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CHANGES IN THE CHEMICAL PROPERTIES OF WATER IN A SMALL POND IN VERTICAL PROFILES

Urszula Szyperek

Chair of Land Reclamation and Environmental Management
University of Warmia and Mazury in Olsztyn

Abstract

The study to determine thermal-oxygen changes and chemical properties of water in a flow-through pond was conducted between April 2004 and March 2005 in three vertical profiles. The study involved the determination of electrolytic conductivity and pH reaction of water as well as the content of nitrate nitrogen and ammonium nitrogen, total phosphorus and sulphates. Thermal stratification was not observed in the investigated pond with the maximum depth of 2.45 m, and oxygen content was represented by a clinograde curve. Biogenic element concentrations in the pond were determined by depth in the vertical profile, and they were subject to seasonal variation. The highest concentrations of mineral substances in water were reported in the bottom layers of the pond. Although the investigated pond is a flow-through water body, it accumulates biogenic elements.

Key words: small pond, thermal profile, water temperature, oxygen profile, biogenic elements.

ZMIANY WŁAŚCIWOŚCI CHEMICZNYCH WODY OCZKA WODNEGO W PROFILACH PIONOWYCH

Abstrakt

Badania nad rozpoznaniem zmian termiczno-tlenowych i właściwościami chemicznymi wody przepływowego oczka wodnego prowadzono od kwietnia 2004 r. do marca 2005 r. w 3 profilach pionowych. Oznaczono przewodność elektrolityczną i odczyn wody oraz zawartość azotu azotanowego i amonowego, fosforu ogólnego i siarczanów. Stwierdzono, że w zbiorniku o głębokości maksymalnej 2,45 m nie przebiega stratyfikacja termiczna, a zawartość tlenu obrazuje krzywa w postaci klinogrady. Stężenia biogenów w wodzie oczka wodnego były uzależnione od głębokości w profilu pionowym i pory roku. Największa zasobność wody zbiornika w substancję mineralną występuje przy dnie. Pomimo przepływowego charakteru zbiornika następuje w nim akumulacja biogenów.

Słowa kluczowe: oczko wodne, profil termiczny, temperatura wody, profil tlenowy, biogeny.

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dr inż. Urszula Szyperek, pl. Łódzki 2, 10-718 Olsztyn, e-mail: ulaszyp@uwm.edu.pl

INTRODUCTION

Due to their small size, ponds generally form a homogeneous environment. Energy and mass circulation in small ponds usually involves the entire water volume which inhibits the development of relatively stable heterogenic systems. The rate and structure of energy and mass exchange between the pond and its surroundings are also determined by factors characteristic of those water bodies. This exchange takes place mostly between water and the atmosphere, while the horizontal exchange with the catchment area is restricted to the inflow of organic matter (DRWAL, LANGE 1985). Ponds are shallow bodies of water which are not marked by significant thermal stratification (BIEDKA, DZIENIS 2001). According to JĘDRCZAK (1992), small ponds are polymictic water bodies which are subject to multiple and full mixing of water in the vertical profile under the influence of wind, also during summer stagnation. In some periods (windless), the mixing process is limited which may lead to a periodical thermal and chemical water stratification.

The development of thermal-oxygen relations and other physical properties of water are investigated mostly in deeper water bodies. The obtained results are used to determine the degree to which lakes are susceptible to degradation. Similar observations carried out in small pond profiles support the investigation of changes in those processes and their causes, not only at various depths, but also in different seasons.

The objective of this study was to investigate thermal and oxygen changes taking place in a small mid-field pond at different times of the year, and to determine changes in the chemical properties of water occurring throughout the year in the vertical profiles of this pond. Since the investigated small pond is a flow-through water body, another aim of this study was to determine the chemical properties of water in the longitudinal profile.

MATERIALS AND METHODS

The study was conducted in a mid-field pond in Wrocikowo near Olsztyn which is supplied mostly by rain, ground and drain water. The investigated pond (covering an area of 0.67 hectares) is a flow-through water body: drain water from the catchment area is supplied to the pond by a drainage ditch (inflow), and water flowing out of the pond is collected also by a drainage ditch (outflow). The pond is characterised by the following morphometric features: maximum length – 127 m, maximum width – 65 m, shoreline length – 327 m, elongation – 1.89, maximum depth – 2.45 m, average depth – 1.11 m, average pond volume (at average water level) – 8701 m^3. For the purpose of determining the thermal-oxygen relations and the chemical properties of water throughout the year, the survey was carried out in April, July, September and November 2004 and in March 2005 (under the ice cover), and the obtained results were interpreted as spring, summer, autumn (September and November) and winter measurements, respectively. Three vertical profiles were identified: on the side of the inflow (L), at the deepest point of the pond (G) and on the side of the outflow (P). Water oxygen content and water temperature were measured with the use of an oxygen probe every 10 cm in every vertical profile of the pond. To determine water reaction and electrolytic conductivity, as well as the content of nitrate nitrogen and ammonium nitrogen, total phosphorus and sulphates in water, samples were taken at four depth levels in L and G profiles, i.e. from the surface (0.1 m), from the central part (0.7 m and 1.5 m) and from the near-bottom layer. In P profile, samples were taken at three depth levels, i.e. from the surface layer (0.1 m), from the central layer (1.0 m) and from the near-bottom layer. Water pH was determined by potentiometry, specific electrolytic conductivity – by conductometry, $N\text{-}NO_3$ – by colorimetry with phenoldisulfonic acid, $N\text{-}NH_4$ – by colorimetry with Nessler's reagent, total phosphorus – by colorimetry with ammonium molybdate and tin chloride, and SO_4^{-2} – by colorimetry with the use of the nephelometric method.

RESULTS

Water temperature in the pond was dependent on air temperature, and was marked by seasonal change (Fig. 1). Over the experimental period, water temperature ranged from +0.1°C in March 2005 to +18.7°C in July 2004. In the spring, the temperature of water in vertical profiles was 8.7°C to 10.6°C. Two layers were distinguished in the analysed vertical profiles: an upper layer (up to 1 m) – marked by a higher temperature and a lower layer - marked by a lower temperature. Similar results were reported by PASCHALSKI (1959) who investigated a three-fold shallower pond in the spring. In the water body analysed in this study, the temperature of the warmer upper layer was nearly uniform (10.6°C – 10.4°C) to a depth of 1 m. The above indicates that this layer is mixed under the influence of wind. The colder lower layer (10.4°C – 8.7°C) was characterized by a significant temperature drop and it was not affected by external factors to the extent reported in the upper layer.

Water temperature measurements pointed to the absence of thermal stratification in the pond during the summer (Fig. 1). The above is due mainly to the relatively low depth of the pond. According to DRWAL and

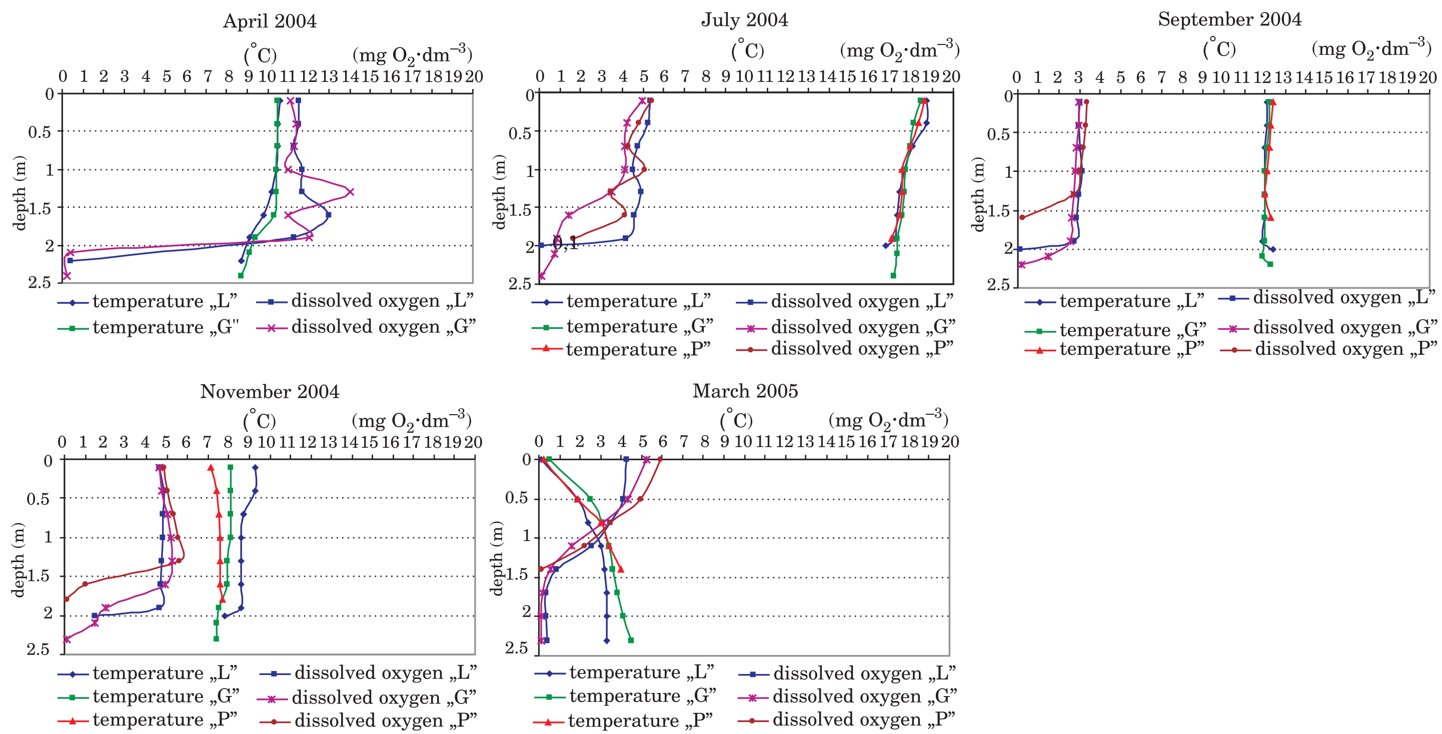

Fig. 1. Seasonal changes of the water temperature and dissolved oxygen in profiles L, G and P of the mid-field pond

LANGE (1985), a clearly pronounced thermal stratification with very high gradients (more than 5°C per meter of depth) may develop in the summer with anticyclonic weather and in the absence of wind. In the investigated pond, the temperature gradient in July reached only 2°C between the surface and the near-bottom layer. In September, water temperature was almost identical (around 2°C) in both the vertical and the horizontal section. The above findings are indicative of autumn circulation in the analysed pond. Dissolved oxygen content in three vertical sections was also most uniform (around 3 mg O_2 dm^{-3}) in the autumn (Fig. 1). In the period when the pond was covered with ice, a reverse thermal stratification was observed in the deepest layers (Fig. 1).

The dissolved oxygen content of water was subject to seasonal modification, reaching from 0.09 mg $O_2 \cdot dm^{-3}$ in July (near the bottom) to 14 mg $O_2 \cdot dm^{-3}$ in April. Positive heterograde oxygen curves were reported in L and G profiles. This could be due to a fast rate of photosynthesis under good trophic conditions and satisfactory light conditions. In July, a clinograde oxygen curve was observed at the deepest point of the pond (G profile) (dissolved oxygen content decreases progressively with depth), where oxygen concentration was lower than in the remaining profiles. In March 2005, when pond water was sampled from under the ice cover, clinograde oxygen curves were reported (Fig. 1). The above testifies to the process of mineralization in the pond, as supported by high values of specific electrolytic conductivity which is characteristic of this season (Fig. 2). This process was also responsible for lowering the pH of water (Fig. 2).

The presented oxygen profiles of the investigated pond (Fig. 1) point to favourable aerobic conditions in the spring, summer and in November. Throughout the entire investigated period (particularly in March 2005 – under the ice cover), an oxygen deficit was observed in near-bottom layers, which is a characteristic feature of stratified lakes.

During the study, the reaction of pond water ranged from pH 5.8 in the bottom layer (July) in L and G profiles to pH 8.05 in April (Fig. 2). Similar results were reported in other ponds (KOC et al. 2002, KOSTURKIEWICZ, FIEDLER 1995, SKWIERAWSKI, SZYPEREK 2002). A slightly acidic reaction was noted in the summer. In the summer, the progressive decrease in pH with depth could result from biological processes occurring in deeper layers of the pond. It should also be noted that the profiles on the side of the inflow (L) and the outflow (P) from the pond, the pH of water was slightly higher than that reported in the profile at the deepest point of the pond (Fig. 2). The higher pH of water and a higher oxygen content in shallower profiles testify to the influence of the littoral zone where photosynthesis takes place (CO_2 consumption leads to a higher pH and a higher oxygen content). Pond water under ice cover had a slightly alkaline reaction.

Throughout the investigated period, the electrolytic conductivity of pond water ranged from 440 $\mu S \cdot cm^{-1}$ (in September 2004, in the surface

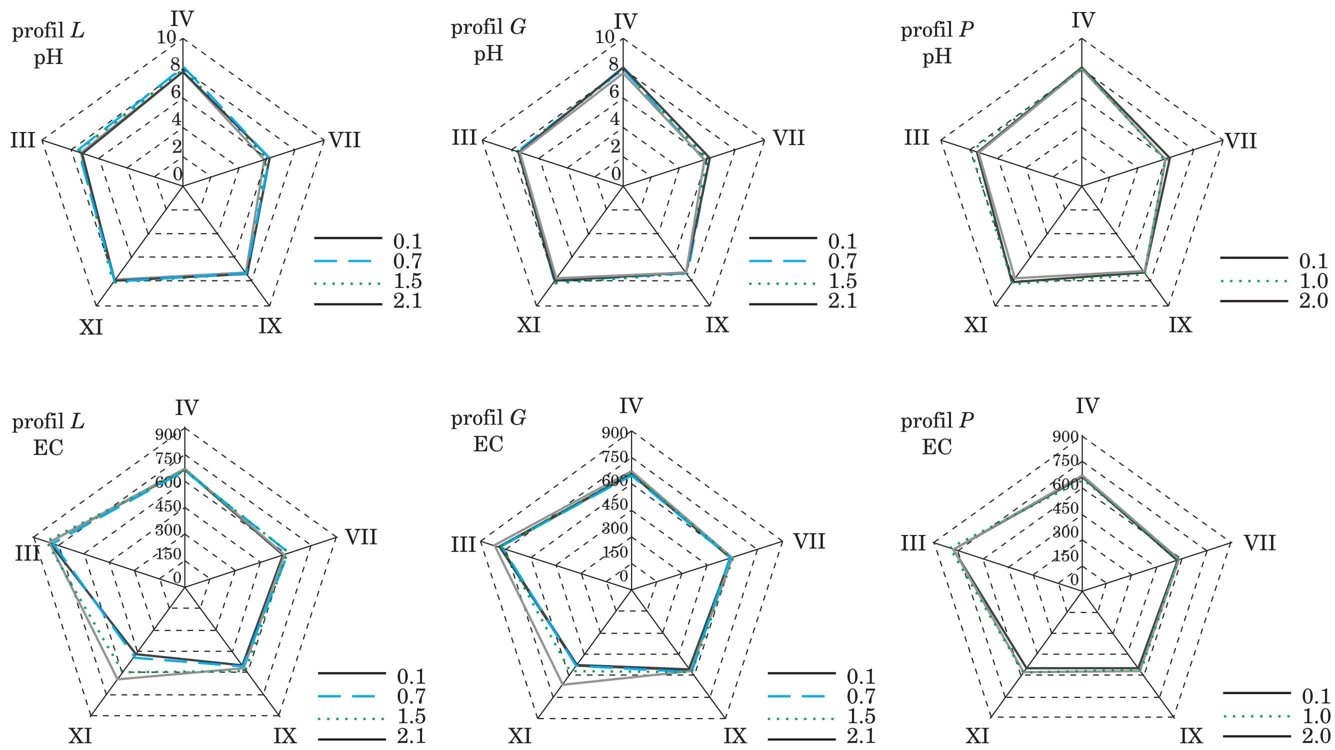

Fig. 2. Seasonal changes of the water reaction and electrolytic conductivity (EC)in profiles L, G and P of the mid-field pond

layer of L profile) to 813 $\mu S \cdot cm^{-1}$ (in March 2005, in G profile) – Fig. 2. The above values are higher than those reported in the lakes of the Masurian Lakeland by ZDANOWSKI and HUTOROWICZ (1994) and in other ponds investigated by KOC et al. (2002). The highest electrolytic conductivity in the examined pond was determined at the bottom (Fig. 2). The above indicates that the bottom layers are marked by higher abundance of mineral substances from the mineralization of organic matter contained in bottom sediments.

The content of nitrate nitrogen in pond water fluctuated throughout the year, reaching from 0.028 $mg \cdot dm^{-3}$ to 2.66 $mg \cdot dm^{-3}$ (Fig. 3). The highest nitrate nitrogen content was observed in April 2004 and March 2005. The increased $N\text{-}NO_3$ concentrations in the spring were most likely caused by significant quantities of nitrogen supplied to the pond with surface runoff from fertilised fields. Significant variations between the investigated profiles were not reported in July, September and November. In March, $N\text{-}NO_3$ concentration levels in pond water dropped significantly in deeper layers (Fig. 3). $N\text{-}NO_3$ concentration in the surface layer was twice that reported in the near-bottom layer, and a similar trend was observed in every profile. The above resulted from clear stratification during that period due to the formation of ice cover which prevented pond water from mixing. An oxygen deficit was also observed in the near-bottom layer (Fig. 1) which reduced nitrate nitrogen to ammonium nitrogen (Fig. 3).

Ammonium nitrogen concentration in the pond ranged from 0.011 $mg \cdot dm^{-3}$ to 1.029 $mg \cdot dm^{-3}$ (Fig. 3) and, similarly to nitrate nitrogen, it was marked by substantial fluctuation throughout the year. Yet the reported values were nearly twice lower than those determined by KOC et al. (2005) in water bodies supplied with drain water in the Sępopol Plain. It could be concluded that the average concentration of ammonium nitrogen in the near-bottom layer of the investigated pond was two-fold higher than in the surface layer (Fig. 3), and this dependency was not observed only in April. The highest variations in ammonium nitrogen concentration levels between the surface and the bottom layers of pond water were found in P profile, smaller differences were reported at the deepest point of the pond (G) and the least significant variations – in L profile.

The highest concentration of total phosphorus was observed at the deepest point of the pond (G) – 0.509 $mg \cdot dm^{-3}$, followed by the profile on the side of the inflow (L) – 0.493 $mg \cdot dm^{-3}$, while the lowest concentration was reported in the profile on the side of the drainage ditch outflow (P) – 0.466 $mg \cdot dm^{-3}$ (Fig. 4). High phosphorus concentrations were determined in July, they were nearly twice lower in November and more than three times lower in March. Similar changes in phosphorus concentration levels throughout the year were observed by KOC et al. (1997) who reported the lowest total P concentrations in the winter. In March, the total phosphorus concentration in the investigated pond was nearly identical in G and P vertical profiles. In general, higher total P concentration levels were found in the bottom layers than the in the surface layers of the pond.

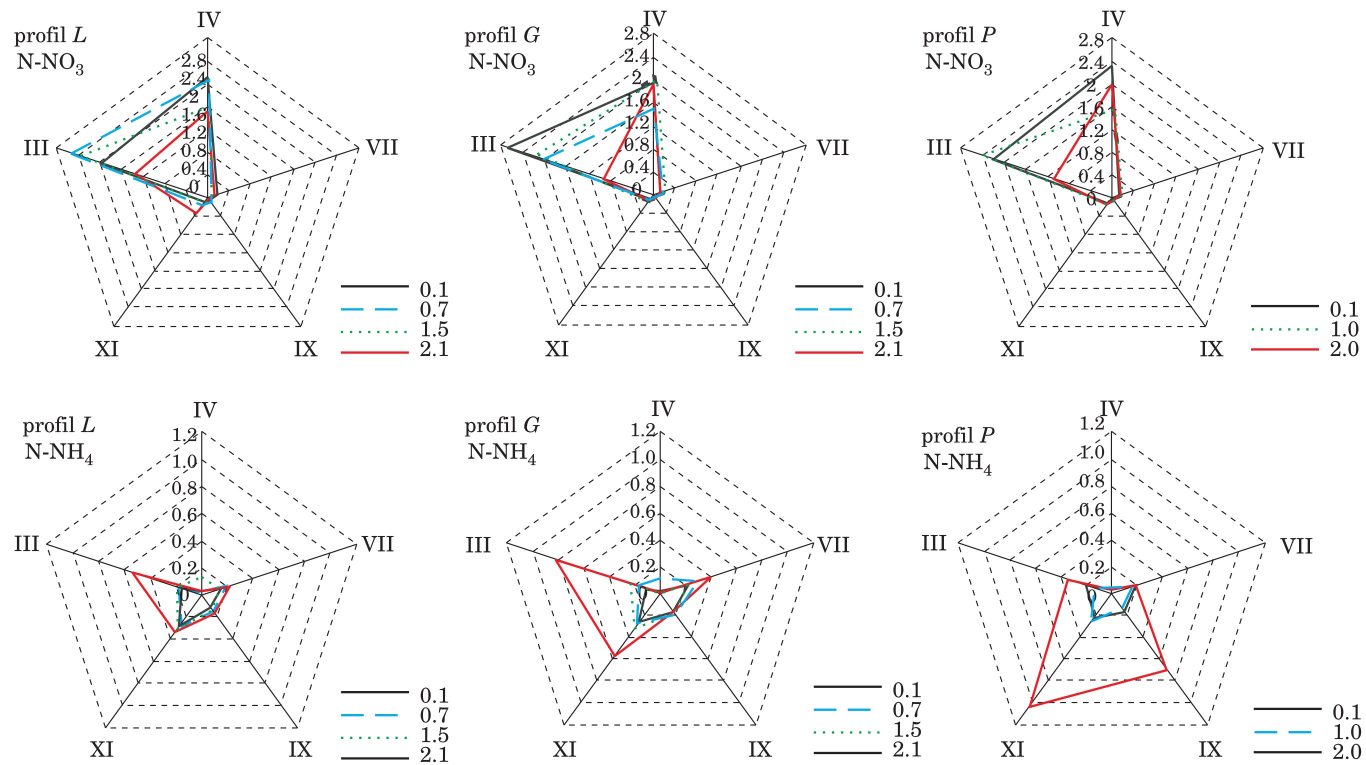

Fig. 3. Seasonal changes of the content of nitrate nitrogen and ammonium nitrogen in the water of mid-field pond in profiles L, G and P

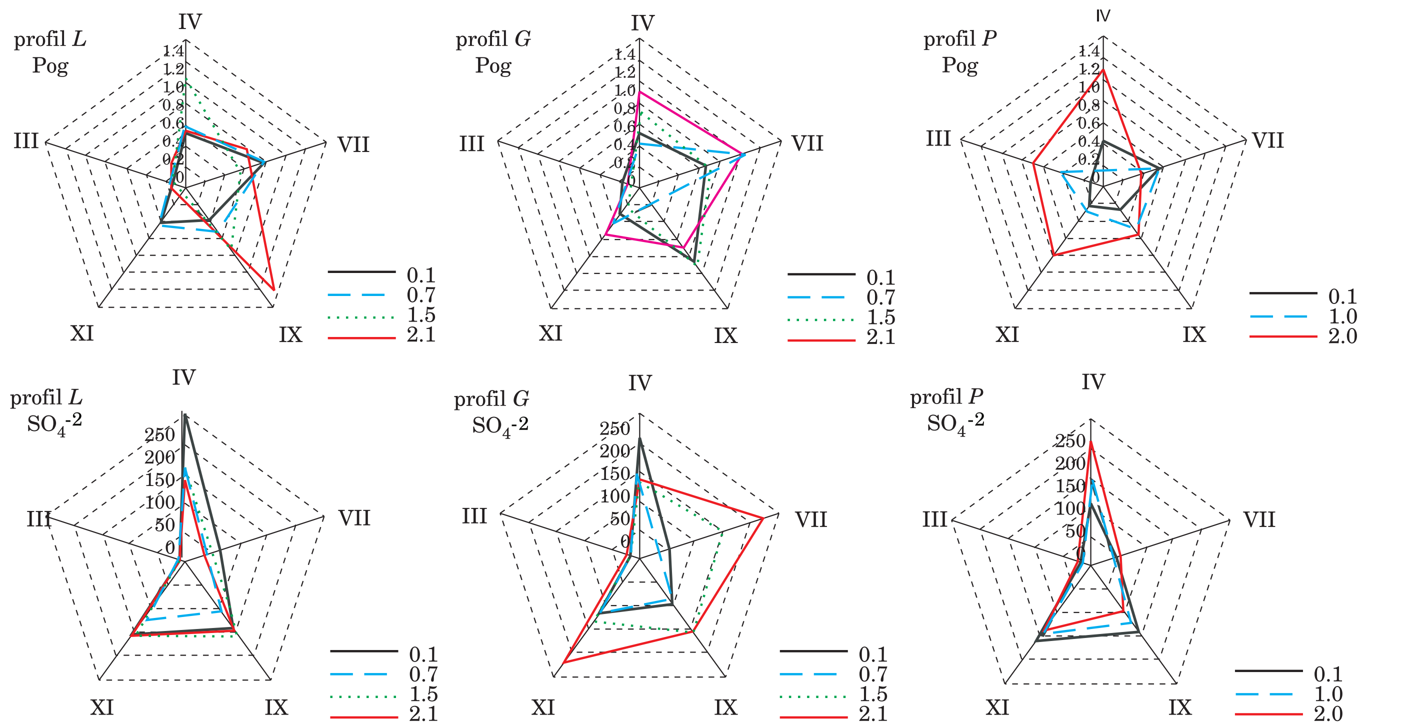

Fig. 4. Seasonal changes of the content of total phosphorus (Pog) and sulphates (SO_4^{-2}) in the water of mid-field pond in profiles L, G and P

Sulphate concentration in pond water ranged from 9.2 mg$\cdot$dm^{-3} to 250.0 mg$\cdot$dm^{-3} (Fig. 4). Higher SO_4^{-2} concentrations were reported in the summer, while the lowest – in the winter. The above was due to anaerobic conditions which led to a significant reduction in sulphate concentration levels. In the remaining investigated periods, sulphate concentration in pond water was nearly ten times higher than in March 2005. A significant increase in sulphate concentration levels was observed in the near-bottom layer at the deepest point of the pond in July, September and November (Fig. 4). A similar trend was reported in P profile in April. In the same profile, sulphate concentration dropped progressively at greater depths in September and November.

In view of the above, it can be concluded that the concentration of mineral components in flow-through ponds varies in the longitudinal profile. The content of nitrate nitrogen decreased in the direction from L profile to P profile, while the highest concentrations of total phosphorus and sulphates were observed at the deepest point of the pond (G). Higher nitrate concentrations in L profile than in P profile are most probably due to the supply of significant quantities of nitrate nitrogen via the drainage ditch network. The high content of total phosphorus and sulphates at the deepest point of the pond (G) testifies to the accumulation of those compounds in bottom sediments, followed by their transport to water. Although the investigated pond is a flow-through water body, it accumulates some of the compounds supplied from the catchment area.

CONCLUSIONS

1. The investigated pond is a relatively shallow water body (2.45 m), which explains the absence of thermal stratification with a simultaneous clinograde distribution of dissolved oxygen.

2. Biogenic element concentrations in pond water are determined by depth in the vertical profile. The highest concentrations of mineral substances were observed in the bottom layers, as indicated by the highest electrolytic conductivity values and higher $N\text{-}NH_4$, total phosphorus and sulphate concentrations.

3. Biogenic element concentrations are marked by seasonal fluctuation regardless of the place and depth of water sampling. Nitrate nitrogen concentrations are higher in the spring, higher levels of total phosphorus are observed in the summer, while the autumn is marked by higher ammonium nitrate concentrations.

4. The average concentration of biogenic elements is determined by the place of water sampling in the pond's longitudinal profile. Although the investigated pond is a flow-through water body, it accumulates bio-

genic elements whose concentration in water decreases in the direction from the ditch supplying water to the pond (inflow) to that collecting water from the pond (outflow).

REFERENCES

BIEDKA P., DZIENIS L. 2001. *Zmienność wybranych parametrów fizyczno-chemicznych wód powierzchniowych w profilu pionowym, na przykładzie wybranych jezior Pojezierza Suwalsko-Augustowskiego*. Zesz. Nauk. Politechniki Białostockiej, 142 (15): 57-65.

DRWAL J., LANGE W. 1985. *Niektóre limnologiczne odrębności oczek*. Zesz. Nauk. Wydz. Biol. Geogr. i Oceanogr. UG, 14: 69-82.

JĘDRCZAK A. 1992. *Skład chemiczny wód Pojezierza Antropogenicznego w Łuku Mużakowskim*. Wyd. WSI w Zielonej Górze, 54: 139.

KOC J., CYMES I., SZYPEREK U. 2005. *Możliwości wykorzystania wód w zlewni rolniczej do pojenia bydła*. J. Elementol., 10(2): 341-348.

KOC J., PROCYK Z., SZYMCZYK S. 1997. *Czynniki kształtujące jakość wód powierzchniowych obszarów wiejskich*. W: *Woda jako czynnik warunkujący wielofunkcyjny i zrównoważony rozwój wsi i rolnictwa*. Konf. Nauk.-Tech. PHARE-FAPA-IMUZ AR w Szczecinie, Falenty 1997.

KOC J., SKWIERAWSKI A., CYMES I., SZYPEREK U. 2002. *Znaczenie ochrony małych zbiorników wodnych w krajobrazie przyrodniczym*. Wiad. Mel. Łąk., 45 (2): 64-68.

KOSTURKIEWICZ A., FIEDLER M. 1995. *Oczka wodne w eksploatacji systemów drenarskich na terenach bogato urzeźbionych*. Zesz. Nauk. AR we Wrocławiu, 266, (8): 191-199.

PASCHALSKI J. 1959. *Obserwacje warunków środowiskowych drobnych zbiorników wodnych okolic Warszawy*. Ekol. Pol., ser. A, 7 (1): 1-20.

SKWIERAWSKI A., SZYPEREK U. 2002. *Wpływ rolnictwa na jakość wody w małych zbiornikach wodnych Pojezierza Mazurskiego*. Fragm. Agron. 19 (2): 236-243.

ZDANOWSKI B., HUTOROWICZ A. 1994. *Sainity and trophy of great masurian lakes (Masurian Lakeland, Poland)*. Ekol. Pol., 42 (3-4): 317-331.