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Assessment of surface waters quality of small water reservoirs in agricultural landscape

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In the article are presented results from water quality monitoring of six small water reservoirs situated in agricultural landscape in different Slovak regions. The study period was from June 2020 to September 2021. Studied parameters covered oxygen regime, total dissolved solids, fluorescent dissolved organic matter, turbidity, chlorophyll a, phycocyanin and phycoerythrin. All parameters were measured directly in the field using EXO YSI 2 probe. For interpretation of the measured data the application of different statistical approaches were used. The cluster analysis divided the six monitored water reservoirs in to two clusters. The Kruskal-Wallis test confirmed the significant differences between groups of water reservoirs. Analysis of normalized data revealed main parameters that caused the distribution in to two clusters: chlorophyll a, cyanobacterial photosynthetic pigments phycocyanin and phycoerythrin, turbidity and pH. In the cluster 2 the concentration ranges for these parameters showed large fluctuations. Comparison of the land cover structure of 500 m buffer zones pointed out the importance of buffer zone composition for better water quality. For the cluster 2 the highest proportion belonged to arable soils (63.63–92.00%) and only 1.12–9.33% to forests.

KEY WORDS: surface water, water reservoirs, agriculture, water quality

Introduction

Water, as an important component of the biosphere, provides many functions for humans. Man uses water for personal consumption, in agriculture, industry and energy production, for transport and recreation. Growth of population and rising living standards cause pressure on the amount and availability of quality water resources (Ormerod et al., 2010).

The legal regulations endorse conditions for protection of surface and groundwaters, including aquatic ecosystems and landscape ecosystems directly dependent on water, e.g. the Water Framework Directive, the Council Directive 91/676/EEC, the so-called Water Act, Act no. 364/2004 Coll. on Waters and on Amendments to Certain Acts. This Act also regulates the rights and obligations of natural and legal persons to surface and groundwater and real estate related to them.

Human activities interfere with the natural water cycle and often result in the drainage of water from the natural cycle. In the past, people have tried to compensate for the lack of water in the area and its retention in the country by building water reservoirs. Water reservoirs can serve to variety of purposes. Many are multi-purpose and often cover the requirements of farmers, fisheries organizations, industry, but also perform protective and aesthetic functions in the landscape (Jurík et al., 2015; Szcykowska and Siemieniuk, 2014). Water reservoirs are technical, water management structures and therefore require regular maintenance. Recently, in field research, we often encounter with insufficient maintenance and care of these water works, which also affects the efficiency of their use. Problems of neglected maintenance are visible especially on the dams of reservoirs, their functional objects and on clogging and grounding, especially of small water reservoirs. Mud removal from small water reservoirs consist in removing sediments coming from catchment and from bank abrasion in to reservoir. These sediments create conditions for eutrophication of the reservoir, growth of biomass and its subsequent decaying and sedimentation in the reservoir. A gradual reduction, even impossibility, of water management, biological and ecological functions of small water reservoirs are caused by the clogging (Čistý, 2005; Ignatius and Rasmussen, 2016).

When protecting surface water, it is important to pay attention to the sources of pollution, which can be point and non-point. Natural organic pollution of surface waters is caused by leaching from soils, sediments and by vital products of plants, animals and aquatic organisms. Excessive supply of nutrients and pollutants threatens the quality of ecosystems and human health. Nutrients enter aqueous sources in dissolved ionic form or bound in organo-mineral soil complexes. Insoluble substances are considered the most significant components of surface water pollution by volume. Dissolved substances enter water sources by infiltration of the soil profile with

rainwater or surface runoff. Undissolved substances are transported by soil erosion, mostly by water erosion, in a lesser extent also by wind erosion (Pekárová and Velísková; 1998; Krengel et al., 2018).
Pollution of anthropogenic origin can come from direct and indirect human activity. The most significant impact on the quality of surface waters is the outflow from agricultural areas and the discharge of municipal or industrial wastewater into watercourses and reservoirs (Kriška Dunajský et al., 2018). In the agricultural land, excessive fertilizers, runoff, and soil erosion can lead to an increase in sediment, nutrients, chemical contaminants, and organic matter into water bodies (Huang et al., 2020). Factors that have a significant impact on water quality include river basin and reservoir management, topography and relief of the surrounding landscape, density and species composition of riparian vegetation, the method and intensity of cultivation of adjacent fields, industrial facilities and, last but not least, the presence and size of settlements (Li et al., 2015; Arocena et al., 2018). Smaller villages located in agricultural landscape are often without a built sewerage network and wastewater treatment plants. The absence of wastewater treatment from settlements and agricultural objects, manures and waste dumps results not only in supply of nutrients but also pathogens and hazardous chemicals, which accumulate in the aquatic environment and enter the bio-geo-chemical cycles and food chains.
As a result of global warming also water temperature is rising and this has a significant impact on water chemistry, as well as on development of harmful cyanobacterial bloom. According to the United Nations World Waters Report (UNESCO, 2020), many lakes and estuaries around the world, providing drinking water to millions of people and supporting ecosystem services, are full of harmful substances entering food chains and supporting development of harmful cyanobacterial bloom, which among other things causes hypoxia. Cyanobacterial cells have dimensions of 0.5–60 μm. In their cells, they have photosynthetic pigment chlorophyll a and other pigments, especially phycocyanin and phycoerythrin (Hindák, 2001; Cohen-Bazir and Bryant, 1982). During their evolutionary development, cyanobacteria have adapted to almost all ecological conditions. They often occur abundantly in fresh but also salt waters in free plankton, trapped on various substrates in the littoral, free on the bottom and sometimes as accumulated biomass visible to the naked eye as so-called water bloom. The presence of a cyanobacterial water bloom is often accompanied by an odour, which indicates a deteriorating biological quality of the water (Huisman et al., 2018). The mass occurrence of planktonic cyanobacteria results not only in aesthetically undesirable changes in water reservoirs, but also in the presence of dangerous toxins. Many cyanobacteria excrete toxic substances, especially neurotoxins and hepatotoxins, during the decomposition of their cells, but also alive. Cyanotoxins are dangerous for humans, but they can also cause poisoning of warm-blooded animals, especially cattle, dogs, and birds that have drunk from such water (Hindák, 2001).
The aim of the study was to assess the water reservoirs on the basis of measured water quality parameters.

Research sites

The research sites represent selected small water reservoirs located in the agricultural landscape in Trnava, Nitra and Banská Bystrica districts. Based on the field survey were selected study water reservoirs (WR) in which we monitored changes in surface water quality. The research sites are following: WR Doľany (Trnava district), WR Suchá nad Parnou (Trnava district), WR Dubník 2 (Nové Zámky district), WR Rúbaň 2 (Nové Zámky district), VN Sklabiná (Veľký Krtíš district), WR Želovce (Veľký Krtíš district) (Fig. 1). The monitored water reservoirs belong to the category of small water reservoirs with a ground construction (Table 1).
The water reservoirs Doľany (19 ha) and Suchá nad Parnou (37.6 ha) were built on a stream Podhájský potok, which flows through them. The WR Doľany is situated in area of large agricultural fields. The WR Suchá nad Parnou is situated on the outskirts of the village. It was created to protect the villages from floods. At its southern bank is a cottage area. In addition to irrigation and fishing, it is also used for recreation. The WR Sklabiná (12 ha) is located on a stream Zajský potok and is used for fish farming and recreation. The WR Želovce (3 ha) is situated on a stream Čegovský potok in the area of large agricultural fields. The WR Dubník 2 (14 ha) was built on a stream Parížsky potok. It is located in the area of intensive agriculture. It is used for irrigation and recreational fishing. It is bordered by tree vegetation on the south. The part of its steep bank on the north is collapsing into the water reservoir. The WR Rúbaň 2 (10 ha) is situated on a stream Cegléd. In summer, it is used for irrigation and recreational fishing. The land use and land cover around the water reservoir have the influence on the water quality. Table 2 shows the differences in land cover in the buffer zone of 500 m around the WRs. The monitored water reservoirs belong to the category of small water reservoirs with a ground construction. Important factors influencing the water quality as the amount of precipitation and wind speed are presented in tables 3–5.

Methods

In the period from June 2020 to September 2021, field measurements of surface water quality and monitoring of water levels were carried out at regular monthly intervals. The measurements were carried out from the dams or piers from representative monitoring points selected before. To select the final monitoring point we did monitoring on several point in the WRs and as the results were almost the same we selected the representative ones. One point for each WR. We did monitoring deployments with averaging the datasets. During the months with higher eutrophic state we performed for the control also measurements in additional points to ensure the measured data are representative for the WRs. However, for statistical analysis we used only the data from the selected representative monitoring points. The monitoring depth was 50 cm to allow us to compare also with another shallow water reservoirs which we study. To avoid differences in measurements caused by the daytime we always kept the sequence of monitoring reservoirs. The monitoring were carried out from 9 am to 2 pm.

The following physico-chemical parameters were selected to evaluate surface water quality: water temperature [°C], conductivity [μS cm^{-1}], total dissolved solids TDS [mg L^{-1}], salinity [psu], optical dissolved oxygen ODO [mg L^{-1}, %sat], water pH, fluorescent dissolved organic matter [RFU], turbidity [FNU], chlorophyll a [μg L^{-1}], phycocyanin BGA-PC [μg L^{-1}] and phycoerythrin BGA-PE [μg L^{-1}]. The measurement of the parameters took place directly in the field using EXO YSI 2 probes. The obtained values were processed by statistical methods.

From June 2021 to September 2021 we also analysed nitrate nitrogen (NO^{3}-N), ammonium nitrogen (NH_4-N), total nitrogen (TN), total phosphorus (TP) and chemical oxygen demand (COD) by Hach cuvette tests LCK339, LCK304, LCK138, LCK349 and LCI500. These analyses were carried out in the laboratory on spectrophotometer DR5000. The water samples for laboratory analysis of volume 1 L were transported in cold and dark in a portable fridge and analysed imediatelly for content of nitrate nitrogen and ammonium nitrogen and on the other day for content of total nitrogen, total phosphorus and chemical oxygen demand.

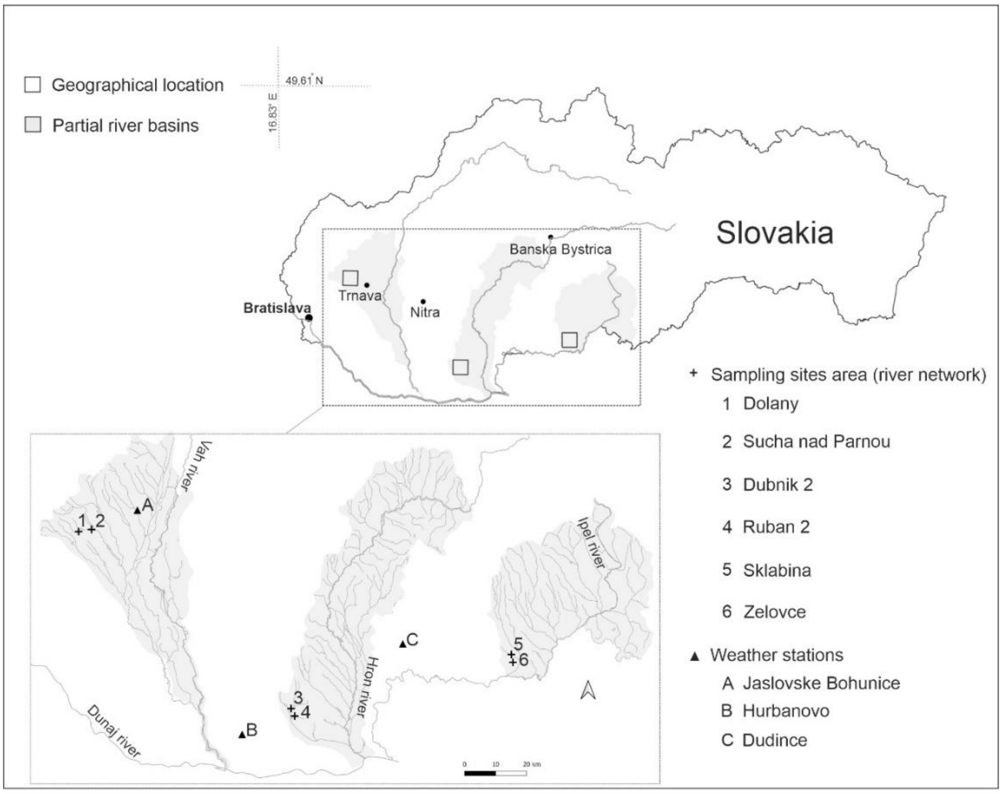

Fig. 1. Location of monitoring water reservoirs and climatic stations (Author: Hubert Hilbert, 2022).

Table 1. Geographical location of the monitoring point (MP) and the water reservoirs´ characteristics

Water Reservoir	MP latitude	MP longitude	Altitude [m]	Area [ha]	Average depth* [m]	Purpose
Doľany	48.373249	17.387733	201	19	6.41	irrigation
Suchá nad Parnou	48.403301	17.41695	174	37.6	5.62	irrigation, fishery, recreational fishing, recreation
Dubník 2	47.946732	18.399433	138	14	3.67	irrigation, fishery, recreational fishing
Rúbaň 2	47.925098	18.417868	144	10	6.91	irrigation, fishery
Sklabiná	48.152451	19.33445	176	12	2.55	irrigation, fishery, recreational fishing, recreation
Želovce	48.129932	19.343233	167	3	3.45	irrigation

**average depth in the monitoring period*

Table 2. Corine land cover structure of 500 m buffer zone of each water reservoir. Codes: 1 urban areas, 2 industrial, commercial and transport areas, 4 areas with urban vegetation, sport and recreational areas, 5 arable land, 6 permanent crops - orchards and vineyards, 7 meadows and pastures, 9 deciduous forests, 10 mixed forests, 17 marshes and peatlands, 18 water areas, 20 nonspecified forests

WR	Doľany		Suchá nad Parnou		Dubník 2		Rubáň 2		Sklabiná		Želovce	
Code	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]
1			204153.92	6.23	56197.30	2.42						
2					21920.19	0.95						
4					22297.21	0.96						
5	1561819.82	77.29	1430192.20	43.66	1475502.87	63.63	1133080.61	68.16	1384449.73	70.47	1174993.11	92.32
6	7227.68	0.36	186767.65	5.70	158564.10	6.84	172328.04	10.37				
7	205595.43	10.17	496939.62	15.17	204509.98	8.82	84885.27	5.11	148218.26	7.54	46066.64	3.62
9			504746.22	15.41	216290.56	9.33	184958.43	11.13	147074.32	7.49		
10			85124.24	2.60								
17					720.14	0.03						
18	135151.45	6.69	324617.30	9.91	162722.96	7.02	87171.52	5.24	134391.30	6.84	37400.99	2.94
20	110979.54	5.49	43189.75	1.32					150401.26	7.66	14280.65	1.12
Summary	2020773.92	100.00	3275730.91	100.00	2318725.31	100.00	1662423.88	100.00	1964534.88	100.00	1272741.39	100.00

Table 3. Monthly means and totals measured at the weather station Hurbanovo: T – temperature, Tmax – maximum temperature, Tmin – minimum temperature, SLP – atmospheric pressure at sea level, H – average relative humidity, PP – total rainfall and/or snowmelt, W – average wind speed, Wmax – maximum sustained wind speed (source: https://en.tutiempo.net/)

Hurbanovo								
Parameter	T	Tmax	Tmin	SLP	H	PP	W	Wmax
Date/Unit	[°C]	[°C]	[°C]	[hPa]	[%]	[mm]	[km/h]	[km/h]
VI. 2020	19.8	25.1	14.2	1011.1	70.1	50.5	11.3	20.8
VII. 2020	22.1	28.9	14.8	1015.7	58.4	30.0	9.7	17.2
VIII. 2020	23.0	29.7	16.5	1013.6	61.6	44.5	9.6	17.2
IX. 2020	17.9	24.9	11.6	1017.1	56.9	83.3	9.5	16.8
X. 2020	11.6	15.7	7.7	1014.9	83.0	136.7	11.0	18.0
XI. 2020	5.6	8.9	2.8	1028.0	89.4	17.8	8.0	13.5
XII. 2020	4.0	5.9	1.9	1015.5	87.8	21.3	11.9	19.5
I. 2021	1.8	5.1	-1.3	1012.8	83.6	30.0	11.2	19.0
II. 2021	3.1	8.0	-1.0	1021.5	80.5	22.6	11.0	18.7
III. 2021	5.8	12.7	-0.8	1021.4	58.9	2.0	13.1	24.0
IV. 2021	9.2	15.1	2.7	1017.1	61.2	39.4	14.2	24.7
V. 2021	14.1	19.1	8.0	1013.9	67.6	84.1	13.2	22.3
VI. 2021	22.8	29.4	14.8	1016.2	55.4	10.2	9.0	15.5
VII. 2021	24.0	30.6	17.1	1013.5	59.7	37.9	10.1	18.2
VIII. 2021	20.5	26.8	14.1	1015.0	67.8	34.8	9.1	17.1
IX. 2021	17.1	24.2	10.0	1019.3	66.4	58.4	9.0	15.8

Untill the analyses the samples were kept in a fridge.
We used Shapiro-Wilk test to analyse normality of data with a p-value<0.05 (Shapiro and Wilk, 1965). All data except pH (p-value 0.704) has been not normally distributed. Based on these results we decided to determine the strength and directions of the relationships between water quality parameters with Spearman correlation, which is more suitable for this type of distribution (Spearman, 1904). A cluster analysis (CA) was applied to analyse the similarity of the water reservoirs. Hierarchical agglomerative clustering was chosen. It is the most common approach and is typically illustrated by a dendrogram (McKenna, 2003). The dendrogram provides a visually interpretation of the grouping processes, presenting a picture of the groups and their similarity with a dramatic reduction in dimensionality of the original data (Shrestha and Kazama 2007). CA was performed on the normalized data by

Table 4. **Monthly means and totals measured at the weather station Dudince: T – temperature, Tmax - maximum temperature, Tmin – minimum temperature, SLP – atmospheric pressure at sea level, H - average relative humidity, PP – total rainfall and / or snowmelt, W – average wind speed, Wmax – maximum sustained wind speed (source: https://en.tutiempo.net/)**

Dudince								
Parameter	**T**	**Tmax**	**Tmin**	**SLP**	**H**	**PP**	**W**	**Wmax**
Date/Unit	**[°C]**	**[°C]**	**[°C]**	**[hPa]**	**[%]**	**[mm]**	**[km/h]**	**[km/h]**
VI. 2020	19.4	25.4	13.4	1010.6	73.8	135.9	6.8	13.4
VII. 2020	21.3	28.2	13.5	1015.7	63.8	68.6	6.1	12.1
VIII. 2020	22.2	29.6	15.0	1013.4	65.6	69.6	6.2	12.6
IX. 2020	17.2	24.9	10.2	1016.9	70.6	71.6	5.9	10.8
X. 2020	11.2	15.7	7.0	1014.8	87.1	131.6	5.8	9.3
XI. 2020	4.7	8.1	1.8	1028.1	90.8	16.2	4.5	7.8
XII. 2020	3.8	5.9	1.7	1016.0	88.0	29.5	7.0	11.7
I. 2021	0.5	3.9	-2.8	1012.8	86.0	44.2	6.3	11.9
II. 2021	1.9	6.9	-2.9	1021.7	82.5	33.3	6.0	11.3
III. 2021	4.5	12.3	-2.8	1021.1	61.4	5.6	7.3	14.9
IV. 2021	8.2	15.0	0.6	1016.7	63.4	34.0	8.4	17.2
V. 2021	13.0	19.4	5.8	1013.6	71.3	101.9	8.3	16.7
VI. 2021	22.0	29.3	13.1	1016.0	60.9	32.8	6.0	12.0
VII. 2021	23.2	30.5	15.9	1013.2	64.5	165.4	6.3	12.5
VIII. 2021	19.5	26.4	12.6	1014.6	68.7	40.1	6.7	13.6
IX. 2021	16.1	24.2	8.2	1019.1	65.7	41.9	6.2	12.2

Table 5. **Monthly means and totals measured at the weather station Jaslovské Bohunice: T – temperature, Tmax – maximum temperature, Tmin – minimum temperature, SLP – atmospheric pressure at sea level, H – average relative humidity, PP - total rainfall and / or snowmelt, W - average wind speed, Wmax – maximum sustained wind speed (source: https://en.tutiempo.net/)**

Jaslovske Bohunice								
Parameter	**T**	**Tmax**	**Tmin**	**SLP**	**H**	**PP**	**W**	**Wmax**
Date/Unit	**[°C]**	**[°C]**	**[°C]**	**[hPa]**	**[%]**	**[mm]**	**[km/h]**	**[km/h]**
VI. 2020	18.8	24.1	13.5	1011.2	73.8	71.6	13.7	22.7
VII. 2020	20.5	27.4	13.7	1015.8	65.8	51.3	10.7	19.2
VIII. 2020	22.1	28.9	15.7	1013.6	64.8	38.1	10.7	19.5
IX. 2020	17.0	23.2	11.6	1017.2	71.2	108.7	11.8	19.7
X. 2020	10.9	14.7	7.7	1014.6	85.7	124.5	13.8	24.0
XI. 2020	5.1	7.5	2.9	1027.8	90.4	17.0	10.2	17.4
XII. 2020	3.3	5.0	1.5	1015.1	90.0	36.1	14.7	22.5
I. 2021	0.5	3.2	-2.2	1012.6	86.7	42.9	12.0	21.6
II. 2021	2.3	6.2	-1.1	1021.5	83.2	19.3	12.5	22.2
III. 2021	4.7	11.0	-1.2	1021.6	64.7	8.6	13.7	24.7
IV. 2021	8.1	14.1	2.2	1017.1	63.0	19.3	16.1	28.2
V. 2021	13.0	18.2	7.2	1013.6	70.5	103.9	14.4	25.0
VI. 2021	21.1	28.0	13.2	1016.3	62.7	13.2	10.8	18.7
VII. 2021	23.0	29.5	16.0	1013.5	59.1	51.3	12.8	22.7
VIII. 2021	19.2	24.9	13.8	1015.0	71.0	94.2	11.1	21.0
IX. 2021	16.3	22.8	10.0	1019.4	68.7	26.7	11.4	20.2

means of the Ward´s method, using squared Euclidean distances as a measure of similarity. The Kruskal-Wallis H test was used to analyse whether there was a significant difference between similar groups of the water reservoirs. When the p-unc (uncorrected p-value) is less than 0.05, there were statistically significantly different from each other (Kruskal and Wallis, 1952).

Results and discussion

The measured values at the study sites were influenced by the season and the amount of water in the reservoirs. In the monitoring period from June 2020 to September 2021, we recorded a water temperature in the range of 3.53°C (XII. 2020, Sklabiná) – 27.91°C (VII. 2021, Rúbaň 2). The reaction of water pH ranged from 7.64 (XII. 2020, Sklabiná) to 9.24 (VI. 2021, Želovce). The average pH value for the monitored sites was 8.42. The conductivity ranged from 143.04 μS cm^{-1} (VIII. 2021, Doľany) to 971.16 μS cm^{-1} (VIII. 2020, Dubník 2) with an average of 421.08 μS cm^{-1}. The TDS content ranged from 103.41 mg L^{-1} (VIII. 2021, Doľany) to 647.00 mg L^{-1} (VIII. 2020, Dubník 2) with an average value of 316.20 mg L^{-1}. The fDOM content was from 1.90 RFU (VII. 2021, Suchá nad Parnou) to 28.36 RFU (XI. 2020, Želovce) with an average value of 10.68 RFU. The value of the measured chlorophyll a content ranged from 2.91 μg L^{-1} (II.2021, Rúbaň 2) to 318.23 μg L^{-1} (VI. 2021, Želovce) with an average value of 36.56 μg L^{-1}. High level of variability in selected parameters were also registered by Noskovič et al. (2013) and Ignatius and Rasmussen (2016). According to Sebíň (2007) water quality of water reservoirs in agricultural landscape is more vurnelable to substantial changes than in water reservoirs in forested microcatchment. The measured dissolved oxygen content ranged from 1.88 mg L^{-1} or 22.3%sat (VIII. 2020, Dubník 2) to 22.63 mg L^{-1} or 271.8%sat (VI. 2020, Dubník 2), with an average value of 11.54 mg L^{-1} or 139.66%sat. According to Higgins (2014) extensive experience in the field and testing instrument at the YSI facility, values over 100% air saturation have indeed proven to be quite common. The levels of dissolved oxygen are affected by many water quality parameters and respond to their variations, either directly or indirectly. Kowalczewska-Madura et al. (2022) described the similar supersaturation in Raczyńskie Lake during their study. They measured the oxygen concentration of 23.1 mg L^{-1} in the summer 2019 (270%sat) at the surface level. When analysed the seasonal variability of this parameter, they found out that there was a gradual increase in the mean oxygen concentration in the surface layer, while above the bottom, concentrations varied. Huang et al. (2017) recorded supersaturated DO levels due to low concentrations of oxygen-consuming substances and strong phytoplankton photosynthesis. Proved that algal respiration and photosynthesis rates are proportional to phytoplankton biomass and therefore, the peaks of DO consumption and production by algal respiration and production are synchronized with the peaks of chlorophyll a. In our case, in the period when the maximum DO concentration was measured also turbidity (97.79 FNU), pH (9.06), BGA-PE (284.68 μg L^{-1}) were increased on the site. In the same time were measured the oxygen concentrations of 16.65 mg L^{-1} (192.6%sat) in an upstream WR Jasová and 14.45 mg L^{-1} (171.3%sat) in the WR Rúbaň 2 where the concentration of chlorophyll a reached 60.39 μg L^{-1}.

After processing all measured data by statistical analysis descibed above the water reservoirs were divided in to two clusters on the basis of their similarities. Figure 2 illustrates the emerged clusters in the form of a dendrogram. The water reservoirs Suchá nad Parnou, Rúbaň 2 and Sklabiná represent the first cluster of reservoirs. The second cluster consists of the water reservoirs Dubník 2, Doľany and Želovce.

To find out which monitored parameters caused the division of reservoirs in to the two clusters a normalized data were analysed and produced a bar graph of dissimilarities (Fig. 3).

The main parameters that differ between the two clusters are pH values, turbidity, concentrations of chlorophyll a, cyanobacterial photosynthetic pigments phycocyanin and phycoerythrin and content of fluorescent dissolved organic matter content (Fig. 3). These parameters are noticeably higher in the second cluster of water reservoirs. These results were also confirmed by the Kruskal-Wallis test (Table 6). The most significant difference were in p-values of phycocyanin (5.08E-08), phycoerythrin (1.36E-08), turbidity (4.11E-07) and chlorophyll a (2.00E-6).

In the box plots graphs (Fig. 4 – 6) are presented median, minimum and maximum values, the first and the third quartiles for the water reservoirs of the two clusters during the monitoring period.

The water reservoirs of the group 2 are similar in their character, location and purpose of usage. In these reservoirs we recorded maximum or above-average values of chlorophyll a, phycocyanin and phycoerythrin during the summer months of June, July 2020 and 2021 and September 2020.

The median values for Chl a were 9.69–64.04 μg L^{-1}, the first quartile range from 6.63 to 35.40 μg L^{-1} and the third quartile range from 11.70 to 254.69 μg L^{-1}. An overall concentrations of Chl a ranged from 5.61 to 318.23 μg L^{-1}.

The median values for BGA-PC were 1.47–13.5 μg L^{-1}, the first quartile range from 1.27 to 9.04 μg L^{-1} and the third quartile range from 1.99 to 25.18 μg L^{-1}. An overall concentrations of BGA-PC ranged from 0.75 to 32.94 μg L^{-1}.

The median values for BGA-PE were 11.94–199.76 μg L^{-1}, the first quartile range from 11.21 to 137.78 μg L^{-1} and the third quartile range from 34.61 to 250.82 μg L^{-1}. An overall concentrations of BGA-PE ranged from 10.96 to 284.68 μg L^{-1}. Concentration ranges for Chl a, phycocyanin and phycoerythrin show large fluctuations.

The median values for turbidity were 2.30–57.09 FNU, the first quartile range from 9.59 to 30.14 FNU and the third quartile range from 27.70 to 93.92 FNU. An overall concentrations of turbidity ranged from 2.90

to 117.41 FNU. The median values for pH were 8.19–8.81, the minimum was 7.74 and the maximum was 9.24. The water in the WRs of the cluster 2 is usually coloured to green during the growing season, mainly by the presence of cyanobacteria of the Microcystis species. Cyanobacteria are capable of chromatic adaptation (Chorus and Bartram eds., 1999) and therefore have no problem adapting and changing the ratio of phycocyanin and phycoerythrin in phycobilisomes, thus using a wider part of the solar spectrum (500–650 nm). Dense bloom of cyanobacteria in the WRs of the cluster 2 was accompanied by high contents of chlorophyll a, phycocyanin and phycoerythrin and also by increased pH above 9.

According to Zepernick et al. (2021), this increase in pH provides a competitive advantage to cyanobacteria, such as e.g. Microcystis aeruginosa.

Dense cyanobacterial bloom also affects penetration of light under water surface. When it decreases, it causes die-offs of plants in littoral zones while also lowering the success of predators that need light to pursue and catch prey (Lehtiniemi et al., 2005). In the water reservoirs of the second cluster were also present in substantial number invasive macrophytes Ceratophyllum demersum and Potamogeton pectinatus, but in June 2021 also rare Batrachium sp.

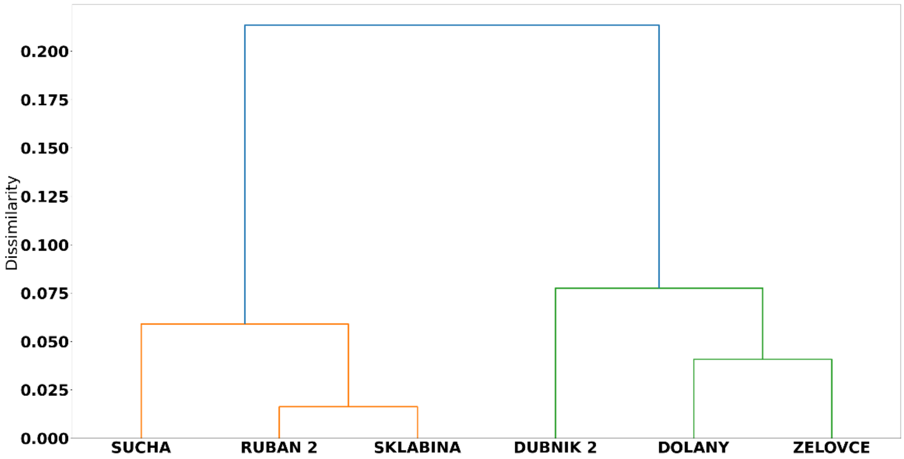

Fig. 2. Dendrogram showing similarities of water reservoirs produced by cluster analysis.

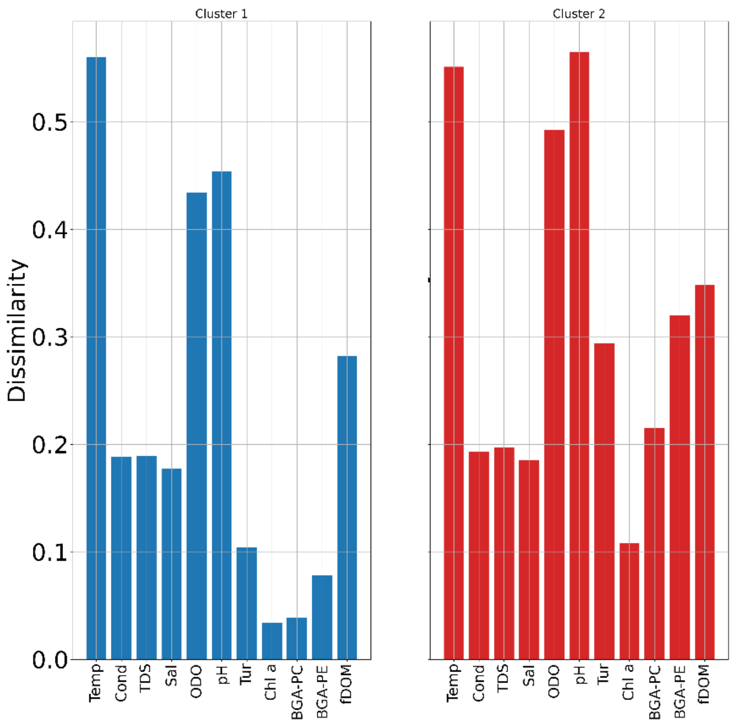

Fig. 3. Bars showing dissimilarities of water quality parameters between clusters.

Table 6. **Results of Kruskal-Wallis H test presenting differences**

Variable	H-test statistics	p-unc
Temperature [°C]	0.07442	0.78501
Conductivity [µS cm^{-1}]	0.14762	0.70082
TDS [mg L^{-1}]	0.14762	0.70082
Salinity [psu]	0.13629	0.71200
ODO [%sat]	2.72949	0.09851
ODO [mg L^{-1}]	2.29166	0.13007
pH	7.82945	0.00514
Turbidity [FNU]	25.64337	0.00000
Chl a [µg L^{-1}]	22.47904	0.00000
BGA-PC [µg L^{-1}]	29.68556	0.00000
BGA-PE [µg L^{-1}]	32.24752	0.00000
fDOM [RFU]	1.09217	0.29599

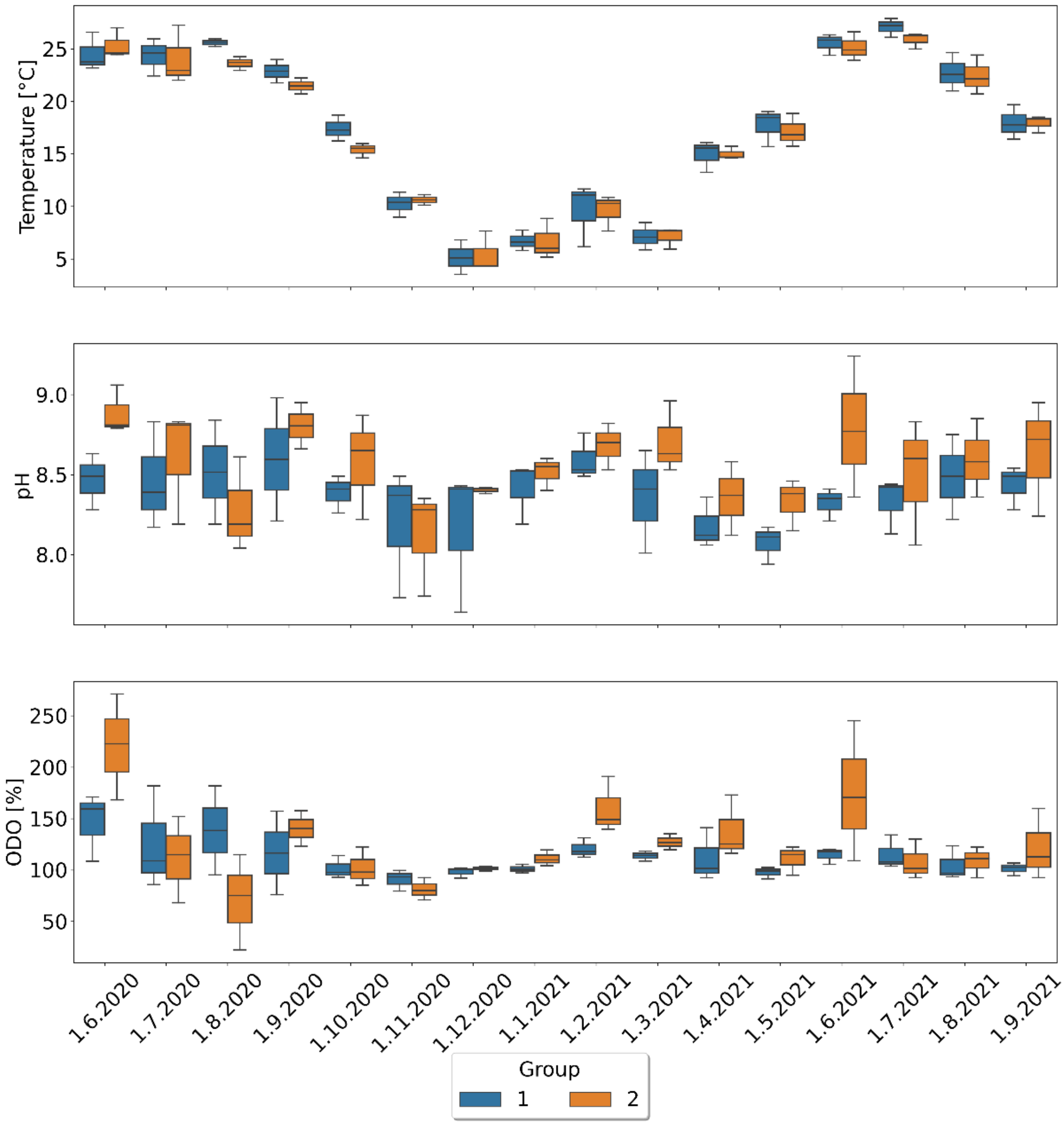

Fig. 4. Box plots showing temporal variations of water quality parameters between clusters: temperature [°C], pH, dissolved oxygen [ODO, %sat].

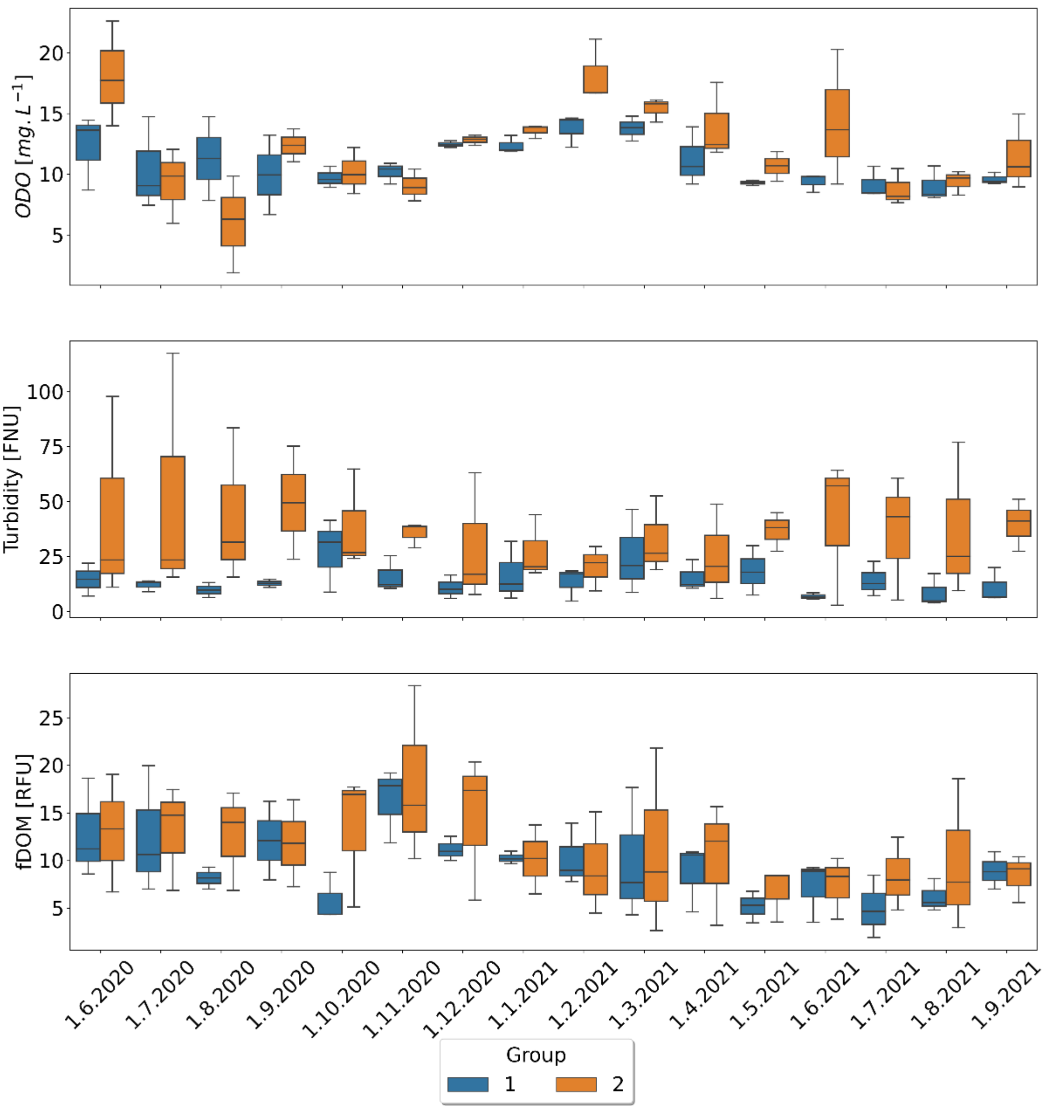

Fig. 5. Box plots showing temporal variations of water quality parameters between clusters: dissolved oxygen [ODO, mg L^{-1}], turbidity [FNU], dissolved organic matter fDOM [RFU].

The land use and land cover in the buffer zone of 500 m around the WRs (Table 2) have the influence on the water quality. For the cluster 2 the highest proportion belongs to arable soils (63.63–92.00%), less to permanent vegetations – orchards and vineyards (0.36 – 6.84 %) and meadows and pastures (3.62–10.17%). Comparing to cluster 1, the cluster 2 has very low coverage of forests ranging from 1.12 to 9,33%. Huang et al. (2020) described a positive affect of forest land buffer zone on water quality indicators. The low percentage of vegetation proper for functioning as buffer zone in cluster 2 contribute to water pollution, mostly by run-off from close arable soils. In cluster 2, the WR Dubník 2 is intensively used for recreational fishing in which fishermen feed fish individually and thereby supply extra nutrients and organic material into the reservoir.

The water reservoirs of the cluster 1 had a better water quality during the observed period, without a harmfull cyanobacterial bloom. Comparing to cluster 2 the median values for Chl a were 5.27–31.32 μg L^{-1}, the first quartile range from 4.23 to 14.78 μg L^{-1} and the third quarlite range from 7.45 to 57.17 μg L^{-1}. An overall concentrations of Chl a ranged from 2.91 to 69.81 μg L^{-1}. The median values for BGA-PC were 0.69–2.37 μg L^{-1}, the first quartile range from 0.53 to 1.89 μg L^{-1} and the third quarlite range from 0.69 to 3.1 μg L^{-1}. An overall concentrations of BGA-PC ranged from 0.17 to 3.15 μg L^{-1}.

The median values for BGA-PE were 13.68–51.43 μg L^{-1}, the first quartile range from 12.35 to 26.30 μg L^{-1} and the third quarlite range from 13.91 to 115.63μg L^{-1}. An overall concentrations of BGA-PE ranged from 8.04 to 137.02 μg L^{-1}.

The median values for turbidity were 4.84–31.52 FNU, the first quartile range from 4.17 to 14.52 FNU and the third quarlite range from 8.06 to 40.10 FNU.

An overall concentrations of turbidity ranged from 3.94 to 46.48 FNU.

The median values for pH were 8.11–8.60, the minimum was 7.64 and the maximum was 8.98.

To compare the land cover (Table 2) with the cluster 2, the WRs of the cluster 1 have lower percentage of arable soils (43.66–70.47%), a little more cover of permanent vegetatations – orchards and vineyards (0.00–10.37%), more meadows and pastures (5.11–15.17%) and higher forests cover ranging from 11.13 to 19.33%. The good water quality makes the water reservoirs of cluster 1, Sklabiná and Suchá nad Parnou, popular recreational localities.

For better interpretation of water quality in the WRs we added from June to September 2021, during the warm season when water quality is mostly endangered by cyanobacterial bloom, analysis of nitrate nitrogen, ammonium nitrogen, total nitrogen, total phosphorus and chemical oxygen demand. Table 7 presents mean values for these parameters for cluster 1 and 2.

All measured concentrations of nutrients presented in the table 7 are higher in WRs of cluster 2. According to the Directive 269/2010 Coll., annex 1A, in any sample wasn´t exceeded the concentration limit for NO^3-N, NH_4- N, TN, and TP. In water reservoirs of the cluster 2 all measured concentrations for COD exceeded limit value of 35 mg L^{-1}. Also according to the annex 2C of the Directive 269/2010 Coll. for the concentration of NH_4-N the recommended (0.15 mg L^{-1}) and the limit (0.8 mg L^{-1}) values for carp zone were not exceeded.

The measured values of the monitored parameters were also statistically processed by Spearman correlation. The obtained correlation matrix expresses the dependences among the individual monitored parameters (Fig. 7).

The values of TDS, conductivity and salinity show

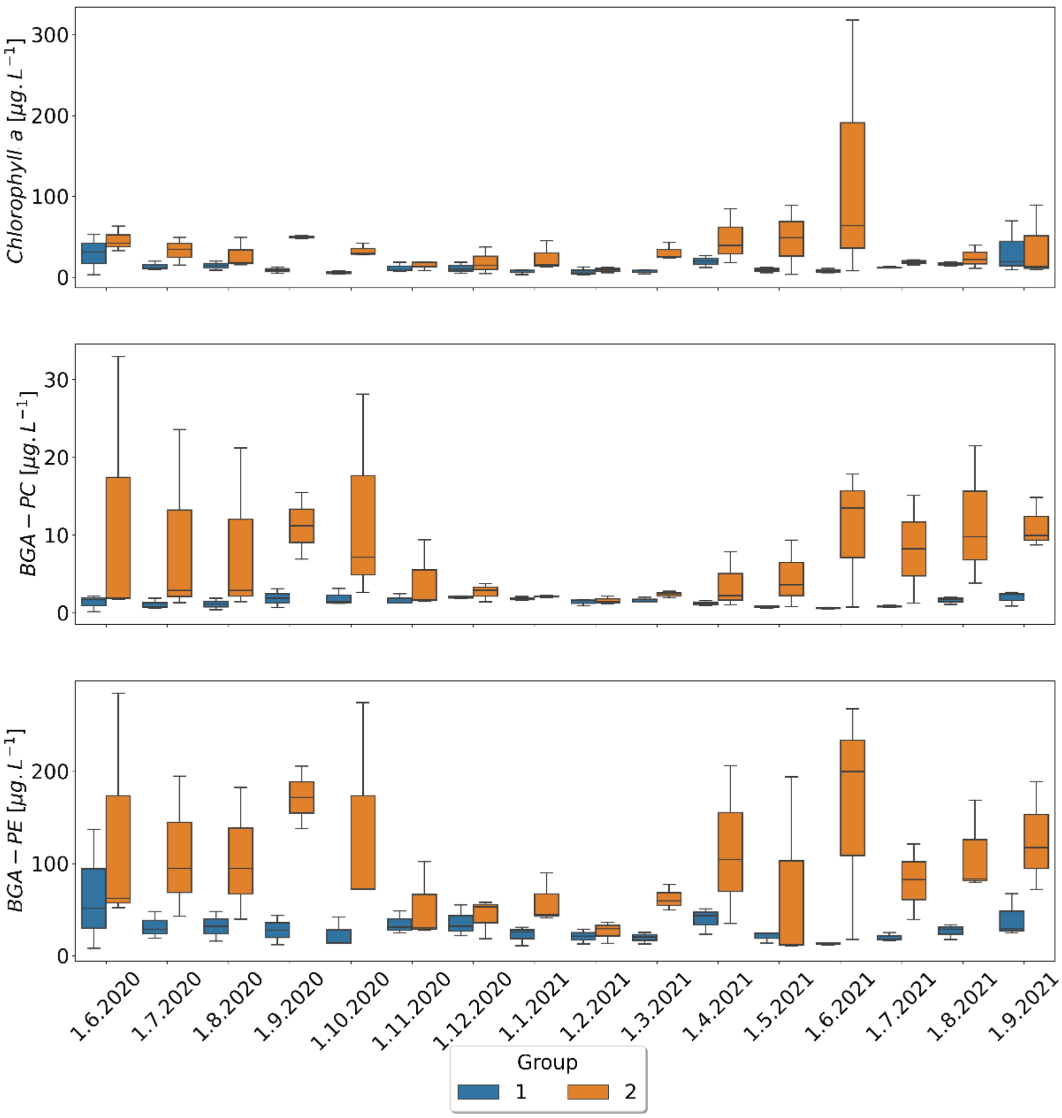

Fig. 6. Box plots showing temporal variations of water quality parameters between clusters: chlorophyll a [µg L^{-1}], phycocyain [BGA-PC, µg L^{-1}], phycoerytrin [BGA-PE, µg L^{-1}].

Table 7. Mean values of measured concentrations of NO3-N – nitrate nitrogen, NH4-N – ammonium nitrogen, TN – total nitrogen, TP – total phosphorus, COD – chemical oxygen demand for cluster 1 and cluster 2

Date	June 2021				July 2021				
Parameter	NO^3-N	NH^4-N	TN	TP	NO^3-N	NH^4-N	TN	TP	COD
Unit	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]
Cluster 1	0.222	0.018	1.142	0.139	0.192	0.012	1.094	0.069	21.150
Cluster 2	0.267	0.096	3.723	0.202	0.281	0.103	3.193	0.209	65.700

Date	August 2021					September 2021				
Parameter	NO^3-N	NH^4-N	TN	TP	COD	NO^3-N	NH^4-N	TN	TP	COD
Unit	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]	[mg L^{-1}]
Cluster 1	0.160	0.011	1.260	0.175	22.533	0.193	0.047	1.510	0.067	23.900
Cluster 2	0.269	0.058	3.493	0.279	58.833	0.247	0.122	3.380	0.270	76.200

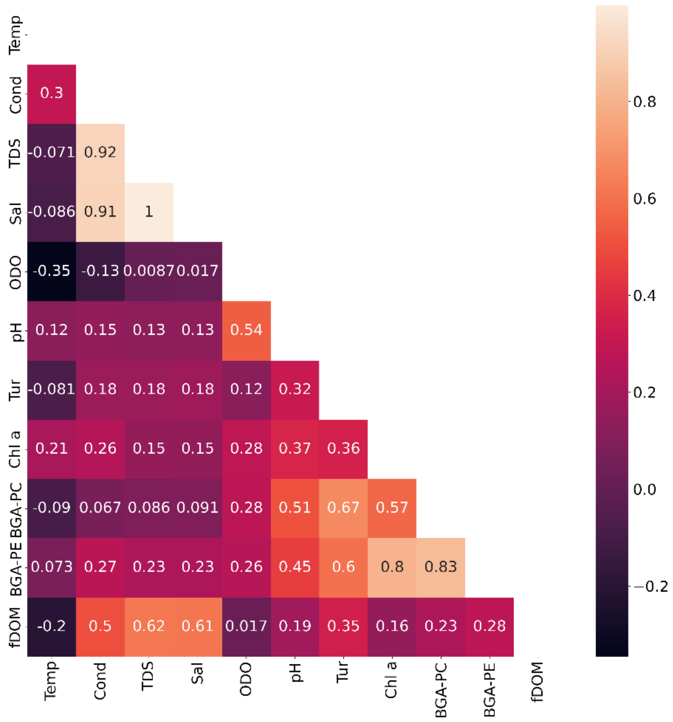

Fig. 7. Spearman correlation matrix among individual parameters.

the highest positive correlation. These parameters are interdependent as they are salts, and the Exo sensor uses the measured conductivity data to calculate salinity and TDS. We confirmed a high positive correlation in turbidity parameters with cyanobacterial phycocyanin and phycoerythrin. The development of a cyanobacterial bloom increases turbidity. On the contrary, turbidity with ODO shows the lowest correlation, which confirms that an increase in the number of cyanobacteria is associated with a decrease in dissolved oxygen content (Okogwu and Ugwumba, 2009). We found the highest negative correlations at ODO and temperature, which confirms the fact that with increasing water temperature, the content of dissolved oxygen decreases.

Conclusion

In our study we monitored the water quality of six small water reservoirs in agricultural landscape. To analyze the measured data we used various statistical analysis for the dataset. The cluster analysis divided the six monitored water reservoirs in to two groups (cluster 1 and 2). Analysis of normalized data revieled main parameters that caused the distribution in to two clusters: pH values, turbidity, concentrations of chlorophyll a, cyanobacterial photosynthetic pigments phycocyanin and phycoerythrin and content of fluorescent dissolved organic matter. The Kruskal-Wallis test prooved the significant differences between groups of water reservoirs.

According to Zhou et al. (2007), Filik Iscen et al. (2008), Pejman et al. (2009) the grouping could facilitate the design of an optimal future monitoring strategy that could decrease monitoring frequency, the number of sampling, and the corresponding costs. For the WRs grouped in one cluster are suitable the same measures of improvement. These measures could be applied on other WRs with the similar characteristics.

In summary, water reservoirs of the cluster 1 had better water quality than water reservoirs of the cluster 2. The major differences were seen in concentrations of Chl a, BGA-PC, BGA-PE, turbidity and pH. The concentration ranges in the cluster 2 for Chl a, phycocyanin, phycoerytrin and turbidity showed large fluctuations. Comparison of the land cover structure of 500 m buffer zone around the water reservois pointed out the importance of buffer zone composition. For the cluster 2 the highest proportion belongs to arable soils (63.63–92.00%). Comparing the forest coverage of the buffer zones, the cluster 1 has forests on 11.13–19.33% of its area and the cluster 2 has forests only on 1.12–9.33% of the area. This agree with Huang et al. (2020) who described a positive affect of forest land buffer zone on water quality indicators.

Position of the WRs in landscape with high quality agricultural soils have a major impact on the intensity of landscape use. Intensive agriculture causes negative effects on the land, water and individual components of the environment. The basic principles of water protection in agricultural landscape require to keep good agrotechnical procedures, good agricultural practices in nutrient management, to apply nutrients only under suitable climatic conditions, to prevent application of fertilizers on steep sloping grounds and to prevent pollution by run-off. Important measure is to maintaine a minimum quantity of vegetation cover during rainy periods. According to our field survey the last requirement was usually not met.

The monitoring reservoirs were build with ground constructions with dams. Reservoirs with dams are ecosystems that accumulate biogenic substancies and various pollutants (Wiatkovski and Paul, 2009, Wiatkovski et al., 2016). Sediments serve as ultimate repository of many pollutants discharged to aquatic systems (Turner et al., 2008). Unfortified banks are one of the significant imperfections that negatively affects the quality and life in water reservoirs. Due to dynamic effect of waves on banks is released soil material and bank areas of reservoirs collapse. This trend was most significant at the WR Dubník 2. The banks of other reservoirs also require protection against the direct effects of waves by technological and biological measures, at least by adjusting the slopes, strengthening the littoral zone with aquatic, especially wetland plants or shrub vegetation. The recommended retention zone of permanent grasslands, which acts as a biological filter for sediments from the environment, should have a minimum width of 15 m (Čistý, 2005).

Reservoirs in agricultural landscape serve during the summer months as sources of water for irrigation, which have a negative impact on the state of water levels. An extra nutrient supply to reservoirs is added via fishermen feeding (corn, grain) that we found in the water. This enriches the reservoir sediments and support the cyanobacterial, algal and macrophytes development. The water in the reservoirs of the cluster 2 is usually coloured to green during the growing season, mainly by the presence of cyanobacteria of the Microcystis species.

Settlements in catchments have also considerable impact on water quality, as many of them still lack public sewerage and efficient wastewater treatment plants.

In order to maintain all the functions of water reservoirs in the landscape, it is necessary to harmonize the management of their active protection and sensitive use. Protection of water resources should become our most important responsibility.

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