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Original Research

Influence of Different Uses of the Environment on Chemical and Physical Features of Small Water Ponds

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Abstract

The water quality of small bodies of water is largely differentiated due to the type of use of the catchment area. The water ponds in agricultural regions can be classified according to different characteristics of the neighborhood (villages, afforestation, meadows, fields). In our study, using statistical analysis CA, a hypothesis about the significance of the influence of the type of neighborhood on the chemical composition of the water of the studied bodies of water situated on soils of high productivity was verified. It was observed that differences between types of environment were related to parameters such as: concentration of K, NO_3^-, Mn, Li, Cd, and pH of water. The smallest concentrations of macro- and microelements were characteristic of the water bodies surrounded by trees. The conducted studies and the results of statistical analysis FA and PCA made it possible to reduce the number of main factors affecting water quality to 60%.

Keywords: ponds, biogens, fields, meadows, trees, villages

Introduction

Some 80% of the ponds found in the intensively farmed land in Europe play a vital role in maintaining biodiversity as a refuge for flora and fauna. They support specific and important hydrological, chemical, and biological processes [1]. Spatially small, they are mainly neglected in national natural resource management activities [2]. Ponds are physically heterogeneous habitats. These bodies of water, due to their small catchment areas, are characterized by highly differentiated individual physicochemical parameters depending on local geology and land use, e.g. entirely wooded areas or heavily grazed pastures causing high acidity of surface layers of soil [3, 4].

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Changes that have taken place in agriculture in Poland in recent years have not significantly improved the aquatic environment. The most commonly grown crops in the Pyrzycko-Stargardzka Plain are canola and wheat. They require high doses of nitrogen and phosphorus fertilizers, on average 150 kg $N\cdot ha^{-1}$ and 30 kg $P\cdot ha^{-1}$. The farms aimed at big profits from agricultural production use even up to 360 kg $NPK\cdot ha^{-1}$ of mineral form. In connection with the reduction in livestock, the amount of mineral fertilizers used in farming also decreased, leading to the final decrease in the use of mineral fertilizers by about 20-25% [5]. According to them, the type of cultivation and associated fertilization have had an impact on the scale of water pollution in midfield ponds. It is estimated that the level of the use of nitrogen from mineral fertilizers is about 65%. Søndergaard et al. [6] point out that the midfield ponds in areas with intensive agricultural production undergo strong degradation related to the surface runoff of biogenic compounds and heavy metals from arable fields. Whereas Bennion et al. [7] emphasize that the water of midfield ponds is threatened by the inflow of impurities of anthropogenic character and, in some cases, undergoes acidification (pH=3.2) and eutrophication (TP above 0.4 mg·dm^{-3}). However, they are not equally transformed, because various factors affect them in slightly different ways, changing the chemical parameters of water or shaping the vegetation [5, 7, 8]. One of the factors affecting their transformation might be the ecosystem of environment surrounding the pond: meadows, trees, urban areas, or typical fields. Its intensity and type determines the degree of transformation [8].

The midfield ponds situated in settlement and agricultural areas and in typically agricultural ones have a larger tendency to lower the quality of their water than those located in afforested areas. On the basis of their studies, Koc et al. [9] explain that such a state is the result of the effect of agricultural use of the area and the vicinity of farms or densely built-up areas or areas of scattered settlements with no sewage system provided, where it often happens that sewage from farms and effluents from the manure storage space are discharged into the midfield ponds, or they get there from leaky liquid manure tanks and from store-pits or silage heaps. Gałczyńska and Gamrat [10] in their research additionally indicate such threats as heavy metals and different types of waste, e.g., construction debris, ceramics, plastic packages, glass, slag, and unused chemicals. In water of this type of pond the average content of nitrate amounted to 0.6, orthophosphates(V) 0.8 mg·dm^{-3}, potassium 16.5 mg·dm^{-3}, zinc 0.017 mg·dm^{-3}, iron 0.5 mg·dm^{-3}, copper 0.06 mg·dm^{-3}, and manganese 0.005 mg·dm^{-3}; color of water 240 mg Pt·dm^{-3}, turbidity 63 mg SiO_2·dm^{-3}, and conductivity 24 mS·m^{-1}; ammonium cation 2.3 mg·dm^{-3}. Kuczera and Misztal [11] observed that the quality of water in midfield ponds located in the areas of agricultural settlements was mostly lowered by phosphates and ammonia.

It might seem that the ponds surrounded by dense grassland ecosystems are characterized by minor transformations, but in reality they are prone to anthropogenic pressure, too. Proper meadow farming requires using high doses of mineral and organic fertilizers, and performing number of agricultural operations, the side effects of which might have a negative impact on water ecosystems occurring in their neighborhood [12]. While studying groundwater around a midfield pond in a small agricultural catchment area, Życzyńska-Bałoniak et al. [13] noticed that concentrations of organic compounds (31.2 mg·dm^{-3}) and humus substances (36.9 mg·dm^{-3}) were moderately high and concluded that it was the result of the shallow location of the groundwater and good permeability of soil.

Midfield ponds are also exposed to the surface runoff of unused mineral and organic fertilizers and plant protection products, and this takes place especially in small surface water reservoirs [5, 14, 15]. Comparing the examined midfield ponds, regardless of their environment they all are characterized by lower concentrations of nitrogen and phosphorus than those studied in rural areas of Meclemburgia. Polluted kettle holes had higher levels of SRP, NH_4^+, K^+, and Fe^{2+} in water at reducing conditions in summer, but they are eutrophicated [16].

Gamrat and Gałczyńska [15] point out that in the group of water midfield ponds characterized by a smaller surface and a smaller inclination of the scarps and a larger degree of plant cover on the sheet of water, values of the studied indices amounted to: conductivity 27.3 mS·m^{-1}, 2.89 PO_4^{-3} mg·dm^{-3}, 0.39 NO_3^- mg·dm^{-3}, 0.38 NH_4^+ mg·dm^{-3}, $N_{inorg.}$/P-PO_4^{3-} 0.42, potassium 11.7 mg·dm^{-3}, sodium 18.2 mg·dm^{-3}, iron 1.69 mg·dm^{-3}, calcium 76.7 mg·dm^{-3}, and magnesium 23.5 mg·dm^{-3}. Gałczyńska et al. [5] observed that the content of mineral nitrogen and orthophosphates(V) in the water of midfield ponds was affected by type of cultivation. On the whole, the content of mineral nitrogen in summer amounted to about 0.7 mg·dm^{-3}, and that of orthophosphates(V) was definitely larger in the water of the midfield pond around which rapeseed was cultivated and it amounted to 3.2 mg·dm^{-3}. Joniak et al. [17] emphasize that in the water of midfield ponds located in degraded areas, electrolytic conductivity, color, and the content of nitrate nitrogen were larger and the content of orthophosphates(V) and nitrate nitrogen(V) was smaller. Studying the water of midfield ponds in the catchment of the Cole River in Southern England, Pascale et al. [18] found out that the concentration of N-NH_4^+ and P-PO_4^{3-} ranged from 0.1 to 38.3 mg·dm^{-3}, and from 0.002 to 2.449 mg·dm^{-3}, respectively. Kuczera and Misztal [11] observed that in the midfield water pond located in a typically agricultural area, the quality of water was lowered only by calcium.

The ponds surrounded by groups or rows of trees are less negatively affected [19, 20]. Distinctiveness of the neighborhood was noticed by Kuczyńska-Kippen and Joniak [21], who showed that midfield ponds, contrary to forest ones, are characterized by a higher trophic level. Kuczera and Misztal [11] found that the quality of the water in forest ponds was definitely better than that of the water in the midfield ponds situated in the vicinity of settlements of people and in fields, which mainly depended on the concentration of calcium, orthophosphates(V), and oxygen dissolved in water.

Due to the fact that literature confirms a lower trophic level of the water in bodies of water located in the vicinity of afforested areas and in forests, and at the same time a higher level of water pollution was observed in the ponds located in the neighborhood of settlements of people, a hypothesis was drawn about differentiation of a physicochemical composition of the water in the midfield ponds depending on the type of the neighborhood. The aim of the study is to verify the hypothesis about the differences of physicochemical parameters affecting the quality of the water of midfield ponds in the southwestern part of the Pyrzycko-Stargardzka Plain, and to try to assess the intensity of the effect of the analyzed neighborhoods.

Materials and Methods

Study Areas

The southwestern part of the Pyrzycko-Stargardzka Plain (the area surrounding the town of Pyrzyce) is one of the most precious areas in West Pomeranian Province, and Poland as a whole, in terms of agricultural production. Arable areas cover up to 85% of its acreage. Strong agricultural pressure through the use of mineral and organic fertilizers, chemical plant protection products, and the intensity of agricultural practices have caused strong transformations in midfield ponds [22]. A temporary or permanent standing water body is between 1 m^2 and 5 ha surface water [23]. The southwestern part of Pyrzycko-Stargardzka Plain, called "Pyrzycki mold" due to the fertility of soil, has long been extensively used for agricultural purposes. These soils generally belong to the 2nd and 3rd valuation classes, and the 1st very good wheat complex. The threat of eutrophication of the aquatic environment is gaining momentum with increasing intensity of agricultural production, and with a large number of farms aimed at very intensive production [24].

In 2003-05 a physicochemical study of small water ponds (0.05±0.02 ha) in the southwestern part of the Pyrzycko-Stargardzka Plain was carried out (Fig. 1). Five water ponds located in each type of environment (meadows, trees, villages, and typical midfield, according to modified distribution by Tandyrak and Grochowska) [25] were selected for further, detailed research. The ponds chosen for the studies were distributed in distances less than 50 m from one another in the whole catchment area, and they were surrounded by particular types of neighborhoods, i.e. a meadow, trees, a village, and a typical field. In the area of those 20 water ponds, measuring and controlling research stations had been located, from which water was taken once a month during three successive months, i.e. in June, July, and August in 2003, 2004, and 2005.

Chemical Analysis

The studies were carried out in the vegetative season due to the occurrence of aquatic flora in these bodies of water. The flora, by taking mineral components, affects the chemical composition of the water. If the changes related to the effect of the neighborhood on the chemical composition of this water are noticed in summer, this impingement will significantly influence the quality of the water in the whole year. All water samples were collected from each body of water from the euphotic layer in 5 acid-washed polyethylene 1 l bottles that were kept in a refrigerator at 5ºC during transport to the laboratory. A collective test was used for physicochemical analyses. In each sample a value of 20 parameters was determined, including: temperature, pH, electrolytic conductivity, color, turbidity, content of mineral forms of nitrogen ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$), and phosphorus ($P\text{-}PO_4^{3-}$), plus the concentration of metal ions: K, Na, Ca, Mg, Fe, Zn, Cd, Li, Sr, Cu, and Mn. The water samples were filtered through microporous filters of 0.45 μm diameter. Orthophosphate(V), nitrate, nitrite, and ammonium cations were measured by the spectrophotometric method according to Polish Standards [26-29]. Concentrations of metal ions in mineralized water samples were determined by an atomic absorption spectroscopy technique using Solaar S AA Spectrometer. The pH of the tested water was measured potentiometrically using a microcomputer pH-

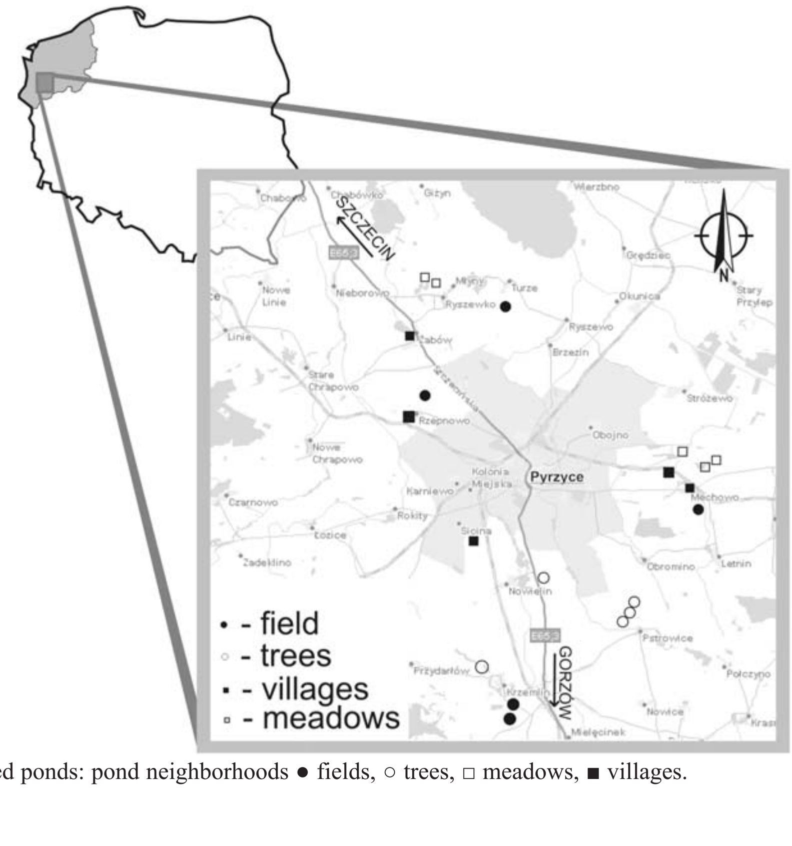

Fig. 1. Location of studied ponds: pond neighborhoods ● fields, ○ trees, □ meadows, ■ villages.

meter CI-316. The conductivity was determined using a N5721M type conductometer. Color and turbidity measurements were made using an LF 205 photometer. All measurements were performed in three replications.

Statistical Analysis

To develop statistical presentation of studies, multivariate analysis was used, including: factor analysis (FA), principal component analysis (PCA), and cluster analysis ward (CA) [30]. 3,500 measurement results of the study were analyzed. The assessment of the impact of various factors on the variability of observations was carried out using Principal Component Analysis. Two first variables of decisive influence were selected for interpretation, according to the Cattell criterion. Cluster Analysis with Ward's method was conducted to evaluate the similarities of the results, depending on the location associated with the four types of environment. The method consists in presenting similarity between objects or their features (variables) as a function of distance. The variables are more similar to one another when the distance between them is smaller. All the calculations were carried out using the computer program Statistica 9 PL for Windows.

Results and Discussion

While analyzing the data included in Table 1, it was observed that the average highest concentration of orthophosphates(V) occurred in the water of midfield ponds in the neighborhood of fields (0.302 mg SRP·dm^{-3}), slightly smaller in the neighborhood of meadows and afforested areas (0.208 and 0.229 mg SRP·dm^{-3}), and definitely the smallest in the vicinity of farms (0.083 mg SRP·dm^{-3}). Gibson [31] measured similar values in regional limnology surveys of agricultural lowland counties of Northern Ireland, and Reynolds [32] measured concentrations ranging from 0.014 to 1.700 mg SRP·dm^{-3} in the lowland meres of Shropshire and Cheshire. Taking into consideration the content of inorganic N, the highest concentration was recorded in water of the midfield ponds located in the vicinity of fields (2.17 mg $N_{inorg.}$ dm^{-3}), almost twice as small – in the vicinity of meadows and villages (1.13 and 1.20 mg $N_{inorg.}$ dm^{-3}), and the smallest in the neighborhood of trees (0.42 mg $N_{inorg.}$ dm^{-3}). Vollenweider [33] defined the limit concentrations of nitrogen and phosphorus (0.01 mg P·dm^{-3}, 0.35 mg $N_{inorg.}$dm^{-3}), the excess of which causes intensive weight gain in phytoplankton mass. In the examined waters, high concentrations of nitrogen and phosphorus indicate that these waters are eutrophicated (Table 1). Padissak et al. [34] reported that for very shallow reservoirs in Hungary, soluble reactive P concentrations were >0.010 mg·dm^{-3} and soluble inorganic N was >0.100 mg·dm^{-3}. The poor environmental state of Danish lakes is attributable to the high level of nitrogen and phosphorus loading. The decisive factor for biological diversity in the majority of Danish lakes is the degree of eutrophication – in particular with phosphorus, but also with nitrogen. The level of waters was decisively affected by the decrease in the level of water in the body of water and the application of pesticides (particularly in small lakes and ponds) [35]. N-NO_3^- concentrations in water ponds (Table 1) were small (on average: 0.15-0.21 mg·dm^{-3}), compared with the levels of 10 mg·dm^{-3} recorded in freshwaters [36]. Taking the ammonium form of nitrogen into account, the highest concentration occurred in the water of ponds in the vicinity of fields (2.49 mg NH_4^+ dm^{-3}), twice as small in the vicinity of meadows and villages (1.20 and 1.28 mg NH_4^+ dm^{-3}) and the smallest in the neighborhood of afforestation (0.38 mg NH_4^+ dm^{-3}). Because the research was conducted during the summer, high water temperatures were measured (Table 1), which caused a reduction in oxygen dissolving capacity, faster growth in BOD process rate, and acceleration of nitrification. On the other hand, Bennion and Smith [22] indicate that the concentration of nitrate nitrogen in waters of ponds was very

Table 1. Chemical and physical composition of analyzed water in midfield ponds (mean value).

Chemical and physical composition	Kind of neighborhood			
	meadow	trees	field	village
Color mg Pt·dm^{-3}	119.8	62.8	266.2	110.1
Turbidity mg SiO_2·dm^{-3}	8.9	9.3	54.8	108.7
Temp. ºC	19.0	16.7	21.5	20.4
pH	6.7	7.1	6.9	6.7
Electrolytic conductivity mS·m^{-1}	36.6	21.7	30.3	41.3
P-PO_4^{3-} mg·dm^{-3}	0.208	0.229	0.302	0.083
NO_3^- mg·dm^{-3}	0.625	0.463	0.614	0.614
NO_2^- mg·dm^{-3}	0.010	0.008	0.010	0.012
NH_4^+ mg·dm^{-3}	1.201	0.38	2.49	1.28
$N_{inorg.}$ mg·dm^{-3}	1.13	0.42	2.17	1.20
$N_{inorg.}$/P-PO_4^{3-}	6.07	1.86	7.42	14.80
Na mg·dm^{-3}	22.3	13.6	13.9	52.2
K mg·dm^{-3}	11.5	12.0	23.9	22.9
Mg mg·dm^{-3}	28.0	12.5	17.0	30.9
Ca mg·dm^{-3}	66.0	51.8	23.2	64.9
Cu mg·dm^{-3}	0.003	0.005	0.004	0.011
Zn mg·dm^{-3}	0.001	0.001	0.011	0.008
Mn mg·dm^{-3}	0.016	0.012	0.013	0.013
Fe mg·dm^{-3}	0.158	0.159	0.341	0.145
Cd mg·dm^{-3}	0.004	0.000	0.002	0.007
Li mg·dm^{-3}	0.018	0.000	0.002	0.015
Sr mg·dm^{-3}	0.759	0.154	0.082	0.499

differentiated, from values of 0.7 to 5.6 mg·dm^{-3}, and in tested ponds the average concentration (regardless of the type of environment in summer) was at the level of 0.55 mg·dm^{-3}.

The largest values of the color index were recorded in the water of the ponds in the neighborhood of fields, more than twice as small in the neighborhood of meadows and villages, and the smallest in the vicinity of afforested areas (Table 1). The color of water depends on many factors, such as humic substances, plankton, vegetation, metal ions (iron, manganese), and domestic sewage. The color of natural waters generally varies from 5 to 25 mg Pt·dm^{-3}. Intensive color means water pollution [25, 37]. The color value obtained by Joniak et al. [17], measured for the water of the ponds in degraded areas, was 40.5 mg Pt·dm^{-3}, and in the remaining areas at 32.7 mg Pt·dm^{-3}. While the highest turbidity of water was observed in the ponds located in the neighborhood of villages, it was twice as low in the neighborhood of fields, and the lowest in the vicinity of meadows and trees (Table 1).

Turbidity can be caused by many different substances, such as rock and soil elements coming from their erosion, suspensions discharged with domestic waste, and the excessive growth of plankton in the eutrophic waters. Most of the particles that cause turbidity, such as clay, silt, precipitating iron, manganese and aluminum compounds, shredded humic substances, plankton, and higher organisms, have in principle, mineral nature, though sometimes they may outweigh organic substances [25].

The lowest water temperature was characteristic of the ponds in the vicinity of afforested areas, and definitely higher was the temperature of the water of the ponds in the remaining areas (Table 1). Gałczyńska and Gamrat [20], comparing midfield ponds near the buffer zone (afforestation and areas with shrubs) and those without such a zone, observed lower temperatures that were higher by 2 degrees than in the present studies (16.7ºC). A higher temperature, on average by 3ºC, was recorded in summer in the water of the ponds located in the agricultural area [38], as compared to the analyzed ponds in the vicinity of villages, meadows, and fields. Considering the concentration of sodium, it was observed that the largest values occurred in the water of the ponds in the neighborhood of villages and the smallest in those located in the vicinity of trees and fields.

The lowest concentration of calcium was noticed in the neighborhood of fields (23.2 mg·dm^{-3}) and that of magnesium was the lowest in the vicinity of fields and trees (12.5 and 17.0 mg·dm^{-3}), and they were twice as large as those obtained by Koc et al. [38] (6.6 mg·dm^{-3}). On the other hand, Kuczera and Misztal [11] obtained the lowest concentration for both magnesium (11.56 mg·dm^{-3}) and calcium (38.41 mg·dm^{-3}) in the water of forest ponds. The content of sodium and magnesium in surface waters is mainly determined by the process of leaching rocks and soils, and discharging municipal and farm sewage or leachates from abandoned, decaying paper packaging. The magnesium concentration in inland surface waters do not normally exceed 40 mg·dm^{-3} [37], which is confirmed by performed studies (Table 1). In order to achieve high productivity and quality of crops, macroelements, of which magnesium (after potassium and calcium) is most important, are added to soil with mineral fertilizers [38]. Calcium compounds found in natural waters are generally of the largest share of mineral salt content in terms of cations. Ions of this element appearing in the soil minerals dissolve in water to bicarbonate and sulphate forms. Calcium compounds may also come from construction waste. On farmland, to prevent acidification of soils, calcium fertilizers are added, which could have contaminated the tested water bodies. In the waters of ponds located near trees, as in Ryszkowski et al. [19], the concentration of calcium was greater than in the waters of ponds in the vicinity of cultivated fields.

Phosphorus is a key component of fertilizer, as critical to agriculture as water. Farmers use millions of tons of phosphorus on their fields every year, much of which eventually goes down the drain (literally) [7, 39, 40]. Aagaard et al. [41] reported that the most important difference in water chemistry between the ponds was the content of particulate matter, phosphorus, and calcium. Urban ponds had a somewhat higher content of calcium than the others and were generally loaded with plant nutrients (especially phosphorus).

Conductivity is determined by the number of ionic particles present in the water. Conductivity values are most likely indicative of anthropogenic sources of excess ions in the water. Anthropogenic sources include urban runoff (metals, sodium), wastewater treatment plants, and agricultural runoff (sediment, phosphorus). The wastewater from our houses contains food residue, human waste, and other solid materials that we put down our drains. High turbidity and electric conductivity values attest that the examined waters were contaminated and eutrophicated (Table 1) [25]. In the analyzed water, the EC value decreased according to the following sequence of the neighborhood: village<meadow<field<trees. In very shallow bodies of water in Hungary, conductivity ranged between 200 and 1,500 μS·cm^{-1} [34]. Despite the fact that Kuczera and Misztal [11], while analyzing the effects of land use, obtained higher EC values (354.54-722.21 μS·cm^{-1}) than the values in the analyzed ponds, the values of this parameter decreased in the same order. Koc et al. [38] inform that pH of the water of the studied ponds was by more than one unit larger than in the analyzed bodies of water, and the EC value was within the range of 206-328 μS·cm^{-1}.

The amount of iron in the water of ponds located in the vicinity of fields is twice as high as that in the water of the remaining ponds, but determined concentration was markedly lesser than that observed by Olszewska et al. [42] in the midfield ponds. Iron compounds in natural waters are generally in low concentrations. Oxygen deficit causes iron to transform into reduced form, divalent, easier dissolving and therefore massively released from seston and bottom sediments. In acidic waters, the iron content is higher than in waters with higher pH values [43]. Different test results of examined metal ions (Fe, Mn) were received by Tandyrak and Grochowska [25] in ponds, divided according to the same criterion of the neighborhood on Olsztyn Lakeland. However, these differences are mainly caused by their location, i.e. the impact of urbanized areas.

Table 2. Results of factorial analysis (normalized rotation method-varimax, marked values are ≥ 0.7) according to Evans et al. [45], and Pucket and Bricker [46].

Sort of variables	Variables – 1				Variables – 2				Variables – 3				Variables – 4			
Type of neighbouring	M	T	F	V	M	T	F	V	M	T	F	V	M	T	F	V
Characteristic																
Color mg Pt·dm^{-3}			0.70			0.87	-0.84									
Turbidity mg SiO_2·dm^{-3}			0.77	0.83		0.88										
Temp. ºC				-0.75		-0.76										
EC mS·m^{-1}												-0.71				
pH					0.75										0.71	
NH_4^+ mg·dm^{-3}	-0.95	0.83	-0.84									-0.71				
P-PO_4^{3-} mg·dm^{-3}				-0.90			-0.82							0.70		
$N_{inorg.}$ mg·dm^{-3}	-0.95		-0.84							0.71		-0.70				
$N_{inorg.}$/P-PO_4^{3-}	-0.90			0.76												
NO_3^- mg·dm^{-3}		-0.72									0.70					
Na mg·dm^{-3}		-0.78	-0.88													
Ca mg·dm^{-3}		0.82						0.84								
Fe mg·dm^{-3}		-0.79													0.71	
K mg·dm^{-3}				-0.88	-0.90		-0.70									
Mn mg·dm^{-3}									-0.71						0.80	0.70
Li mg·dm^{-3}					-0.70			0.73								
Mg mg·dm^{-3}							-0.85									
Sr mg·dm^{-3}	-0.75	0.76		-0.72							0.75					
Cd mg·dm^{-3}				0.70												
Variability of chemical composition of water by the factors (%)	26.9	27.4	29.6	27.0	22.2	21.9	20.7	18.9	14.2	15.8	14.3	13.5	13.1	10.0	11.3	9.4

according to Statistica 9 PL for Windows
Type of neighborhood: M – meadow, T – trees , F – field, V – village

The recorded concentrations of zinc, cadmium, and copper was much higher in the water of ponds located in the vicinity of villages than in the neighborhood of other places. Aagaard et al. [41] reported that there were differences in the content of heavy metals depending on land use. In general, the ponds held low concentrations of heavy metals, but some stood out with comparatively high concentrations of zinc and copper (woodland ponds), or nickel and lead (a few urban and ice-production ponds).

High iron concentrations in ponds in western Pennsylvania may also adversely affect pond aesthetics by precipitating as an orange coating on the pond bottom, docks and vegetation. Iron concentrations above 0.3 mg·dm^{-3} and manganese concentrations above 0.05 mg·dm^{-3} will impart a metallic taste to water. Similarly, copper concentrations above 1.0 mg·dm^{-3} can cause an offensive metallic taste. High copper concentrations may result from repeated use of copper-based algaecides in a pond [44]. The highest concentration of strontium and manganese was recorded in the ponds located in the neighborhood of meadows.

As far as the content of potassium is concerned, the same and nearly the same values were observed in the neigbourhood of fields and villages, and they were almost twice as low and also similar – in the vicinity of meadows and trees. Pascale et al. [18], while studying the ponds in the catchment of the Cole River in Southern England, found out that the concentration of potassium ranged within 0-30.80 mg·dm^{-3}.

Table 2 shows the results of factorial analysis for the four discussed habitats of studied water ponds. Using the

Kaiser and Cattell criteria, it was determined that four factors have in all cases a decisive influence on the variability of parameters. Differences in physicochemical parameters of water were found between circumscriptions. Analyzing the impact of reduced parameters for the ponds surrounded by meadows, positive correlations were found only for the reaction of water and negative for: NH_4^+, $N_{inorg.}$, $N_{inorg.}/P\text{-}PO_4^{3-}$, ions: Sr, K, Li, Mn. In the surroundings of countryside, positive correlations occurred for: turbidity, $N_{inorg.}/P\text{-}PO_4^{3-}$, ions: Cd, Li, Ca, Mn, and negative for: temp., $P\text{-}PO_4^{3-}$, ions: Sr and K, electrolytic conductivity, NH_4^+, $N_{inorg.}$. Determined physicochemical parameters of waters extracted from both environments are mostly the same, which is confirmed by Ward's cluster method.

In the surroundings of trees, positive correlations were found for: NH_4^+, ions: Ca and Sr, color, turbidity, $N_{inorg.}$, $P\text{-}PO_4^{3-}$, and negative for: NO_3^-, ions: Na and Fe and temperature. On the other hand, in the ponds surrounded by fields, positive correlations were identified for: turbidity, temp., NO_3^-, ion Sr, Mn, Fe and pH, and negative for: NH_4^+, $N_{inorg.}$, ion Na, color, $P\text{-}PO_4^{3-}$, ions: K and Mg.

Factor analysis (FA), principal component analysis (PCA), and cluster analysis ward (CA) were used by Evans et al. [45], Puckett and Bricker [46] and Skorbiłowicz and Skorbiłowicz [47]. The dendrogram (Fig. 2) has four types of studied pond environments marked on the axis of abscissae. Analyzing the data, three groups can be distinguished:

1) samples located in meadow and rural environments,
2) samples surrounded by trees, and
3) surrounded by fields.

The chemical composition of water within the first group is similar (the variables are more similar to one another when the distance between them is smaller). It can be assumed that the minerals flowing into the water are of similar type and concentration. Ponds from the second group differ significantly in chemical composition from those in the first group, and the concentrations of $N_{inorg.}$, ions: K, Mg, Na, and Zn and values of physical parameters such as color, temperature, turbidity, and electrolytic conductivity were the lowest (Table 1).

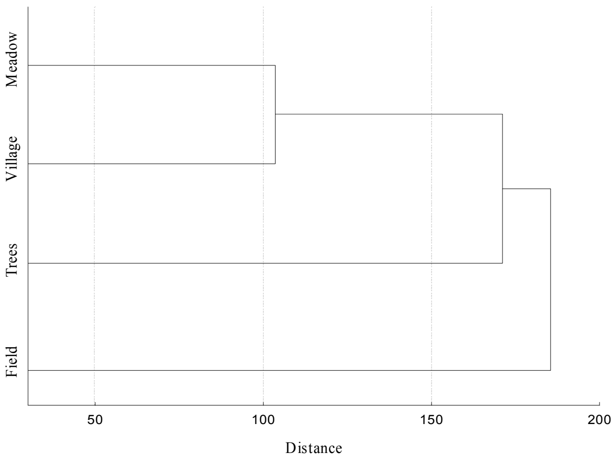

Fig. 2. Hierarchical dendrogram of the CA according to Warda for the clustering values depending on locations (according to Statistica 9 PL for Windows).

Table 3. Results of factorial analysis (normalized rotation method-varimax, marked values are ≥0.7) according to Evans et al. [45] and Pucket, Bricker [46]

Characteristic	Variables – 1	Variables – 2	Variables – 3
Color	-0.35	**-0.85**	-0.29
Clarity	**-0.83**	-0.13	0.46
Temp.	**-0.76**	-0.34	-0.03
pH	0.63	0.04	0.29
Electrolytic conductivity	**-0.83**	0.36	-0.14
$P\text{-}PO_4^{3-}$	0.36	**-0.73**	-0.42
NO_3^-	-0.37	0.07	-0.33
NO_2^-	-0.31	-0.01	0.07
NH_4^+	-0.54	**-0.70**	-0.30
Ninorg.	-0.55	**-0.70**	-0.31
Ninorg./$P\text{-}PO_4^{3-}$	**-0.85**	0.12	0.20
Na	**-0.71**	0.51	0.29
K	-0.60	-0.55	0.12
Mg	**-0.73**	0.40	-0.20
Ca	-0.18	**0.86**	-0.17
Cu	-0.41	0.02	0.47
Zn	-0.68	-0.56	0.25
Mn	0.06	0.32	-0.46
Fe	-0.05	**-0.93**	-0.13
Cd	-0.52	0.31	0.12
Li	-0.45	0.62	-0.49
Sr	-0.38	**0.70**	-0.48

according to Statistica 9 PL for Windows

This is due to a high level of absorption of mineral nutrients by the root systems of trees [19, 20]. Ponds from the third group significantly differ from those representing the first group, but they do not differ that much from the second group.

On the basis of factorial analysis based on the Cattell criterion and the Kaiser criterion (Table 3, Fig. 3), three factors explaining the variability of the impact of habitat on the physicochemical parameters of water in the analyzed system were identified.

Factor I explains the variability of chemical composition of water in the examined ponds in 31.24%. Negative factor charges are noticeable. They are "coefficients of correlation" between variables $N_{inorg.}/P\text{-}PO_4^{3-}$, Na, Mg, and also turbidity, electrical conductivity, temp., and factor I (Table 3).

Factor II explains in 28.08% the variability of general chemical composition of waters in tested ponds. It is positively correlated with calcium, negatively with $P\text{-}PO_4^{3-}$, ion Fe, and color (Table 3).

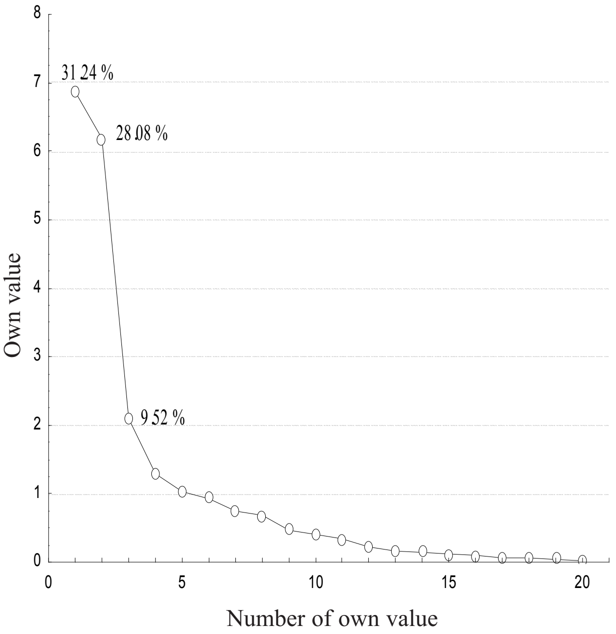

Fig. 3. Scree test (Cattell criterion) basis on own value and percent of clarify variables (according to Statistica 9 PL for Windows).

Factor III explains in 9.52% the changeability of general chemical composition of waters in the tested ponds. Correlation coefficients below 0.7 indicate the small impact of analyzed parameters on reducing measurement variables (Table 3).

The chemical and physical parameters of pond waters in this environment found in factor analysis are different from those described above, but do not differ greatly among themselves. The percentage share of four factors in the variability of chemical and physical composition of water differed due to the nature of their environment (about 70%), and if this variability was not taken into account it had a similar value, but described by three factors.

Of 22 studied chemical and physical parameters, factor analysis helped to identify only 13. The number of parameters of high correlation rates of parameters characterizing the chemical composition of water ponds located in different types of circumambiences. Parameters such as concentration of NO_3^-, ions: K, Mn, Li, Cd, and pH of water did not occur in the factor analysis for different types of circumambiences.

In multidimensional analysis of statistical data, the basic studies aim to show significant relationships between variables describing multidimensional phenomena. In order to reduce the dimension of the data space, principal components analysis is used. The next steps lead to the reduction in the contribution of the variance of successive main components to the entire variability of multidimensional observations. The studies showed considerable differences between the water of the ponds, depending on the type of neigborhood: villages, fields, afforested areas and meadows. Statistical analysis FA made it possible to reduce, in the evaluated dataset, the number of determined parameters by 60%. Such analyses are usually used in search of the relationships describing multidimensional phenomena concerning, for example, physicochemical indices of the water, flora, and fauna species, and also sociological parameters [45, 47]. The limitation of the number of parameters decreases the time and costs of the analysis. The water of bodies of water is characterized by a different quality depending on the location and the use of the catchment area. However, in the areas of similar geomorphological conditions and definitely agricultural build-up of the area, impact of different types of neighborhood on the composition of small bodies of water is possible.

Conclusions

1. Differences between types of environment were related to parameters such as concentration of NO_3^-, ions: K, Mn, Li, Cd, and pH of water. The smallest concentrations of macro- and microelements characterized bodies of water surrounded by trees.
2. Ward's cluster analysis (CA) has shown the similarity of the chemical composition of water in bodies of water, surrounded by meadows and villages. Ponds located in the surroundings of trees differed significantly in their chemical composition from those representing the previous group, but only slightly in comparison to typical midfield ponds.
3. The conducted studies and the results of statistical analysis of FA and PCA made it possible to reduce the number of main factors affecting water quality in the surveyed midfield ponds from 22 to 13.

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