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CHARACTERISTICS OF THE MACRO – AND MICROELEMENTS IN BENTHIC SEDIMENTS OF SELECTED MID-FIELD PONDS

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Abstract

The agricultural landscape of Western Pomerania is characterised by frequent occurrence of small, post-glacial water ponds commonly called mid-field ponds. They serve numerous important functions, both with regard to agriculture and ecology. Due to their specific location in the agricultural landscape, they are exposed to permanent and strong anthropic pressure, which often translates into pollution of surface water and benthic sediments with macro-and microelements. This study attempts to assess and determine the level of macro – and microelements in benthic sediments, depending on the type of agricultural production, on the example of selected mid-field ponds. The assessed benthic sediments of both ponds were characterised by varied macro – and microelement levels, depending on the collection site and the depth of their deposition. Based on the performed chemical analyses it was found that both observation points in the pond Żelisławiec were characterised by the highest concentrations occurring in the top layer (0-5 cm), which is related to the fact that there are areas of agriculture in the pond basin with the use of mineral and organic fertilisation and occurrence of higher water erosion. And the other assessed mid-field pond (Stare Czarnowo) showed the highest concentration of microelements in the middle layer, 5-15 cm. Statistical analyses revealed that statistically significant differences were observed only for potassium levels, depending on the type of agricultural production in the basin of both assessed ponds. This may result from various types of agricultural crops (Brassica napus L. var. napus and ×Triticosecale Wittm. ex A.Camus) and intense fertilization of arable land in Stare Czarnowo. Statistically significant differences in particular layers of sediment confirm that depending on the type of agricultural activity, mid-field ponds are supplied with various mineral matter at different times, resulting in its accumulation in benthic sediments.

Keywords: benthic sediments, mid-field ponds, macroelements, microelements, chemical composition.

INTRODUCTION

Region Western Pomerania in Poland is characterised with frequently occurring small water ponds commonly called mid-field ponds. Being located in the agricultural landscape, they constitute natural stopover habitats for migrating animals, as well as living and breeding enclaves for numerous species of fauna and flora (Symonides 2010). In addition to an ecological role, they also serve numerous other functions. The ponds affect hydrological relationships in the basin, stabilization of ground water and surface water level (Szydłowski and Podlasińska 2016, Podlasińska and Szydłowski 2017). Mid-field and mid-forest ponds also constitute water reservoirs for agricultural purposes, as well as for the animals and plants having their natural habitat there (Korytowski and Szafrański 2014). They may also act as specific "nutrient traps", which is quite important for retention of fertiliser doses delivered to other surface waters (Pietrzak 2014).

The degradation of surface waters is confirmed by current data of the Central Statistical Office [GUS 2018]. Water ponds accumulate mineral and organic material, as well as chemical contaminants which are transported with surface and ground water (Pietrzak *et al.* 2017). The type and amount of supplied contamination depends on numerous factors, such as the type of basin utilization and management, as well as basin hydrological conditions (Bąk *et al.*, 2014, Gałczyńska *et al.*, 2009). In the bottom sediments of lakes, not only are autochthonous phosphorus sources (Siwek *et al.* 2014), but also macro – and microelements accumulated (Vincevica-Gaile and Stankevica 2017). Agricultural production, due to a vast area of operation, significantly affects the quality of water environment, with special impact on water ponds. Poor fertilizer management in the basin area causes degradation of various components of the water environment. Determination of the element contents in benthic sediments of mid-field ponds is important for the assessment of the water environment quality and for determination of substance delivery from the basin (Szydłowski *et al.*, 2017). Various element levels in benthic sediments result e.g. from water level fluctuations, amount of overland flow and supply of substances with ground water to the water ponds (Marcinkowski 2014, Wesołowski *et al.*, 2014). Due to adsorption, hydrolysis and coprecipitation, only a small amount of substances remain in water, while large amounts are deposited in benthic sediments (Gaur *et al.*, 2005, Hau *et al.*, 2013). It is exactly in benthic sediments, where often persistent and toxic contaminants released to the environment are accumulated, while they are integral part of water environment creating habitats for living, feeding, breeding and growth of numerous aquatic organisms (Madeyski and Tarnawski 2006, Brysiewicz and Wesołowski 2017).

The study objective was to determine the level of macro – and microelements in benthic sediments, depending on the type of agricultural production, on the example of selected mid-field ponds.

OBJECT AND METHODS OF STUDY

In order to achieve the objective set, samples of benthic sediments were collected from mid-field ponds Żelisławiec (Z) and Stare Czarnowo (S) (zachodniopomorskie voivodship). The ponds were situated in the middle of crop fields, where strawberries (*Fragaria ananasa* Duchesne), winter rape (*Brassica napus* L. var. *napus*) (Żelisławiec) and triticale (*Triticosecale* Wittm. ex A. Camus) (Stare Czarnowo) were cultivated. Due to the characteristics and limited possibilities of access to sediments accumulated in mid-field ponds, sediment samples were collected from a boat with the use of KC Denmark Kajak core sampler, once in the autumn period.

Drilling was performed at two points located in the pond in Żelisławiec (Z-1; Z-2) and in Stare Czarnowo (S-1; S-2) at both sides of the ponds, assuming that was the place with the highest accumulation of the smallest sediments. The sediments were collected from the following layers: 0-5 cm, 5-20 cm for the pond in Żelisławiec and additionally 20-30 cm from the pond in Stare Czarnowo. The material deposited in the mid-field ponds was conventionally divided into 2 batches (Żelisławiec) and 3 batches (Stare Czarnowo) of layers differing in the quality of the deposited material, time of formation, colour and particle size. In the collected samples of benthic sediments, the analyses were performed on the fraction with particle diameter below 1 mm. The total content of the elements, i.e. Ca, Fe, K, Mg, Mn, Na was determined with the atomic absorption spectrometer ASA ICE 3000 ThermoScientific following mineralization in a mixture (5:1) of concentrated HNO_3 (65%) and $HClO_4$ (60%) acids.

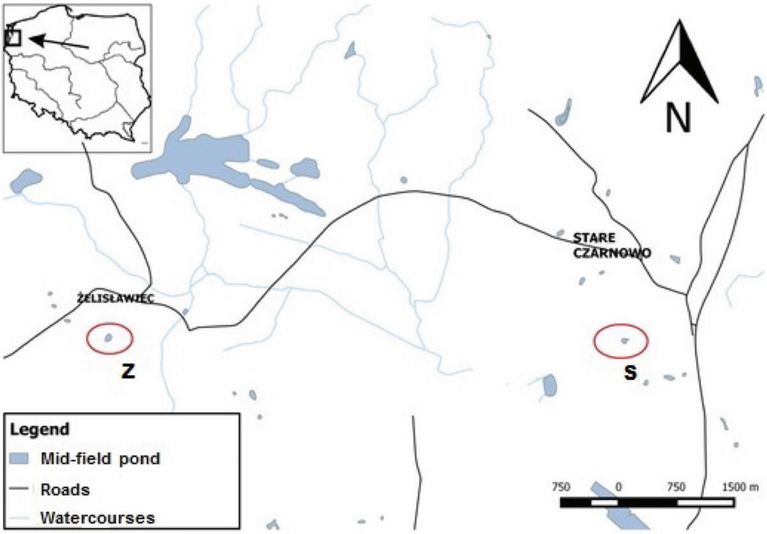

Figure 1. Map of the assessed mid-field pond location – *source: own compilation*

STATISTICAL COMPILATION

The achieved results were statistically compiled with the use of Statistica 12.0 software. In order to determine normal distribution of the achieved results, the Shapiro-Wilk test of normality was used ($p \leq 0.05$). To determine statistically significant differences in the levels of selected parameters, the Tukey's test was used ($p \leq 0.05$). The Pearson linear correlation coefficient ($p \leq 0.05$) was also used in the study in order to determine correlations between the test parameters.

CHARACTERISTICS OF THE STUDY OBJECT

Both assessed mid-field ponds are surrounded by arable land (utilised agriculturally) on brown soil deposited on clay average class IVa.

The mid-field pond located in the village of Żelisławiec is a closed pond situated in depression and supplied with ground water from the surrounding agricultural areas. At the time of the study (2014), strawberries and winter rape were cultivated in its direct basin. The pond shore zones were intensively covered by reed-bed plants: common reed (*Phragmites australis* (Cav.) Trin. ex Steud) and broadleaf cattail (*Typha latifolia* L.). The average pond depth was about 75 cm. The analysed oval mid-field pond was also characterised by high differentiation of bottom configuration with different depths of the water table.

The other mid-field pond, in Stare Czarnowo, is also a closed pond situated in depression and supplied with ground water from the surrounding agricultural areas utilized by Zakład Doświadczalny Instytutu Zootechniki, Państwowy Instytut Badawczy in Kołbacz. At the time of the study (2014), triticale was cultivated in the direct basin. The pond was characterised by high differentiation of bottom configuration with different depths of its water. In 2014, the mean depth of the pond water was 95 cm. The mid-field pond in Stare Czarnowo is characterised by a long shape and periodic drying. At the time of the study, the shore of the mid-field pond was covered by reed-bed plants – great manna grass (*Glyceria maxima* (Hartm.) Holmb.) in the form of simple community of a single-species aggregation. The great manna grass showed its permanent presence on shallow waters, which stayed in the range of 23-32 cm. On deeper waters, off the shore, two communities of reed-bed plants were observed, common reed and broadleaf cattail. On the shore slopes of the pond, single trees were located, e.g. the white willow (*Salix alba* L.).

RESULTS AND DISCUSSION

The assessed benthic sediments of both analysed mid-field ponds were characterised by varied macro – and microelement levels, depending on the collection site and the depth of benthic sediment deposition. Based on the performed chemical analyses it was found that both observation points in the mid-field pond Żelisławiec were characterised by the highest concentrations occurring in the top layer (0-5 cm) (Table 1), which is most probably related to the fact that there are areas of agriculture in the pond basin with the use of mineral and organic fertilisation and occurrence of higher water erosion. The other assessed mid-field pond showed the highest concentration of microelements in the middle layer, 5-15 cm (Table 1). Also, the same layer or benthic sediments revealed the highest mean concentration of the said elements (Table 1).

The analyses of these ponds performed by Szydłowski *et al.* [2017] showed that benthic sediments of the pond in Stare Czarnowo were richer in organic matter than the pond in Żelisławiec. The content of elements in both ponds is satisfactory. It is generally believed that sediments characterised by such content of organic matter and elements should be utilized for agricultural purposes, assuming, however, that they do not show such levels of heavy metals which would prevent their agricultural utilization. Sammel (2015) observed comparable levels of elements in the study of benthic sediments in the ponds of Szczecin agglomeration, Syrenie Stawy.

Mean calcium levels were between 0.139 $g \cdot kg^{-1}$ and 2.650 $g \cdot kg^{-1}$ (Table 1) and they were much lower than the results achieved by other researchers (Jasiewicz and Baran 2006, Sammel 2015). The highest mean calcium levels at the observation point S-1 were more than six times lower that the highest mean concentration of this element in the studies by Sammel (2015): at the observation point S-1 it was 2.650 g·kg^{-1}, while in the studies performed in Syrenie Stawy, the mean calcium concentration was 18.0 g·kg^{-1}. Studies of benthic sediments in the storage reservoir Chańcza conducted by Tarnawski *et al.* (2012) showed an even higher mean calcium concentration of 40.570 g·kg^{-1}, which is twelve times higher than the highest result recorded at the collection point S-1 in the layer of 5-15 cm in the mid-field pond Stare Czarnowo (3.404 g·kg^{-1}). Such significant differences may result from a higher anthropic pressure in the basin of the reservoir Chańcza and from recreational utilization of this facility.

Table 1. Concentrations of selected macro – and microelements in point determinations of benthic sediments in mid-field ponds Żelisławiec and Stare Czarnowo collected in 2014 [g· kg^{-1}]

Sampling point	Depth	Ca	Fe	K	Mg	Mn	Na
ŻELISŁAWIEC							
Z-1	**0-5 cm**	0.140	19.798	3.304	1.191	0.308	0.270
	5-20 cm	0.138	16.405	3.135	0.954	0.183	0,171
AVERAGE		0.139	18.102	3.219	1.073	**0.246***	0.221
Z-2	**0-5 cm**	2.018	18.934	4.827	1.412	0.329	0.254
	5-20 cm	1.322	2.148	4.724	1.296	0.236	0.236
AVERAGE		0.626	10.541	4.622	1.180	**0.197***	0.219
STARE CZARNOWO							
S-1	**0-5 cm**	1.231	15.245	2.064	1.347	0.283	0,162
	5-15 cm	3.404	17.541	3.287	1.482	0.328	0,206
	15-30 cm	3.315	15.645	1.977	1.005	0.257	0,095
AVERAGE		2.650	16.143	2.443	1.278	**0.290***	0.155
S-2	**0-5 cm**	1.585	10.996	0.581	0.659	0.134	0,151
	5-15 cm	2.122	19.822	1.732	1.107	0.211	0,269
	15-30 cm	1.186	6.283	1.096	0.482	0.058	0,089
AVERAGE		1.631	12.367	1.137	0.749	**0.134***	0.170

Explanation: * – significance $p \leq 0.05$

As for iron contents, the highest values were observed in the top layer 0-5 cm of benthic sediments in the pond Żelisławiec collected at the collection point Z-1 (19.798 g·kg^{-1}). The lowest values were observed in the layer 5-20 cm at the collection point Z-2 of the same pond, and amounted to 2.148 g·kg^{-1}. The benthic sediments studied by Tarnawski *et al.* (2012) showed a mean iron content of

14.930 g·kg^{-1}, which was similar to the result achieved in our own studies. Much lower iron content was observed by Sammel (2015), since the highest results he observed were twelve times lower than the lowest mean value observed in the benthic sediments of the mid-field pond Żelisławiec at 5-20 cm (Table 1). Such big differences in iron content may be due to the location of the analysed mid-field ponds, since the ponds Żelisławiec and Stare Czarnowo are located in a truly agricultural basin, while the ponds analysed by Sammel (2015) are located in the forest region near the Szczecin agglomeration.

The analysed material revealed significant differences in the mean potassium content. The value recorded in the mid-field pond Żelisławiec was 4.622 g·kg^{-1} (sampling point Z-1), while the samples collected from the pond in Stare Czarnowo showed the mean potassium content more than four times lower (1.137 g·kg^{-1} sampling point S-2) (Table 1). In the studies conducted by Sammel (2015), the mean potassium content in two analysed reservoirs showed similar values: 2.190 g·kg^{-1} and 2.780 g·kg^{-1}, respectively. The highest potassium concentration was recorded at the observation point Z-2 in the top layer 0-5 cm (4.27 g·kg^{-1}), while the lowest concentration of this element was observed in the top layer 0-5 cm at the point S-2 (0.581 g·kg^{-1}) (Table 1). The potassium content observed in the studies of Tarnawski *et al.* (2012) is more than five times lower than the lowest concentration observed at the observation point S-2 in benthic sediments of the pond in Stare Czarnowo in the top layer 0-5 cm (0.581 g·kg^{-1}) (Table 1).

More magnesium was found in the sediments of the pond in Żelisławiec (between 0.954 g and 1.412 g·kg^{-1}) than in the sediments of the pond in Stare Czarnowo (between 0.482 g·kg^{-1} and 1.482 g·kg^{-1}). The highest magnesium content was observed in the measurement point S-1 in the layer 5-15 cm (1.482 g·kg^{-1}) (Table 1). The highest mean magnesium content observed in the sediments of the pond in Żelisławiec is almost two times lower than the mean value of this element observed by Sammel (2015). The ponds in Stare Czarnowo and Żelisławiec are richer in magnesium as compared with the pond studied by Tarnawski *et al.* (2012), where magnesium concentrations were between 0.320 g·kg^{-1} and 0,620 g·kg^{-1} which was twice lower that the values achieved in our studies.

The manganese content in the studied benthic sediments mid-field ponds Żelisławiec and Stare Czarnowo was between 0.058 g·kg^{-1} and 0.329 g·kg^{-1} (Table 1), which was higher than the values observed in the studies by Sammel (2015). The highest concentration of manganese was observed in the top layer 0-5 cm, both for the observation point Z-1 and Z-2 for benthic sediments in the pond of Żelisławiec. Slightly different results were recorded in Stare Czarnowo, where the highest manganese accumulation was observed in the layer 5-15 cm at the collection points S-1 and S-2. The manganese content is similar in the studies by Tarnawski *et al.*, (2012), where the lowest manganese content of 0.360 g·kg^{-1} is higher than the mean concentration recorded at the observation points of benthic sediments in both Stare Czarnowo and Żelisławiec (0.229 $g \cdot kg^{-1}$). In comparison with the results achieved by Sammel (2015) and Tarnawski *et al.*, (2012), the highest manganese content was twice higher (0.620 $g \cdot kg^{-1}$) than the highest value recorded at the top layer 0-5 cm at the observation point Z-2 (0.329 $g \cdot kg^{-1}$) (Table 1).

The sodium content in benthic sediments of the analysed mid-field ponds was between 0.095 $g \cdot kg^{-1}$ and 0.270 $g \cdot kg^{-1}$, and the mean concentration was between 0.155 $g \cdot kg^{-1}$ and 0.221 $g \cdot kg^{-1}$ in particular observation points (Table 1). The values were twice lower than the ones observed in the studies conducted by Sammel (2015).

STATISTICAL COMPILATION

Statistical calculations showed statistically significant differences (the Tukey's test $p \leq 0.05$) in potassium content between the study objects, where in 2014 triticale was cultivated (Stare Czarnowo), and rape and strawberries were cultivated near the pond in Żelisławiec. The differences in potassium concentration in the sediments of both mid-field ponds are most probably caused by different doses of fertiliser used by the farmers in the cultivation of crops and strawberries. On arable land in Stare Czarnowo, NPK mineral fertilizers were used in the amount of 43.9 kg $N \cdot ha^{-1}$, 60 kg P_2O_5 ha^{-1}, 100 kg K_2O ha, and nitrogen fertilizers in quantity of 188 kg $N \cdot ha^{-1}$ were used for rapeseed. Only mineral fertilization (NPK) – including 30.0 kg N ha^{-1}, phosphorus 50 kg P_2O_5 ha^{-1}, 40 kg K_2O ha, was used in Żelisławiec. The data was taken from users of agricultural areas surrounding the mid-field ponds.

Only mineral fertilization (NPK) – including phosphorus 50 kg P2O5 – was used in Żelisławiec. ha-1. The data was taken from users of agricultural areas surrounding the ponds.

The statistical analysis also revealed statistically significant differences (the Tukey's test $p \leq 0.05$) in the content of manganese in particular observation points of the studied mid-field ponds (Żelisławiec and Stare Czarnowo) (Table 1). These differences may result from varied supply of matter from the basin, and also from the processes of sorption, adsorption, hydrolysis and coprecipitation (Gaur *et al.*, 2005, Hau *et al.*, 2013).

In the assessed ponds, the statistical analysis showed no statistically significant differences (the Tukey's test $p \leq 0.05$) in particular layers of sediment collection for the mid-field pond in Żelisławiec. Statistically significant difference in the sodium content were observed only between the layer 5-15 cm and 15-30 cm and referred to the analyses performed at particular layers of the benthic sediments in mid-field pond Stare Czarnowo (Table 2).

Table 2. Concentrations of macro – and microelements in particular layers of benthic sediments in mid-field ponds Żelisławiec and Stare Czarnowo collected in 2014 [g· kg^{-1}]

Layer of benthic sediments	Ca	Fe	K	Mg	Mn	Na
ŻELISŁAWIEC						
0-5 cm	1.078	17.670	4.066	1.302	0.319	0.262
5-20 cm	0.383	10.973	3.879	1.067	0.190	0.195
STARE CZARNOWO						
0-5 cm	1.408	13.121	1.323	1.003	0.231	0.157
5-15 cm	2.763	18.682	2.510	1.295	0.247	**0.182***
15-30 cm	2.251	10.964	1.537	0.744	0.158	**0.148***

Explanation: * – significance $p \leq 0.05$

The calculated Pearson linear correlation coefficient ($p \leq 0.05$), showed a statistically significant correlation in both the assessed objects (Table 3-4). The highest statistically significant correlations for the sediments in the mid-field pond in Stare Czarnowo were observed between manganese and magnesium (Table 3). This shows that the magnesium increase in the analysed benthic sediment samples is associated with the manganese increase. A high correlation was also observed between potassium and magnesium, as well as manganese (Table 3).

Table 3. Pearson linear correlation coefficient ($p \leq 0.05$) for the mid-field pond Stare Czarnowo

Macroelements	Ca	Fe	K	Mg	Mn
Fe	0.581				
K	0.688	0.646			
Mg	0.506	**0.824***	**0.883***		
Mn	0.647	**0.814***	**0.866***	**0.964***	
Na	0.148	0.760	0.351	0.560	0.411

Explanation: * – significance $p \leq 0.05$; n.s. – not significant

A statistically significant correlation was also observed between iron and magnesium, as well as manganese. For the sediments in the mid-field pond in Żelisławiec, the Pearson linear correlation coefficient ($p \leq 0.05$) showed a highly statistically significant correlation between calcium and potassium (Table 4).

Table 4. Pearson linear correlation coefficient ($p \leq 0.05$) for the mid-field pond Żelisławiec

Macro – and microelements	Ca	Fe	K	Mg	Mn
Fe	-0.250				
K	**0.963***	-0.476			
Mg	0.868	-0.156	0.879		
Mn	0.477	0.430	0.402	0.780	
Na	0.363	0.125	0.403	0.774	0.907

Explanation: * – significance $p \leq 0.05$; n.s. – not significant

CONCLUSIONS

1. In the mid-field pond in Żelisławiec, the richest layer of benthic sediments was the top layer (0-5 cm), while in the mid-field pond in Stare Czarnowo, the highest concentrations of the analysed elements were observed in a lower layer (5-15 cm).
2. The statistical analysis of macro – and microelements concentrations showed statistically significant differences only for the potassium level, which may result from different types of agricultural crops in the area of the mid-field ponds.
3. The differences in the distribution of macro – and microelements in the sediments of the assessed mid-field ponds may result from different steepness of slopes and from the presence or absence of buffer zones, which stop to a various extent the mineral water flowing from the basin into the pond.

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