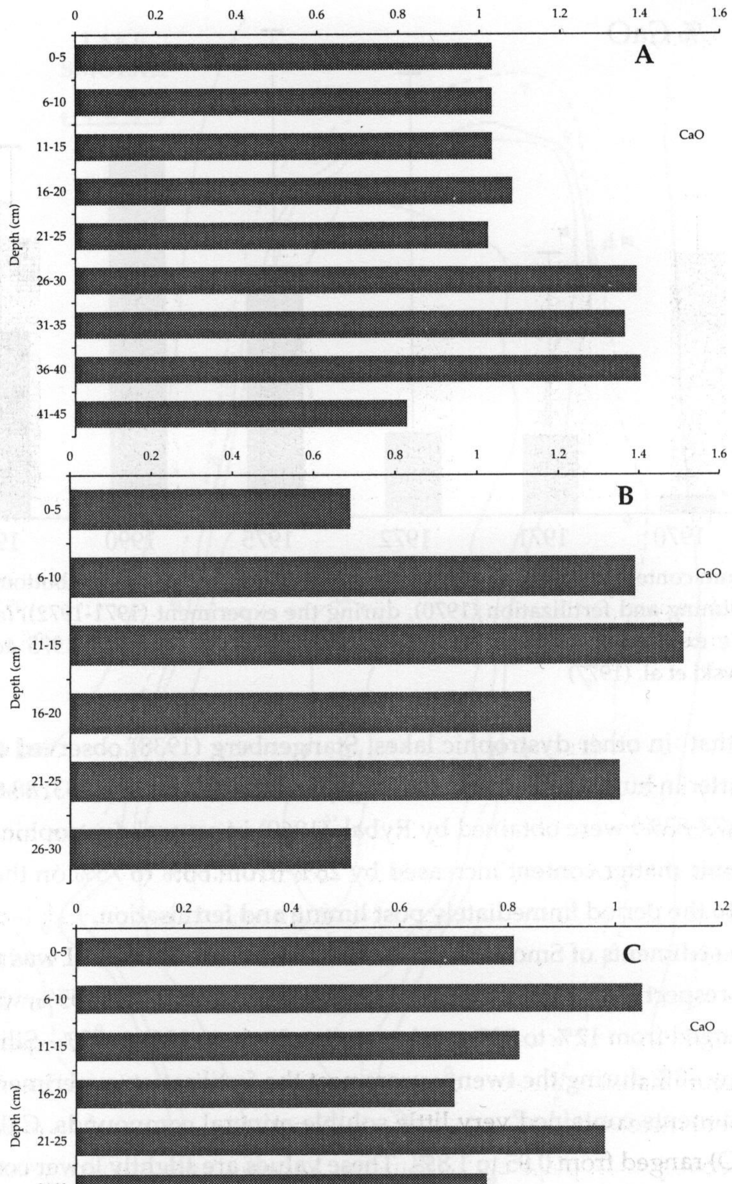

Fig. 3. Calcium content (% of dry mass) in the bottom sediments in October 1990 (A – station I, B – station II, C – station III)

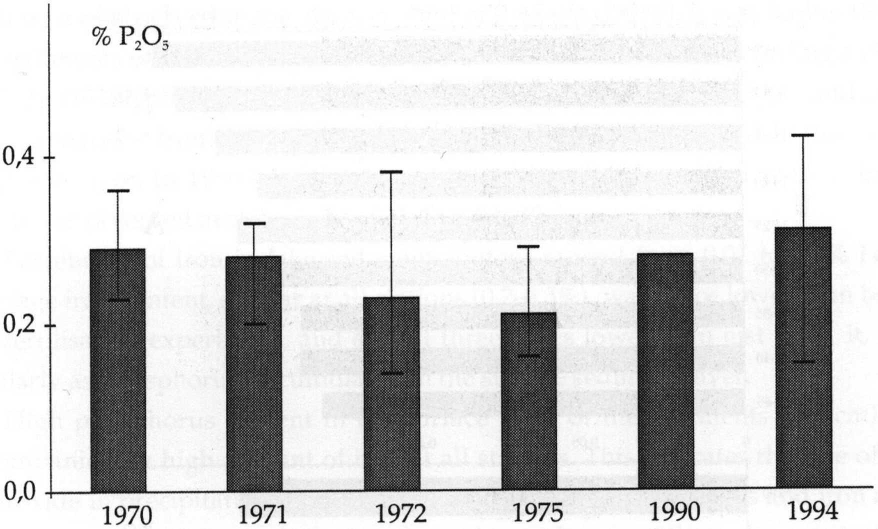

Fig. 4. Phosphorus content (avarage and range) in surface layer (0-5 cm) of the bottom sediments before liming and fertilisation (1970), during the experiment (1971-1972), immediately after the experiment (1975), and in 1990 and 1994. Data for 1970-1975 according to Zdanowski et al. (1977)

cium accumulated in the deeper sediment layers in the central part of the lake (Fig. 3A). Similarly high calcium concentration (over 1.4%) was observed at station II in a shallow layer of the sediments (Fig. 3B). In the lake littoral, calcium concentration was lower and changed irregularly with the sediment depth (Fig. 3C).

Changes of calcium concentration in the sediments of Lake Smolak induced by 4 years of liming were very similar to those observed in Lake Flosek, in which liming in July-October 1970 caused an increase of calcium concentration from 0.3-0.4% to 0.6-2.2% CaO (Hillbricht-Ilkowska et al. 1977). Twenty years after the experiment calcium still accumulated in the surface sediment layer (0-5 cm) of Lake Flosek. Content of this element increased to 1.3-2.4% CaO (Hillbricht-Ilkowska et al. in print). Similar changes probably took place also in Smolak Lake sediments, as suggested by the results of October 1990. In the subsequent years this tendency was reversed. In 1994 the average and maximum calcium content in the sediments was lower compared to the period post the fertilisation (Fig. 2).

Phosphorus content in Smolak Lake sediments ranged from 0.1 to 0.5% P_2O_5. The highest mean percentage of phosphorus (0.3%), resembling that before ferti-

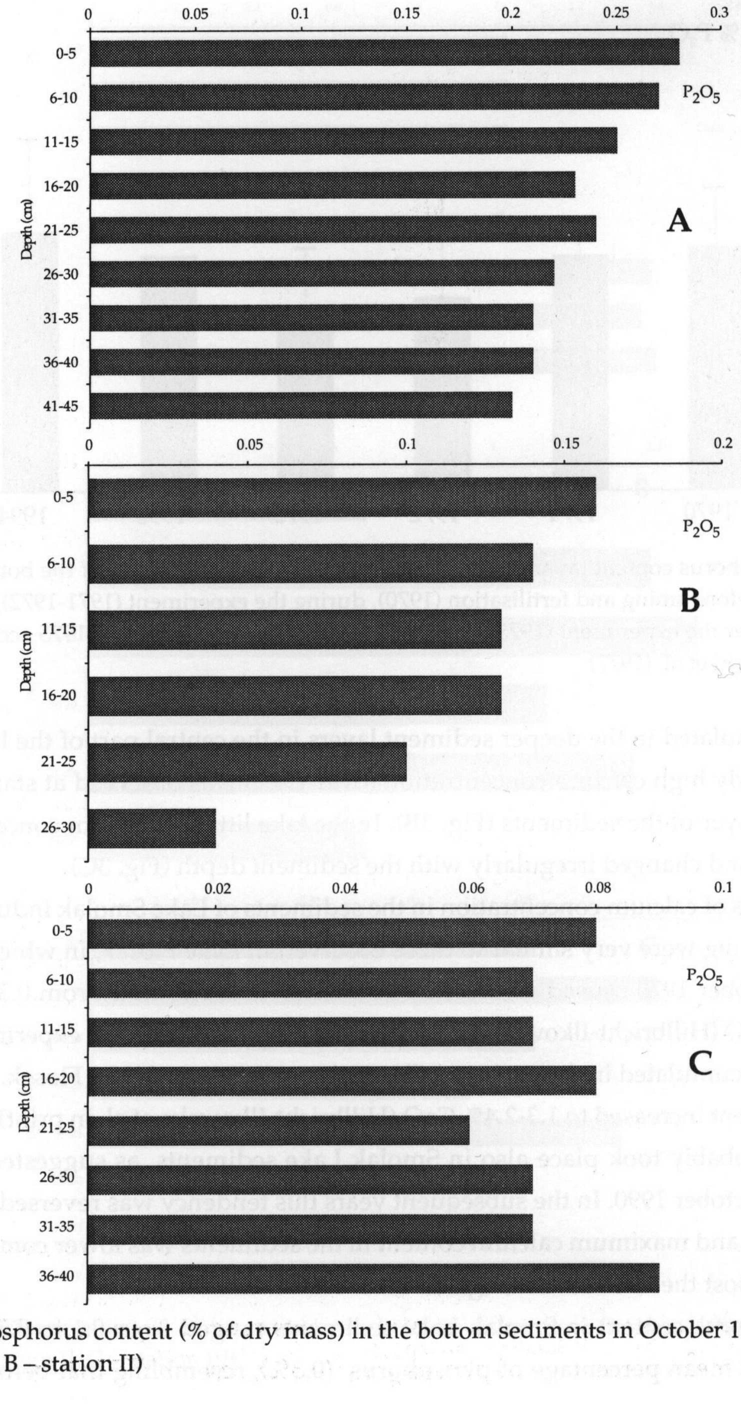

Fig. 5. Phosphorus content (% of dry mass) in the bottom sediments in October 1990 (A – station I, B – station II)

lisation, was observed in the deepest point of the lake (Fig. 4). It was higher than in the sediments of Suwałki Lakeland humic reservoirs, in which, according to Stangenberg (1938), phosphorus content ranged from traces to 0.1% of P_2O_5, and according to Marek – from 0.1 to 0.2% of P_2O_5. Phosphorus accumulated in the surface sediment layer. In 1990 considerable drop of phosphorus content with sediment depth was observed at stations I and II (Fig. 5A, B).

Percentage of iron in lake sediment content ranged from 0.01 to 0.7% Fe_2O_3. Average iron content, similar at all stations (0.2-0.3%), was twice lower than before the fertilisation experiment, and almost three times lower than just after it. Iron, similarly as phosphorus, accumulated in the surface sediment layer.

High phosphorus content in the surface layer of the sediments (0-5 cm) was accompanied by high amount of iron at all stations. This indicates the role of iron hydroxide in precipitating phosphates from the water. Phosphorus and iron accumulation in layer 0-5 cm, and calcium– in deeper layers of the sediments indicate that phosphorus was more strongly bound to iron than to calcium (Tab. 1).

CONCLUSIONS

Twenty years post the fertilisation and liming experiment, considerable decrease of water salinity was observed in Lake Smolak. Calcium content in surface waters dropped from 31 to 7 mg dm^{-3}, potassium – from 8.7 to 1.3 mg dm^{-3}, bicarbonates – from 96 to 21 mg dm^{-3}, and average water pH – from 8.3 to 7.1 (only at the bottom pH dropped down to 5.8) (Zdanowski, Hutorowicz 1998). Organic matter content in the bottom sediments increased again by 26%, phosphorus content –28%, and silica content decreased by 48%, calcium –24%, and iron –74%. The results obtained in October 1990 revealed that phosphorus and iron accumulated in the surface sediment layer, and calcium – in deeper layers (Fig. 3A, B, 5A, B) This suggests that phosphorus forms stronger bonds with iron than with calcium (adsorption on iron hydroxide).

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STRESZCZENIE

ZMIANY SKŁADU CHEMICZNEGO OSADÓW DENNYCH DYSTROFICZNEGO JEZIORA SMOLAK PO DWUDZIESTU LATACH OD ZAKOŃCZENIA WAPNOWANIA I MINERALNEGO NAWOŻENIA

Osady denne dystroficznego jeziora Smolak na podstawie badań prowadzonych na trzech stanowiskach w 1994 r. (rys. 1), uzupełnionych o dane pochodzące z października 1990 r. zaliczono do typu organicznego (59-84% materii organicznej). Krzemionka stanowiła nie więcej niż 36,7%, a pozostałe składniki kilka procent suchej masy osadów (tab. 1). Akumulacja fosforu i żelaza w warstwie 0-5 cm, a wapnia w głębszych warstwach osadu (26-40 cm) świadczyły o silniejszym związaniu fosforu z żelazem niż z wapniem i o współudziale wodorotlenku żelaza w procesie wytrącania fosforanów z wody jeziora.

W porównaniu z okresem bezpośrednio po wapnowaniu i nawożeniu mineralnym (1975) o 25% zawartość materii organicznej wzrosła o 25%, a zawartość wapnia obniżyła się o 27% (rys. 2). Udział żelaza był również prawie trzykrotnie mniejszy niż w czasie eksperymentu. Nie zmienił się natomiast średni udział (0,3%)fosforu.

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